Spring 2002

A WORKBOOK IN MECHANICS

FOR

PHYSICS 103

PRINCE GEORGE'S COMMUNITY COLLEGE

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The principle of science, the definition almost, is the following: The test of all knowledge is experiment.......But what is the source of knowledge? Where do the laws that are to be tested come from? Experiment, itself, helps to produce these laws, in the sense that it gives us hints. But also needed is imagination to create from these hints the great generalizations -- to guess at the wonderful, simple, but very strange patterns beneath them all, and then to experiment to check again whether we have made the right guess.

– Richard Feynman
(from the Feynman Lectures on Physics)

Our imagination is stretched to the utmost, not, as in fiction, to imagine things which are not really there, but just to comprehend those things which are there.

– Richard Feynman
Nobel Laureate, 1965

.... science is a way of thinking much more than it is a body of knowledge.

– Carl Sagan
(from Broca's Brain, 1979)

A Workbook in Mechanics for Physics 103
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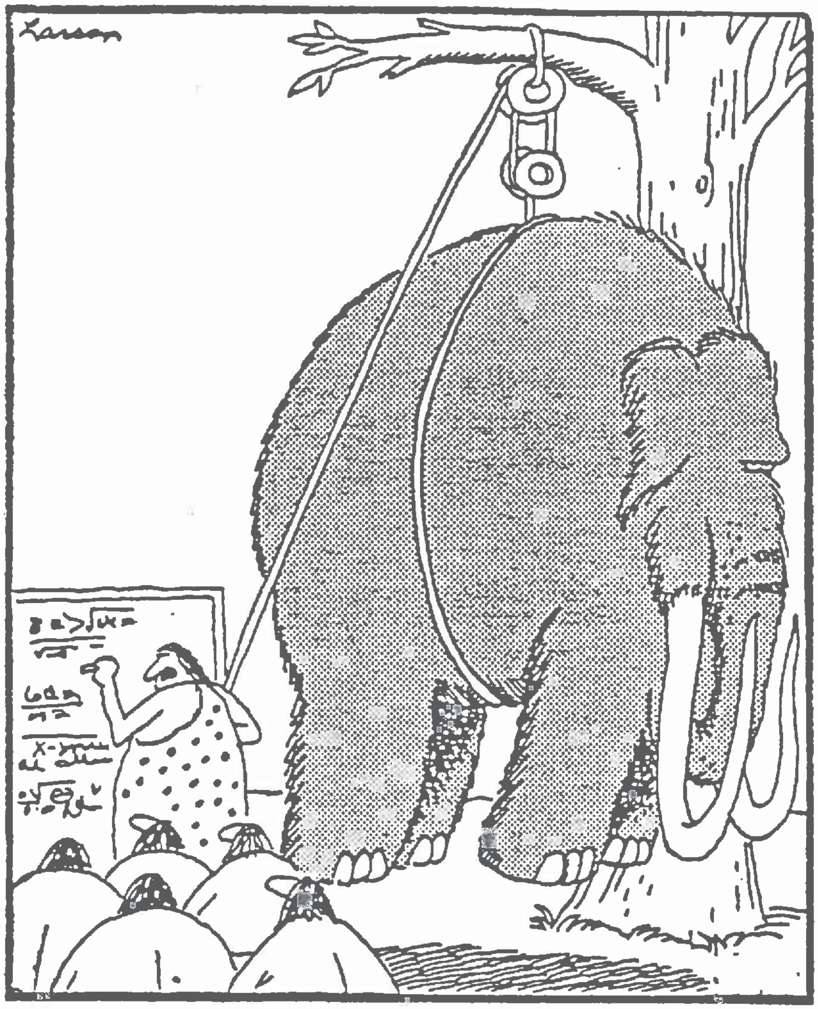
PREFACE

The purpose of this workbook is to provide a set of worksheets on kinematics and mechanics that you can use to test your understanding of each topic you study in your physics course. To be successful at problem solving, you must understand the meaning of the concepts, know the definitions and units of the physical quantities, and have the ability to work with the relationships expressed by the principles and laws. Each worksheet has questions that probe your knowledge and understanding of the basic ideas and has simple numeric problems that test your ability to use the important relationships. Many questions probe some of the common misconceptions about familiar physical situations that people often have. All the questions and problems are designed to make you think more deeply about the physics that you have studied.

The questions and problems in these worksheets are very different from those found in your textbook. Before trying a given worksheet, study your lecture notes, read the text, work through the example problems in the text, and do your homework assignment. Try these worksheet questions and problems later, perhaps as a chapter review when you have gained some experience with the material. Try them again as a review for your exams. Use the worksheets to probe your understanding, to reveal gaps in your knowledge, and to strengthen your ability to work with the relationships. I hope that you find these worksheets useful and fun. Think physics.



Early physics

STUDY PHYSICS? HOW DO I DO IT?

With apologies to Shakespeare, this is the question! Students often ask their physics instructors, "How do I study physics? I read the text, outline the chapter, work the homework, but I can't answer the exam questions. What am I doing wrong?"

There is no easy answer to this question. Physics is difficult. It is difficult because the basic ideas are organized around unfamiliar concepts that don't seem to relate to our everyday experience. Physics uses words that are often unfamiliar to us and the basic relationships are written in mathematics, a foreign language we don't understand very well. Because of its nature, it takes time to understand physics. You must work on it continually over a period of time and let the ideas run around in your head. For most people, there is a time lag between the first encounter with a physical concept and the beginning of understanding. When you first see a new painting or hear a new type of music, you may not immediately understand or like it. But, in time, if you keep looking and listening, understanding comes, and you find that your knowledge of the world has increased. This time lag between exposure and understanding is probably responsible for the frustrating experience many students have with physics. As expressed in the quotes from Feynman and Sagan on page ii, scientific understanding is related to imagination and imagination requires time to develop and grow. Perhaps the best advice that can be given to the beginning student of physics is, no matter how you study, *study early* and *study often*.

How you study physics depends on your learning style. But everyone would probably agree that each topic in physics requires understanding in the following four basic areas:

1. The Concepts. Concepts are those ideals and physical quantities that are used to describe and to measure the basic structures and behaviors of physical systems. For example, to completely describe the motion of a car, you need the concepts of position, rate of change of position, velocity, rate of change of velocity, momentum, and energy. This is where your imagination must come into play because many concepts (for example, acceleration or gravity or energy) are not concrete and require you to imagine things that you can't see or feel. You can see what gravity or energy does, but not what they are. Some physical ideas will not be intuitive. That is, they will disagree with your everyday ideas about nature. For example, most people believe that forces cause motion, but this is not strictly true. *Learn the meaning of a concept (not just its name) as soon as possible* (i.e. study early). Spend time thinking about it (i.e. study often). Learn why it is needed, what structure or behavior it describes, and how it is used.

2. The Language. Like other sciences, physics has its own vocabulary that must be learned. Every quantity in physics has a name and units. *You must know what a thing is called and what its units are*. Since scalar and vector quantities behave differently, part of knowing the vocabulary of physics is knowing the scalar/vector nature of each quantity. At the beginning, it is probably easiest to memorize the vocabulary, but with constant use, it will become familiar.

3. The Principles and Laws. Principles and laws express the basic relationships between physical quantities and allow you to explain why something happens the way it does or to predict (under given conditions) how it will happen in the future. This is where you encounter mathematics because most of the principles and laws of physics are written as mathematical formulas. Don't panic! Math is used as a shorthand for expressing relationships between physical ideas. The math is not important. *The relationship is important*! If you were to express the relationship in words, it may take a paragraph, a page, or even an entire chapter in a book. It is the relationship that you want to understand. Does the relationship make sense? What knowledge is expressed by the relationship? Under what conditions is the relationship correct and when does it fail to work? The relationship comes first, the math second. When a relationship is found to be valid, it is expressed mathematically because mathematics can convey, without ambiguity, the precise nature of a relationship. And the formula serves to remind you of the relationship. Don't memorize formulas. They can always be looked up in a textbook. *Learn the relationships*. And then learn how they apply to physical situations.

4. Problem Solving. There is no doubt that this area is very troublesome for the beginning student. Problem solving is an important part of physics. Given a physical situation, you are required to analyze it using your accumulated knowledge of the concepts, the vocabulary, and the principles of physics. Thus, it is essential that you have a good understanding of the above three areas to be successful in problem solving. In addition, since you must often find a numerical answer, you must be fairly good with calculational mathematics including arithmetic, algebra and trigonometry. This is a tall order! But it is made easier by the fact that the steps for solving problems in physics do not depend upon the specific type of problem to be solved. *There are general methods for solving problems which can be applied to all the problems you encounter*. When starting a problem, even if you have no idea about its answer, these general methods will get you started and allow you to proceed toward a correct solution. In fact, one reason why physics is a required course in so many fields of study is that these general methods of problem solving are extensively used in all technical areas. These problem solving methods are not mathematical skills, but are reasoning skills. They are taught in your physics course because there is so much opportunity to practice them.

As stated above, how you study physics depends on your learning style. However, there are some general suggestions that you may find useful.

1. ***Go over your lecture notes as soon as possible after the lecture and before the next lecture.*** You're not going to learn everything during the lecture. Treat the lecture is as road map or a guidepost that conveys what you should learn. Learning will occur as you review and modify your notes, as you think about the descriptions and definitions presented in class, and as you work through the examples shown in class. Put the basic ideas in your head as soon as possible so that they can bounce about and stimulate your thinking. Find out early what you don't understand and ask questions of your instructor at the very next class.

2. ***Keep a list of the physical terms presented in lecture and update it after each class.*** Write a definition or description of each term in your own words. Note its scalar or vector nature and write down its MKS units.

3. ***Use your text as teacher, tutor, and reference.*** If you don't understand a topic, carefully read about it in the text. If you do understand, then use the text as a review to check your understanding and to see a different way of explaining a topic. Focus on new concepts, new vocabulary, definitions, and notation and compare to what you heard in class. Use the features of your text such as diagrams,

boxed expressions or explanations, margin notes, and chapter summaries as learning aids. And, most importantly, work through (just don't read) all the example problems in the text.

4. ***Practice as much as you can.*** As any athlete or musician will tell you, you have to practice to be good. The quotes below from individuals that lived over 2000 years apart express this important idea. Practice lets you test your skills to keep them sharp. Practice leads to improved skills and to new skills. In physics, practice means answering questions and working problems, lots of problems. Work as many problems as you can. Work through the example problems presented in lecture and the example problems in the text. Work the homework questions and problems. And work through the worksheets in this workbook.

... one must learn by doing the thing; for through you think you know it, you have no certainty until you try it.
- Sophocles
Poet, 496 - 406 B.C.

You do not know anything until you have practiced.
- Richard Feynman
Nobel Laureate, 1965

How you study physics depends upon your learning style. I hope you find a style that suits you and is successful. If possible, form a study group with two or three other individuals with similar learning styles to talk about the problems and check answers. Good luck and have fun learning physics.

GOALS FOR THIS COURSE

1. Convey the vocabulary, the major concepts and the physical ideas of mechanics.

2. Convey the basic relationships in mechanics as expressed by the fundamental principles and the laws of motion.

3. Provide the tools (including mathematical tools) and skills to analyse physical situations and solve problems in mechanics.

Preparing for Exams

The following information about exam preparation was taken from the Study Skills Package Web Page provided by the University of Waterloo, Ontario, Canada located at http://www.adm.uwaterloo.ca/infocs/Study/time.html

Students know that they need to study and that they should probably start well in advance of the exam. But they may not know why this is so and have not developed the habit to study early and properly. The following suggestions about exam preparation comes from the results of research on how we learn.

TRY Not cramming!

WHY? Because short-term memory hasn't enough space for all you need to know. Also, cramming stupefies long-term memory (where well-learned material lives), and it can set you up for panic and "blanking".

TRY Starting well in advance, breaking your studying into chunks, and reviewing often.

HOW?

1. A week or more before the exam, do an initial overview (a 2-4 hr quick review of the material); this will help motivate you and to determine the structure of the course, where your difficult material is, and the volume to be covered.
2. Develop and follow a plan for getting yourself through this volume of material, starting (if possible) with your most difficult stuff.
3. At the beginning of each study period, do a 10 min review of the previous period's material.

TRY Studying "from the top down."

WHY? Because it is easier to understand and retain material that is well-organized. Therefor, start with a good grasp of the course's main ideas, then follow with the sub-topics and supporting details.

TRY Studying by jogging your memory.

WHY? Because real understanding comes not when we stuff information in, but when we draw it out. Exams require this same drawing out of information. So this should be the focus of studying: answering question, solving problems, writing essays, defining, explaining, and applying terms, and working through past exams.

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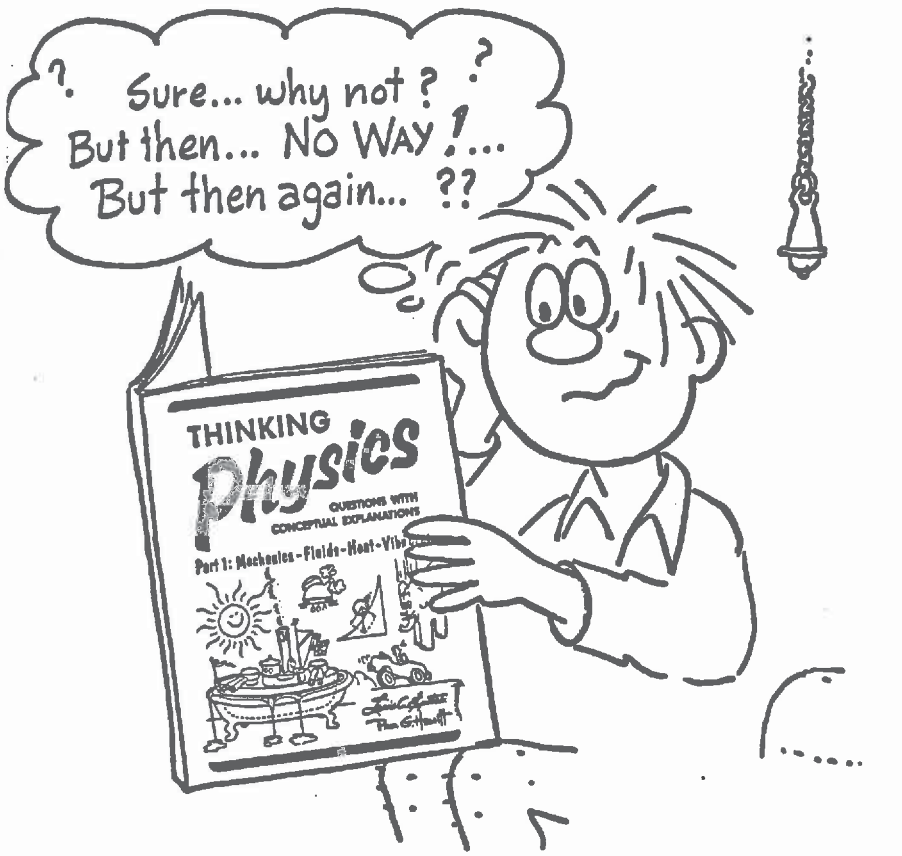
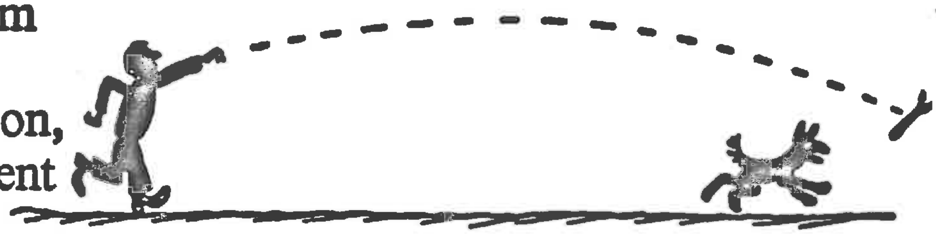
PHYSICS IS ABOUT THINKING

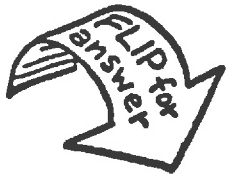


SAM

Dr. Pisani exercises his dog Sam on a 15-minute walk by throwing a stick that Sam chases and retrieves. To keep Sam running for the longest time as Dr. Pisani walks, which way should he throw the stick?

a) In front of him
b) In back of him
c) Sideways
d) In any direction, as all are equivalent





ANSWER: SAM

The answer is: d. Again, time is the important factor. Pisani is going to keep Sam running for 15 minutes regardless of which way he throws the stick! If the question asked for the most running time per throw, then the answer would be b, backward, because Sam would have to run the additional distance Pisani moved during his chase for the stick. But the question simply referred to Sam's running time during Pisani's 15-minute walk. Tricky? Perhaps — but there is a point here, and that is to be sure you're answering the question that is asked. How unfortunate that so many students taking exams often answer questions that are not really asked. Check yourself on this mishap when *you* take exams!

Biographical Sketch

Richard P. Feynman
(1918–1988)

Richard Phillips Feynman was a brilliant theoretical physicist who together with Julian S. Schwinger and Shinichiro Tomonaga shared the 1965 Nobel Prize for Physics for their fundamental work in the principles of quantum electrodynamics. His many important contributions to physics include the invention of simple diagrams to represent particle interactions graphically, the theory of the weak interaction of subatomic particles, a reformulation of quantum mechanics, the theory of superfluid helium, and his contribution to physics education through the magnificent three-volume text, *The Feynman Lectures on Physics*.

Feynman did his undergraduate work at MIT and received his PhD in 1942 from Princeton University where he worked under John Archibald Wheeler. During World War II, he worked on the Manhattan project at Princeton and then at Los Alamos, New Mexico. He then joined the faculty at Cornell University in 1945 and was appointed professor of physics at California Institute of Technology in 1950 where he remained for the rest of his career.

It is well known that Feynman had a passion for finding new and better ways to formulate each problem, or, as he would say, "turning it around." In the early part of his career, he was fascinated with electrodynamics, and developed an intuitive view of quantum electrodynamics. Convinced that the electron could not interact with its own field, he said, "That was the beginning, and the idea seemed so obvious to me that I fell deeply in love with it . . . ." Often called the outstanding intuitionist of our age, he said in his Nobel acceptance speech, "Often, even in a physicist's sense, I did not have a demonstration of how to get all of these rules and equations, from conventional electrodynamics . . . I never really sat down, like Euclid did for the geometers of Greece, and made sure that you could get it all from a single set of axioms."

In 1986, Feynman was a member of the presidential commission to investigate the explosion of the space shuttle *Challenger*. In this capacity, he performed a simple experiment for the commission members which showed that one of the shuttle's O-ring seals was the likely cause of the disaster. After placing a seal in a pitcher of ice water, and squeezing it with a clamp, he demonstrated that the seal failed to spring back into shape once the clamp was removed.[1]

Feynman worked in physics with a style commensurate with his personality, that is, with energy, vitality, and humor. The following quotes from some of his colleagues are characteristic of the great impact he made on the scientific community.[2]

"A brilliant, vital, and amusing neighbor, Feynman was a stimulating (if sometimes exasperating) partner in discussions of profound issues—we would exchange ideas and silly jokes in between bouts of mathematical calculation—we struck sparks off each other, and it was exhilarating." *Murray Gell-Mann*

"Reading Feynman is a joy and a delight, for in his papers, as in his talks, Feynman communicated very directly, as though the reader were watching him derive the results at the blackboard." *David Pines*

"He loved puzzles and games. In fact, he saw all the world as a sort of game, whose progress of "behavior" follows certain rules, some known, some unknown . . . Find places or circumstances where the rules don't work, and invent new rules that do." *David L. Goodstein*

"Feynman was not a theorist's theorist, but a physicist's physicist and a teacher's teacher." *Valentine L. Telegdi*

Laurie M. Brown, one of his graduate students at Cornell, noted that Feynman, a playful showman, was "undervalued at first because of his rough manners, who in the end triumphs through native cleverness, psychological insight, common sense and the famous Feynman humor. . . . Whatever else Dick Feynman may have joked about, his love for physics approached reverence."

[1] Feynman's own account of this inquiry can be found in *Physics Today*, 4:26, February 1988.

[2] For more on Feynman's life and contributions, see the numerous articles in a special memorial issue of *Physics Today* 42, February 1989. For a personal account of Feynman, see his popular autobiographical books, *Surely You're Joking Mr. Feynman*, New York, Bantam Books, 1985, and *What Do You Care What Other People Think*, New York, W.W. Norton & Co., 1987.

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FOR

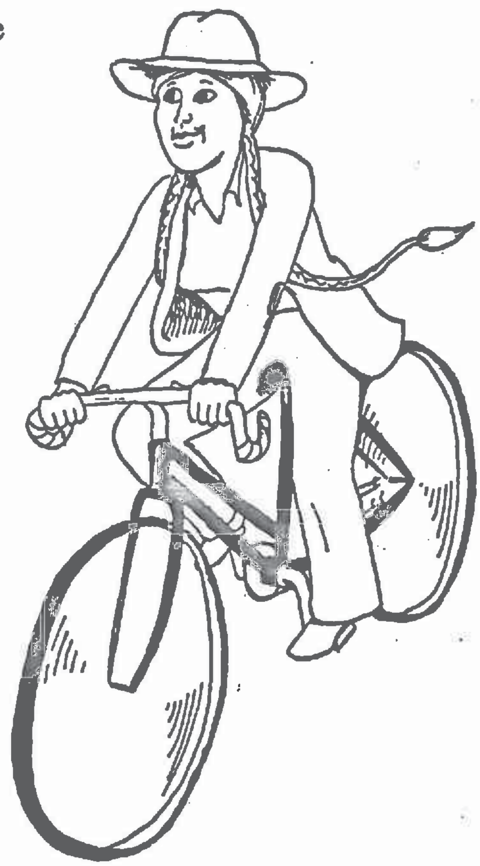
PHYSICS 103

PART I - WORKSHEETS

VISUALIZE IT

Suppose you are going for a long bicycle ride. You ride one hour at five miles per hour. Then three hours at four miles per hour and then two hours at seven miles per hour. How many miles did you ride?

a) five
b) twelve
c) fourteen
d) thirty-one
e) thirty-six



THE UNITED STATES AND THE METRIC SYSTEM

A Capsule History

The United States is now the only industrialized country in the world that does not use the metric system as its predominant system of measurement.

Most Americans think that our involvement with metric measurement is relatively new. In fact, the United States has been increasing its use of metric units for many years, and the pace has accelerated in the past three decades. In the early 1800s, the U.S. Coast and Geodetic Survey (the government's surveying and map-making agency) used meter and kilogram standards brought from France. In 1866, Congress authorized the use of the metric system in this country and supplied each state with a set of standard metric weights and measures.

In 1875, the United States solidified its commitment to the development of the internationally recognized metric system by becoming one of the original seventeen signatory nations to the **Treaty of the Meter**. The signing of this international agreement concluded five years of meetings in which the metric system was reformulated, refining the accuracy of its standards. The Treaty of the Meter, also known as the "Metric Convention," established the *International Bureau of Weights and Measures (BIPM)* in Sèvres, France, to provide standards of measurement for worldwide use.

In 1893, metric standards, developed through international cooperation under the auspices of BIPM, were adopted as the fundamental standards for length and mass in the United States. Our customary measurements -- the foot, pound, quart, etc. -- have been defined in relation to the meter and the kilogram ever since.

The *General Conference of Weights and Measures*, the governing body that has overall responsibility for the metric system, and which is made up of the signatory nations to the Treaty of the Meter, approved an updated version of the metric system in 1960. This modern system is called *Le Système International d'Unités* or the International System of Units, abbreviated SI.

The United Kingdom began a transition to the metric system in 1965 to more fully mesh its business and trade practices with those of the European Common Market. The conversion of the United Kingdom and the Commonwealth nations to SI created a new sense of urgency regarding the use of metric units in the United States.

In 1968, Congress authorized a three-year study of systems of measurement in the U.S., with particular emphasis on the feasibility of adopting SI. The detailed U.S. Metric Study was conducted by the Department of Commerce. A 45-member advisory panel consulted with and took testimony from hundreds of consumers, business organizations, labor groups, manufacturers, and state and local officials.

The final report of the study, **"A Metric America: A Decision Whose Time Has Come,"** concluded that the U.S. would eventually join the rest of the world in the use of the metric system of measurement. The study found that measurement in the United States was already based on metric units in many areas and that it was becoming more so every day. The majority of study participants believed that conversion to the metric system was in the best interests of the Nation, particularly in view of the importance of foreign trade and the increasing influence of technology in American life.

The study recommended that the United States implement a carefully planned transition to predominant use of the metric system over a ten-year period. Congress passed the **Metric Conversion Act of 1975** "to coordinate and plan the increasing use of the metric system in the United States." The Act, however, did not require a ten-year conversion period. A process of voluntary conversion was initiated, and the U.S. Metric Board was established. The Board was charged with "devising and carrying out a broad program of planning, coordination, and public education, consistent with other national policy and interests, with the aim of implementing the policy set forth in this Act." The efforts of the Metric Board were largely ignored by the American public, and, in 1981, the Board reported to Congress that it lacked the clear Congressional mandate necessary to bring about national conversion. Due to this apparent ineffectiveness, and in an effort to reduce Federal spending, the Metric Board was disestablished in the fall of 1982.

The Board's demise increased doubts about the United States' commitment to metrication. Public and private sector metric transition slowed at the same time that the very reasons for the United States to adopt the metric system -- the increasing competitiveness of other nations and the demands of global marketplaces -- made completing the conversion even more important.

Congress, recognizing the necessity of the United States' conformance with international standards for trade, included new encouragement for U.S. industrial metrication in the **Omnibus Trade and Competitiveness Act of 1988**. This legislation amended the Metric Conversion Act of 1975 and designates the metric system as the "preferred system of weights and measures for United States trade and commerce." The legislation states that the Federal Government has a responsibility to assist industry, especially small business, as it voluntarily converts to the metric system of measurement.

Federal agencies were required by this legislation, with certain exceptions, to use the metric system in their procurement, grants and other business-related activities by the end of 1992. While not mandating metric use in the private sector, the Federal Government has sought to serve as a catalyst in the metric conversion of the country's trade, industry, and commerce.

The current effort toward national metrication is based on the conclusion that industrial and commercial productivity, mathematics and science education, and the competitiveness of American products and services in world markets, will be enhanced by completing the change to the metric system of units. Failure to complete the change will increasingly handicap the Nation's industry and economy.

Questions and Answers

Q. If the distance between the sun and earth is 149.6×10^6 km and there are 1610 meters to a mile, what is the distance in meters?, in centimeters?, in megameters?, in gigameters?, in miles? in megamiles? in gigamiles?

A. 149.6×10^9 m, 149.6×10^{11} cm, 149.6×10^3 Mm, 149.6 Gm, 92.9×10^6 mi, 92.9 Mmi, 0.0929 Gmi.

Q. If the flash from a laser occurs in 12×10^{-9} seconds, what is the flash interval in microseconds?, in nanoseconds? in pico-seconds?, in hours?, in femtohours?

A. 0.012 µs, 12 ns, 12,000 ps, 3.33×10^{-12} hr, 3,330 fhr.

Q. If there are 1610 meters to a mile, how fast is 1500 mi/hr in m/s?, km/hr?

A. 670.8 m/s, 2415 km/hr.

Q. A rainstorm drops a total of 1.0 cm of water on a city 5 km wide and 8 km long in a 2 hour period. If 1 cm^3 of water has a mass of 10^3 kg and there are 1000 kg in a metric ton, how many metric tons of water fell on the city during the rainstorm?

A. 400,000 metric tons.

AVERAGE SPEED

The everyday description of motion is given by the definition of average speed. This is often the first formula discussed in kinematics. When an object travels a distance d in meters during a time interval t in seconds, the average speed, u, of the object is defined to be

$$u = d/t$$

meters per second. This formula is often written in the form

$$d = u\ t$$

which expresses the distance traveled in time t by an object moving with an average speed u. The problems below illustrate some of the uses of this formula. The problems are expressed in English units rather than metric units to help you better visualize the speeds.

The Situation: You are driving from the Washington DC area to a place near Philadelphia which is 120 miles away. Your drive is essentially on interstate highways which offer few obstacles to continuous driving.

1. On a recent trip you find that your average speed for the first half of the trip was **40 mph** and that the average speed on the second half was **60 mph**. What was your average speed for the entire trip?

2. On another trip you find that your average speed for the first half of the trip was **40 mph**, but you wanted to average 50 mph for the entire trip. What average speed is required for the second half of the trip to obtain your overall average speed?

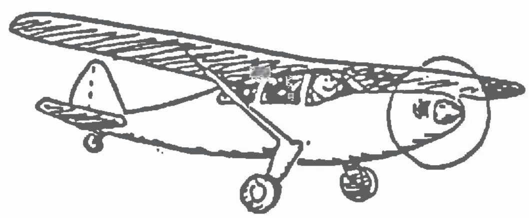
3. On another trip you find that your average speed for the first half of the trip was **50 mph**. At the end of the trip, you find that your overall average speed was 60 mph. What was your average speed for the second half of the trip?

4. On another trip you find that your average speed for the first half of the trip was **60 mph**, but you wanted to average only 50 mph for the entire trip. What average speed is required for the second half of the journey to obtain your overall average speed?

5. On a recent trip you find that your average speed for the first <u>40 miles</u> of the trip was **40 mph** and that the average speed for the rest of the trip was **60 mph**. What was your average speed for the entire trip?

6. On a recent trip you find that your average speed for the first <u>40 miles</u> of the trip was **40 mph**, but you wanted to average 50 mph for the entire trip. What average speed is required for the second part of the trip to obtain your overall average speed?

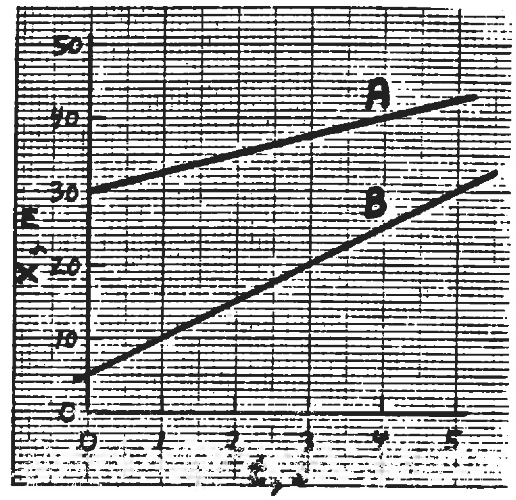
Figuring Physics



An airplane makes a straight back-and-forth round trip, always at the same airspeed, between two cities. If it encounters a mild steady tailwind going, and the same steady headwind returning, will the round trip take more, less, or the same time as with no wind?

GRAPHICAL ANALYSIS I - Interpretation of Graphs.

1. The graph at the right shows position vs. time for the motion for two cars, car A and car B.



a) Which car has the greater velocity? ________

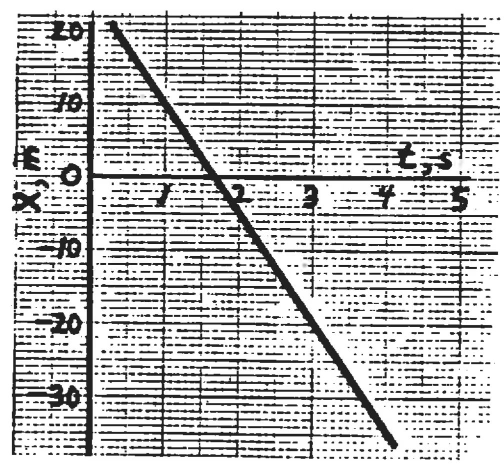
b) What is the velocity of each car?

c) Which car arrives first at the position x=60 m?

d) Determine mathematically the time at which the two cars have the same position?

e) The equation of motion of a third car, car C, is given by the expression $x = 15 + 5t$ m. Sketch the position vs. time plot for this car on the above graph..

2. A portion of the position vs. time plot for a moving object is shown on the graph at the right.



a) What is the instantaneous velocity of the object at t=3 sec?

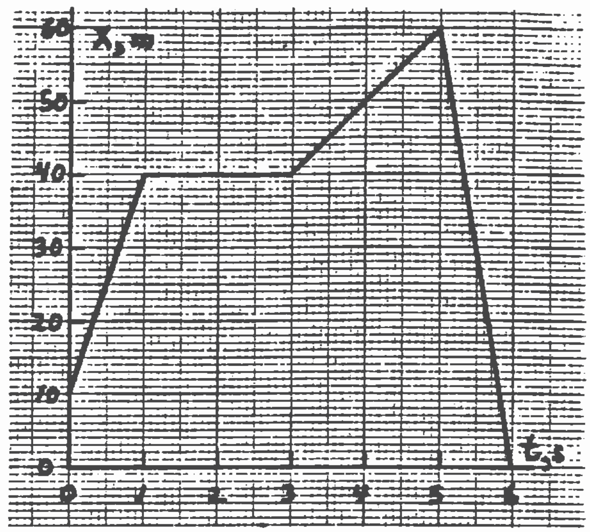
b) What is the displacement of the object between t=1 sec and t=4 sec?

c) Find the initial position of the object without completing the graph.

d) At what time does the object travel through the origin?

GRAPHICAL ANALYSIS I - WORKSHEET 2

3. The position vs. time graph of a moving object is shown at the right.



   a) For which time intervals, if any, is the object moving in the negative direction?

   b) For which time intervals, if any, is the object at rest?

   c) What is the position of the object at t = 3 sec and at t = 5 sec?

   d) Find the displacement of the object between t = 1 sec and t = 5 sec.

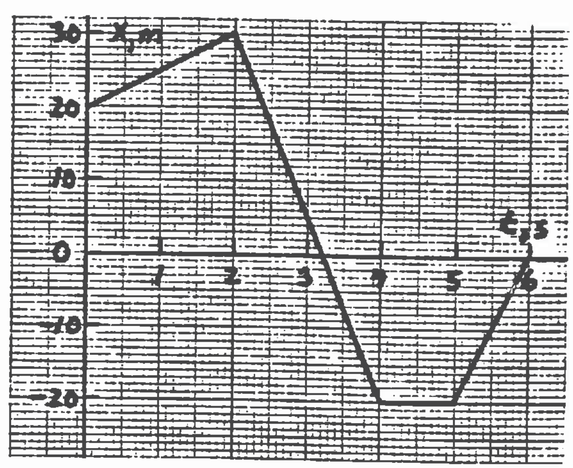
   e) Find the distance travelled by the object between t = 1 sec and t = 5 sec.

   f) Find the average speed of the object between t = 1 sec and t = 6 sec.

   g) Find the average velocity of the object between t = 1 sec and t = 6 sec.

   h) Find the instantaneous velocity of the object at t = 2 sec and at t = 3.5 sec.

4. The graph at the right shows position vs. time for a moving object.



   a) For which time intervals, if any, is the object moving in the negative direction?

   b) For which time intervals, if any, is the object at rest?

   c) What is the position of the object at t = 3 sec and at t = 5 sec?

d) Find the displacement of the object between t = 1 sec and t = 5 sec.

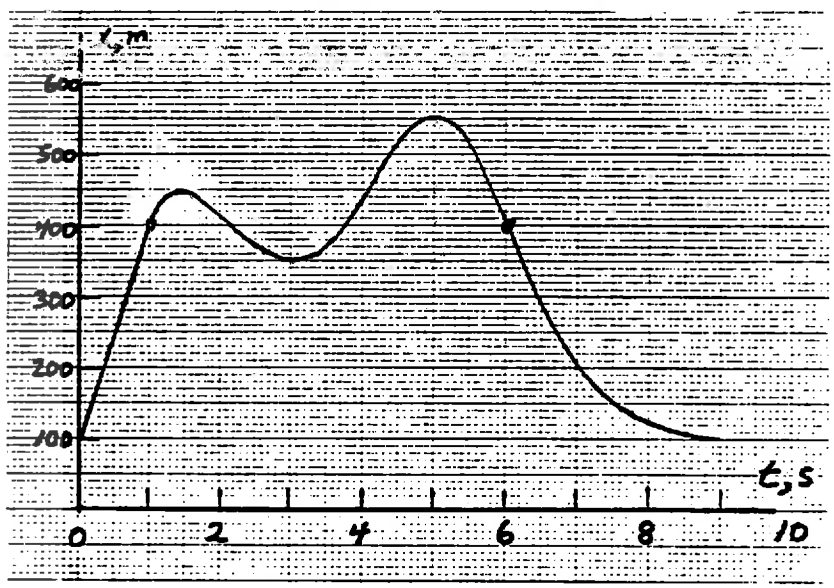
e) Find the distance travelled by the object between t = 1 sec and t = 5 sec.

f) Find the average speed of the object between t = 1 sec and t = 6 sec.

g) Find the average velocity of the object between t = 1 sec and t = 6 sec.

h) Find the instantaneous velocity of the object at t = 1 sec, at t = 3.5 sec.

5. The graph at the right shows position vs time for a high speed object moving along the x-axis.



a) What is the initial position and initial velocity of the object?

b) Find the total distance moved by the object between t = 3 sec and t = 8 sec.

c) At what time or times, if any, is the instantaneous velocity of the object equal to zero?

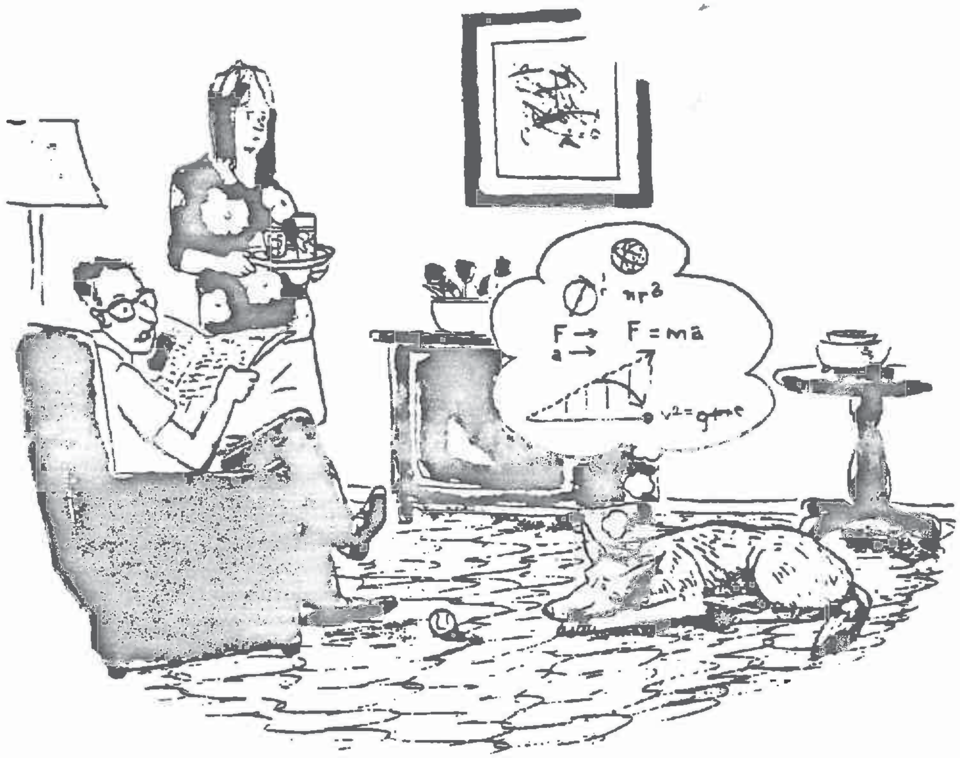
d) What is the displacement of the object between t = 1 sec and t = 7 sec?

e) Find the average speed of the object between t = 1 sec and t = 6 sec.

$d = 50 + 100 + 200 + 150 = 500\text{ m}$ $\quad v = \frac{500\text{ m}}{5\text{ s}} = 100\text{ m/s}$

f) Find the average velocity of the object between t = 3 sec and t = 7 sec.

g) Find the instantaneous velocity at t = 4 sec.

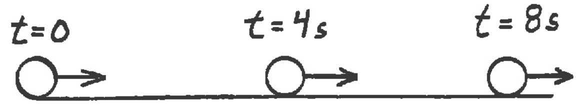


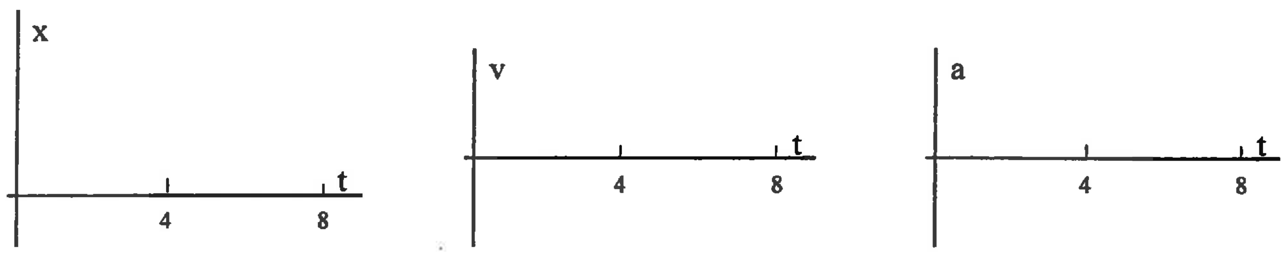
"All he thinks about is that stupid ball."

GRAPHICAL ANALYSIS II - Sketching Graphs.

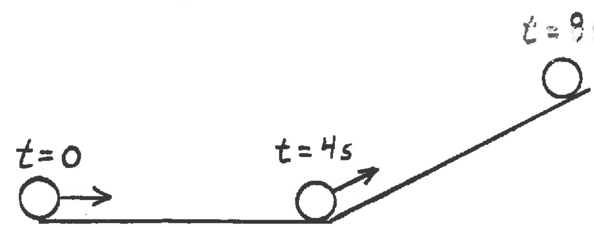
1. Sketch the **position vs time**, the **velocity vs time**, and the **acceleration vs time** graphs for the first 8 seconds for each of the motions described below.

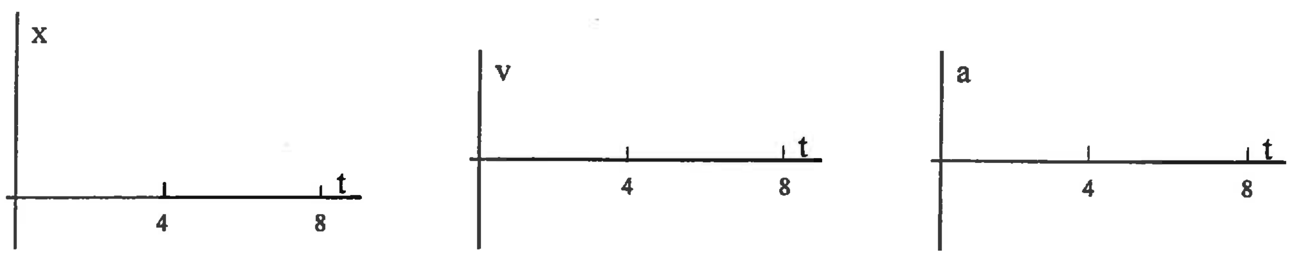
a) A ball is rolled along a horizontal surface as shown. Its position is shown at t = 4 s and t = 8 s.



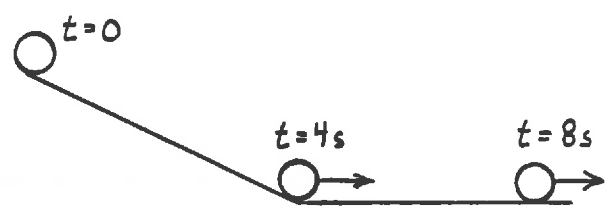


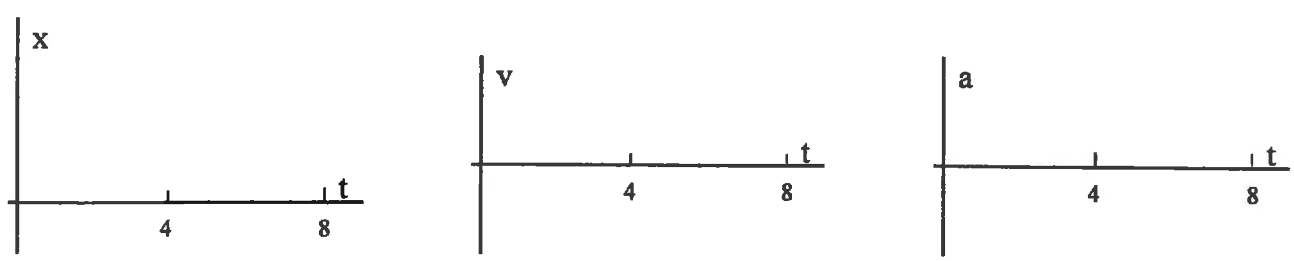
b) A ball is rolled along a hoizontal surface as shown. At t = 4 s it encounters a ramp and rolls up the ramp coming momentarily to rest at 8 s.





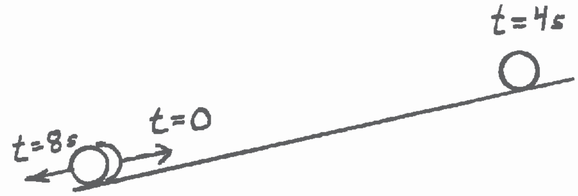
c) A ball is released from rest at the top of an incline as shown. At 4 s, it reaches the bottom of the incline and rolls along a horizontal surface until t = 8 s.

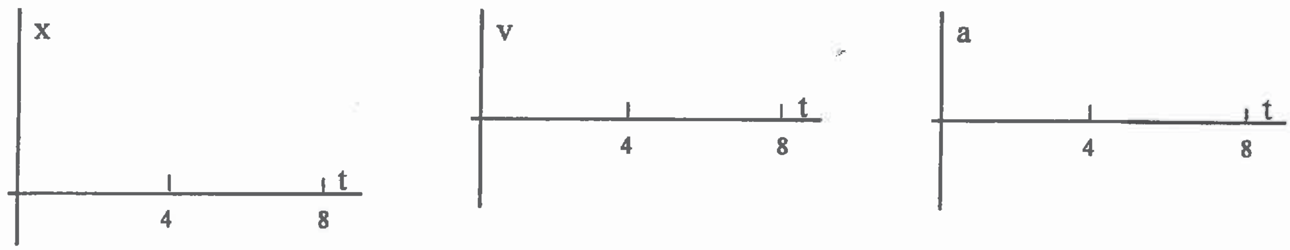




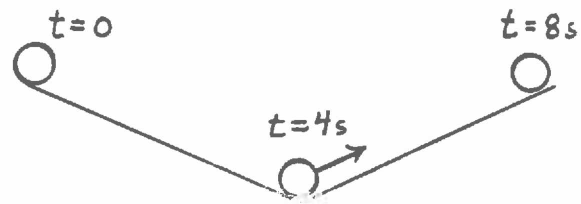
GRAPHICAL ANALYSIS II - WORKSHEET 3

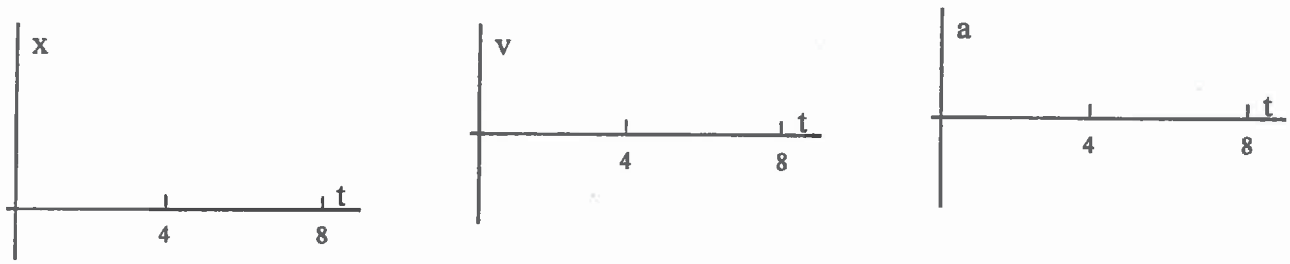
d) A ball is rolled up an incline with an initial velocity that carries it to a position near the top of the incline at t = 4 s where it momentarily comes to rest. It then rolls back down the incline, passing its initial position at t = 8 s.



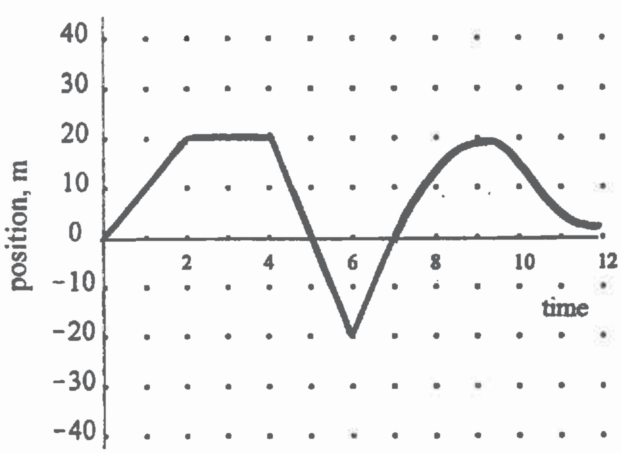


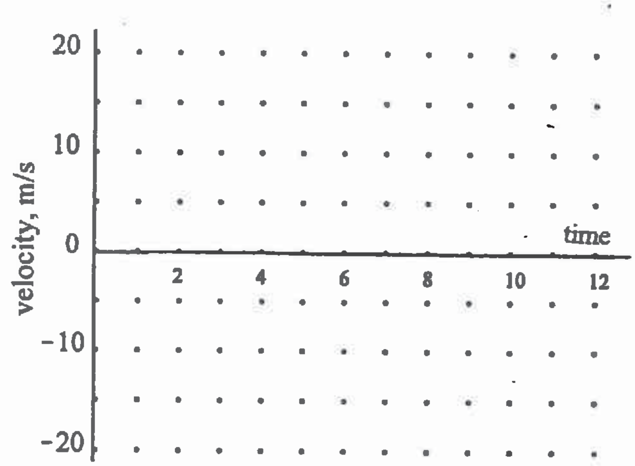
e) A ball is released from rest near the top of an incline as shown. At t = 4 s, it reaches the bottom of the incline and encounters an upward ramp. It rolls up the incline coming momentarily to rest at 8 s.



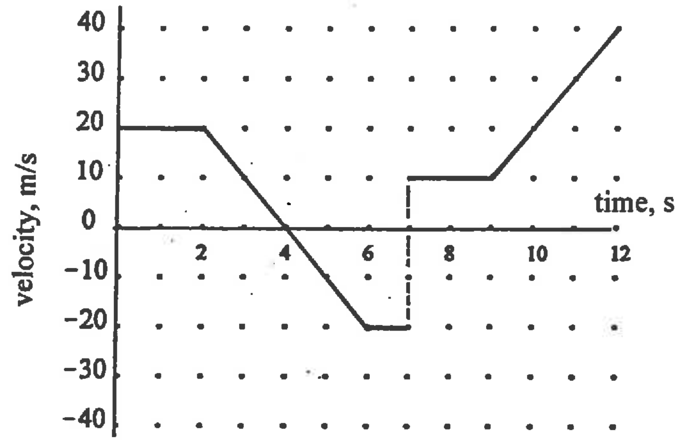


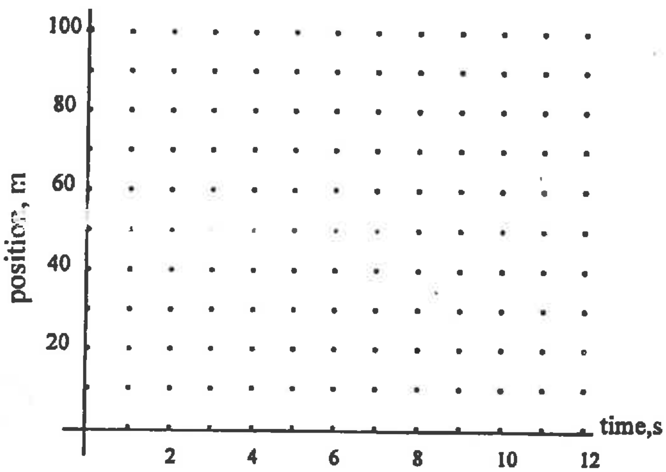
2. Below is shown the **position-time** graph for an object. On the graph at the right sketch the **velocity-time** graph for this object.

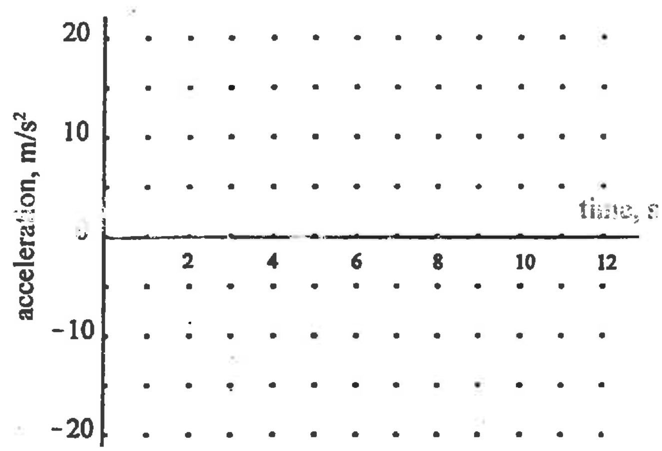




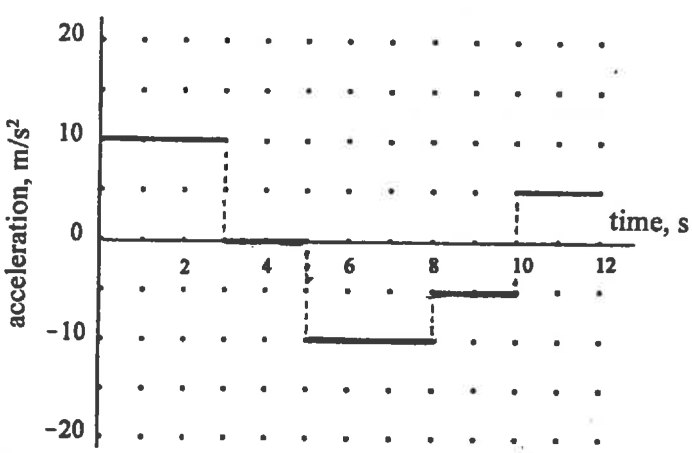
3. At the right is shown the **velocity-time** graph for a moving object. On the graphs below, sketch the **position-time** graph and the **acceleration-time** graph for this motion. Assume the initial position of the object was $x_o = 0$.

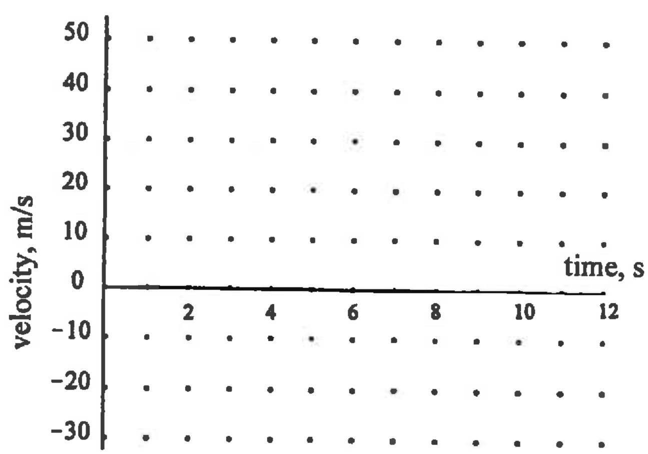


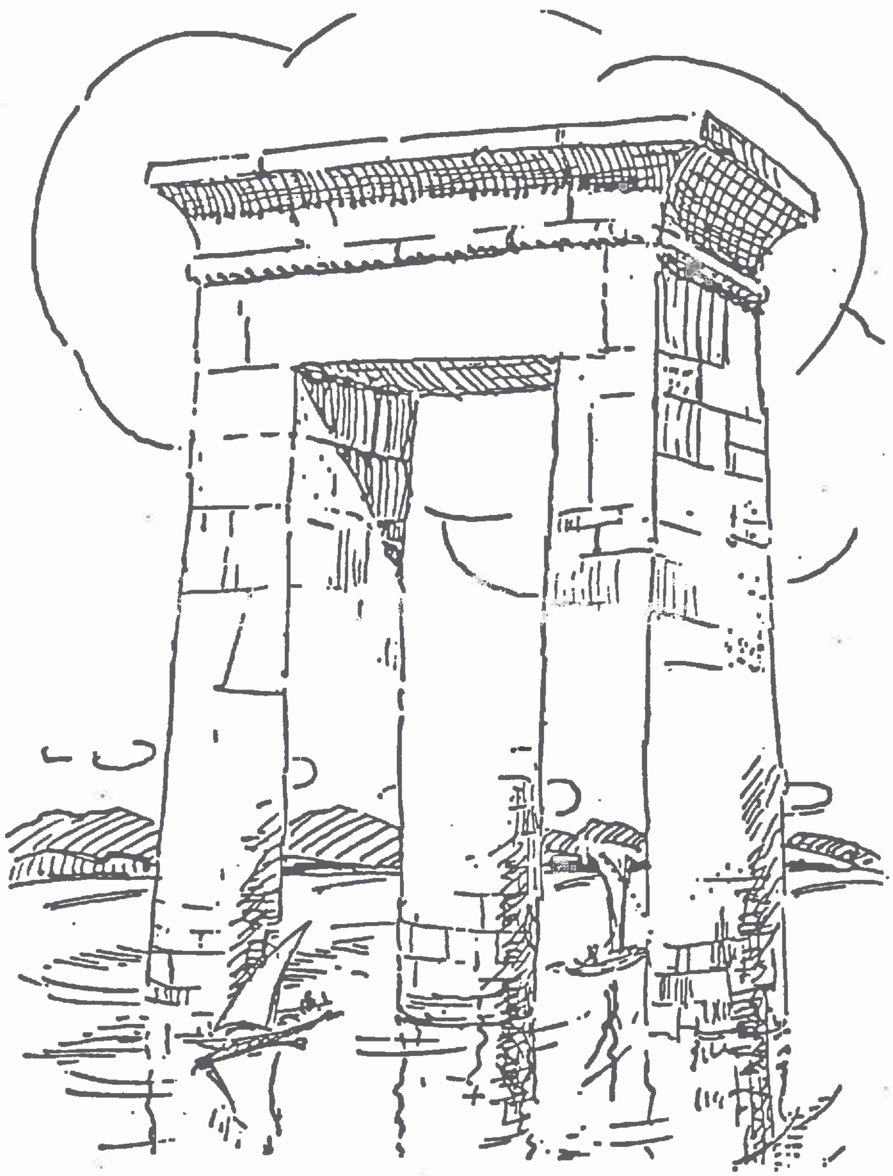




4. Below is shown the **acceleration-time** graph for an object. On the graph at the right, sketch the **velocity-time** graph for the object. Assume the initial velocity of the object was 15 m/s.







ZENO'S PARADOX

A TALE FROM ANCIENT GREEK SCIENCE

The concepts of speed and acceleration were not well understood by the Greeks. Because of this, the study of motion did not advance until Galileo. The ideas of Galileo were expanded and put on a firm mathematical foundation by Newton in 1687. If the Greeks had made more progress in kinematics, it is possible that our present knowledge of physics could have been discovered 2000 years ago which means that our present state of knowledge would be much farther advanced.

As an example of how confused some Greeks were about motion, consider the following story told by Zeno (about 450 BC), a Greek who never got it all together. Paraphrased into modern English, here is Zeno's tale:

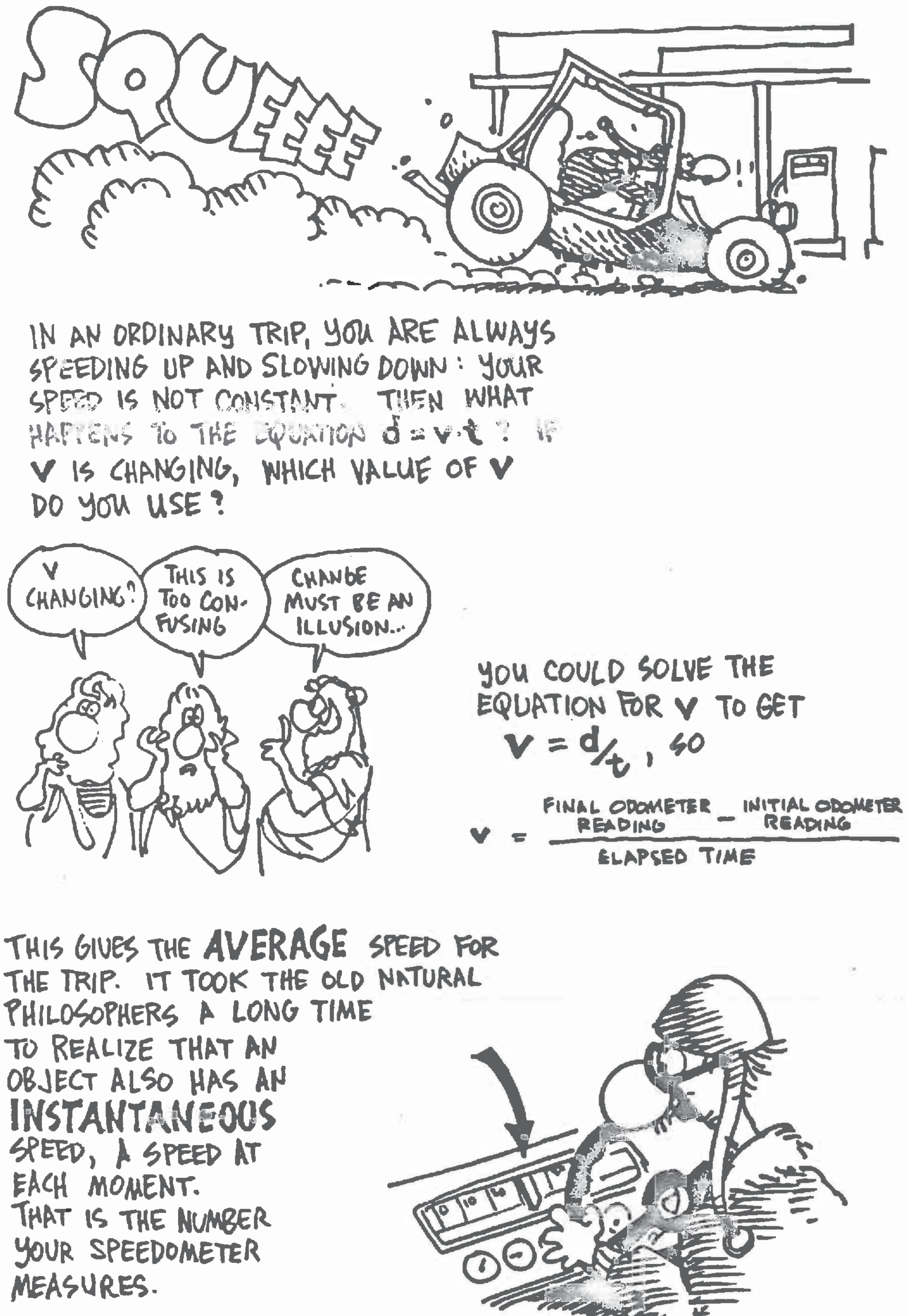
> *Achilles runs 10 times faster than the tortoise, but the tortoise challenged Achilles to a race and promised to beat Achilles if given a head start of 100 meters. Achilles asked the tortoise how this could be done and upon hearing the reasoning of the tortoise, Achilles gave up without a contest conceding defeat. The reasoning, as told by the tortoise to Achilles is as follows. When Achilles has run 100 meters to the place where the tortoise was, the tortoise has proceeded 10 meters, having run 1/10 as fast as Achilles. Achilles must run another 10 meters to catch the tortoise, but upon arriving at this new position, the tortoise is still one meter ahead. Likewise, whenever Achilles arrives where the tortoise was, the tortoise is always ahead. Achilles can never catch up!*

Can Zeno be correct? Does Achilles forever remain behind the tortoise? The argument seems well reasoned. Can you find a flaw? Do you believe Zeno?

NOTE. Clearly Zeno is wrong as demonstrated by Newton about 2000 years later. But what about the comment made above in the introduction to Zeno's tale which stated that if Zeno had Newton's knowledge of kinematics, we would be 2000 years ahead in our scientific knowledge? Many historians of science have suggested that the advancement of science is related, sometimes closely, with the need to know specific scientific knowledge or the desire to apply it to particular problems. The application of science to solve problems is what technology and engineering is all about. So as you ponder this question of whether or not we would be 2000 years ahead if the Greeks had not been so confused, ask yourself what use they had for this knowledge. Although there are many differences between the world of 450 BC and the world of 1687, some historians believe that there was a single crucial difference in society between the two times which made it unlikely that the Greeks would advance science beyond the ideas of Zeno and which had began to force the advancement of science in the time of Newton. Can you think of what this major difference is?

$d = v \cdot t$

An illustrated comment concerning the first formula of kinematics (as written by Larry Gonick and illustrated by Art Huffman)[1]



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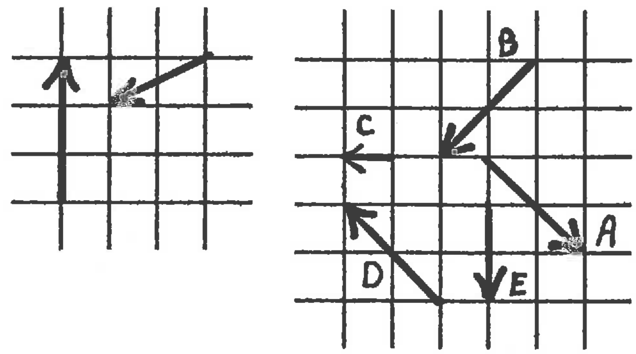
[1] Borrowed from **THE CARTOON GUIDE TO PHYSICS** by Larry Gonick and Art Huffman, Harper Perennial, 1991, p 5.

VECTOR ALGEBRA

I. Key Terms and Phrases - Write a definition or description of each term.

a) scalar quantity
b) vector quantity
c) vector
d) negative of a vector
e) resultant
f) polygon method
g) rectangular components
h) unit vectors
i) position vector
j) Cartesian coordinates
k) polar coordinates

II. QUESTIONS



1. The two vectors shown at the right are added together. Which vector at the far right represents the **vector sum** of the two vectors.
   a) A b) B c) C d) D e) E

2. The velocity of an airplane is 500 km/hr in a direction 25° N of E. The **eastward** speed of the airplane is a) 500 km/hr. b) 211 km/hr. c) 250 km/hr d) 453 km/hr.

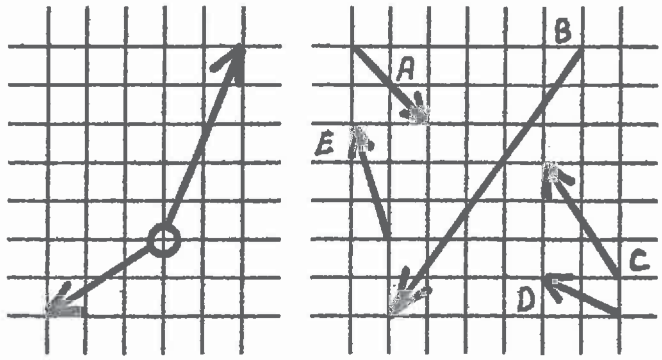
3. The velocity of an airplane is 500 km/hr in a direction 25° N of E. The **northward** speed of the airplane is a) 500 km/hr. b) 211 km/hr. c) 250 km/hr d) 453 km/hr.

4. Two displacement vectors have magnitudes of 5 meters and 7 meters respectively. When these vectors are added, the magnitude of the **largest** possible resultant is a) 1 m. b) 2 m. c) 6 m. d) 8.6 m. e) 12 m.

5. Two displacement vectors have magnitudes of 5 meters and 7 meters respectively. When these vectors are added, the magnitude of the **smallest** possible resultant is a) 1 m. b) 2 m. c) 6 m. d) 8.6 m. e) 12 m.

6. The vector sum of two vectors is zero. What is the angle between them? a) 0° b) 90° c) 45° d) 180° e) It cannot be determined.

7. Answer Y or N.
   ___ Can a vector have a zero component and a nonzero magnitude?
   ___ Can a vector have a zero magnitude and a nonzero direction?
   ___ Can the magnitude of a vector be negative?
   ___ Can two vectors of different magnitudes be added to give zero resultant?
   ___ Can you add a scalar quantity to a vector quantity?
   ___ Can you multiply or divide a vector by a scalar?



8. Two forces are acting as shown at the right. Which vector at the far right is the **resultant** of the two force vectors? a) A b) B c) C d) D e) E

9. If vector **A** has x and y components of 1.5 m and 2.0 m respectively, and vector **B** has x and y components of −1.5 m and 2.0 m respectively, what is the magnitude of vector **C** where **C** = **A** + **B**? a) 7 m b) zero c) 4 m d) 3 m e) 1 m

10. If vector **A** has x and y components of 1.5 m and 2.0 m respectively, and vector **B** has x and y components or −1.5 m and −2.0 m respectively, what is the magnitude of vector **C** where **C** = **A** − **B**? a) 7 m b) 5 m c) 4 m d) 3 m e) zero

11. If vector **A** has x and y components of 1.5 m and 2.0 m respectively, and vector **B** has x and y components of 1.5 m and −2.0 m respectively, what is the magnitude of vector **C** where **C** = **A** + **B**? a) 7 m b) zero c) 4 m d) 3 m e) 1 m

12. Vector **A** has x and y components of 3.0 and −6.0 respectively. In what direction does vector **A** point? a) 0° b) 296.6° c) 315° d) 330° e) 42.2°

13. Vector **A**, acting at 130°, is added to vector **B** = 70 N at 50°. If the resultant vector acts at 90°, what is the magnitude of vector **A**? a) 70 N b) 50 N c) 45 N d) 35 N e) 94.3 N

14. Vector **A**, acting along 130°, is added to vector **B** = 70 N at 30°. If the resultant vector acts at 90°, what is the magnitude of vector **A**? a) 70 N b) 50 N c) 45 N d) 35 N e) 94.3 N

15. Vector **A** has x and y components of 9 m and 20 m respectively. Vector **B** has x and y components of −15 m and −10 m respectively. If **C** = **A** + **B**, what is the x-component of **C**? a) −10 m b) −6 m c) 23.3 m d) 10 m e) 6 m

16. Vector **A** has x and y components of 9 m and 20 m respectively. Vector **B** has x and y components of −15 m and −10 m respectively. If **C** = **A** + **B**, what is the y-component of **C**? a) −10 m b) −6 m c) 23.3 m d) 10 m e) 6 m

17. Vector **A** has x and y components of 9 m and 20 m respectively. Vector **B** has x and y components of −15 m and −10 m respectively. If **C** = **A** + **B**, what is the magnitude of **C**? a) 10 m b) 9 m c) 11.7 m d) 23.3 m e) 6 m

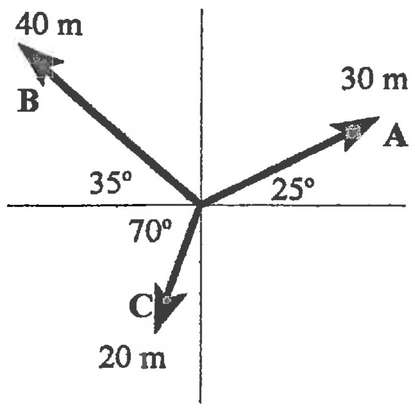
18. A car travels 10 km north, then 10 km east, then 10 km south, then 10 km east, and finally 10 km north. The magnitude of the net displacement is a) 10 km. b) 20 km. c) 22.4 km. d) 38.6 km. e) 40 km.

19. You know that **A** = **B**. If **B** = 3 **i** + 5 **j** −7 **k**, then what is the magnitude of A_x? a) 3 b) −3 c) −1 d) −5 e) It cannot be determined.

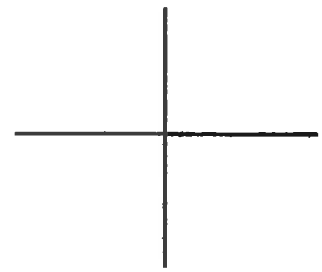
VECTOR ALGEBRA - WORKSHEET 5

III. PROBLEMS - Each problem below shows three vectors drawn with their tails at the origin. On the diagram, sketch the perpendicular components of each vector. Find and record the componets of each vector in the table and find the components of the resultant. On the small diagram at the right, sketch the components of the *resultant* and to enter the magnitude and direction of the resultant

1.



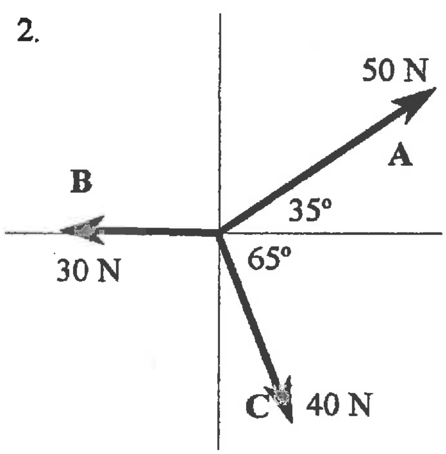
	x-component	y-component
A		
B		
C		
R		



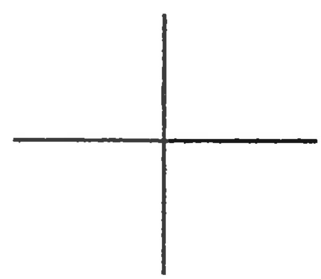
R = __________

θ = __________

2.



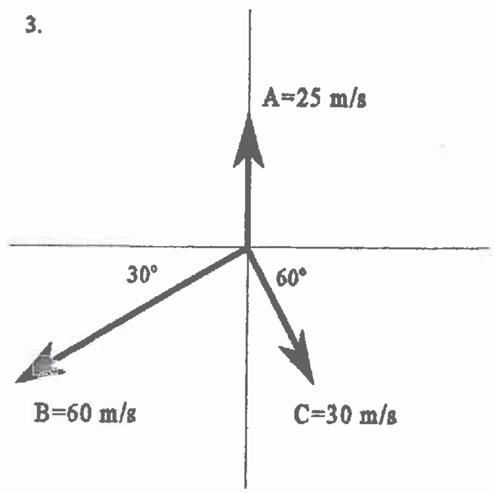
	x-component	y-component
A		
B		
C		
R		



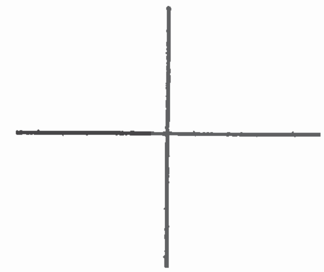
R = __________

θ = __________

3.



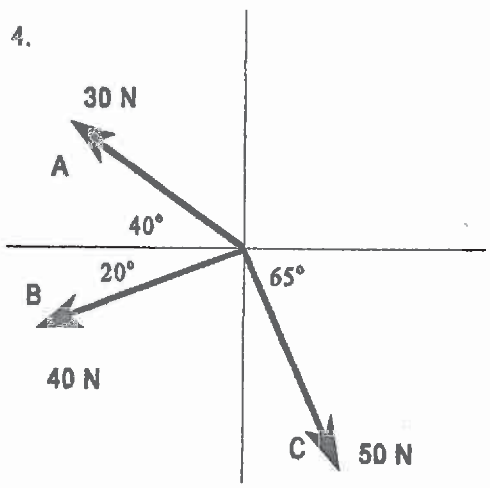
	x-component	y-component
A		
B		
C		
R		



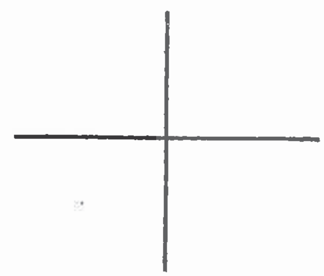
R = ________

θ = ________

4.



	x-component	y-component
A		
B		
C		
R		



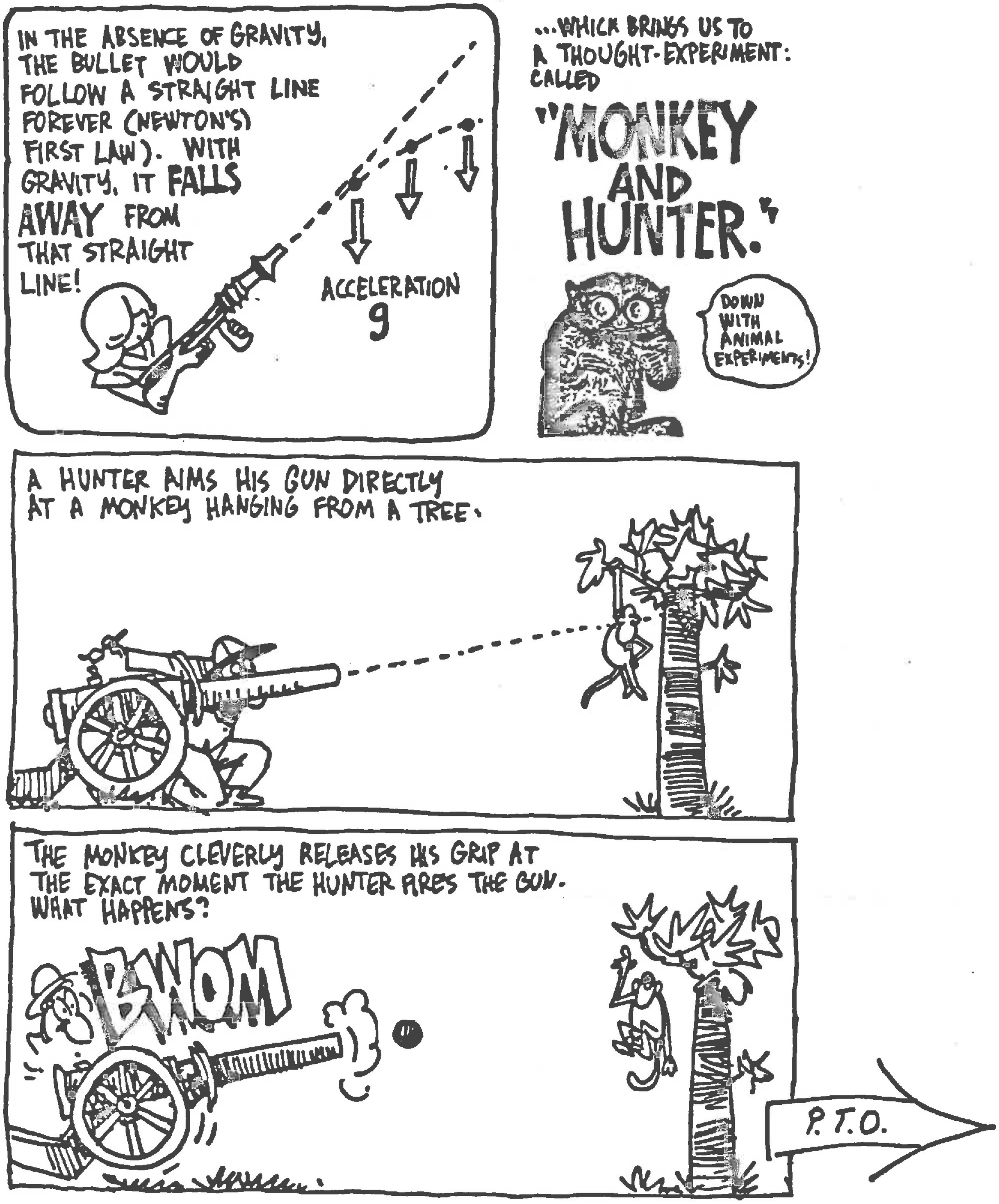
R = ________

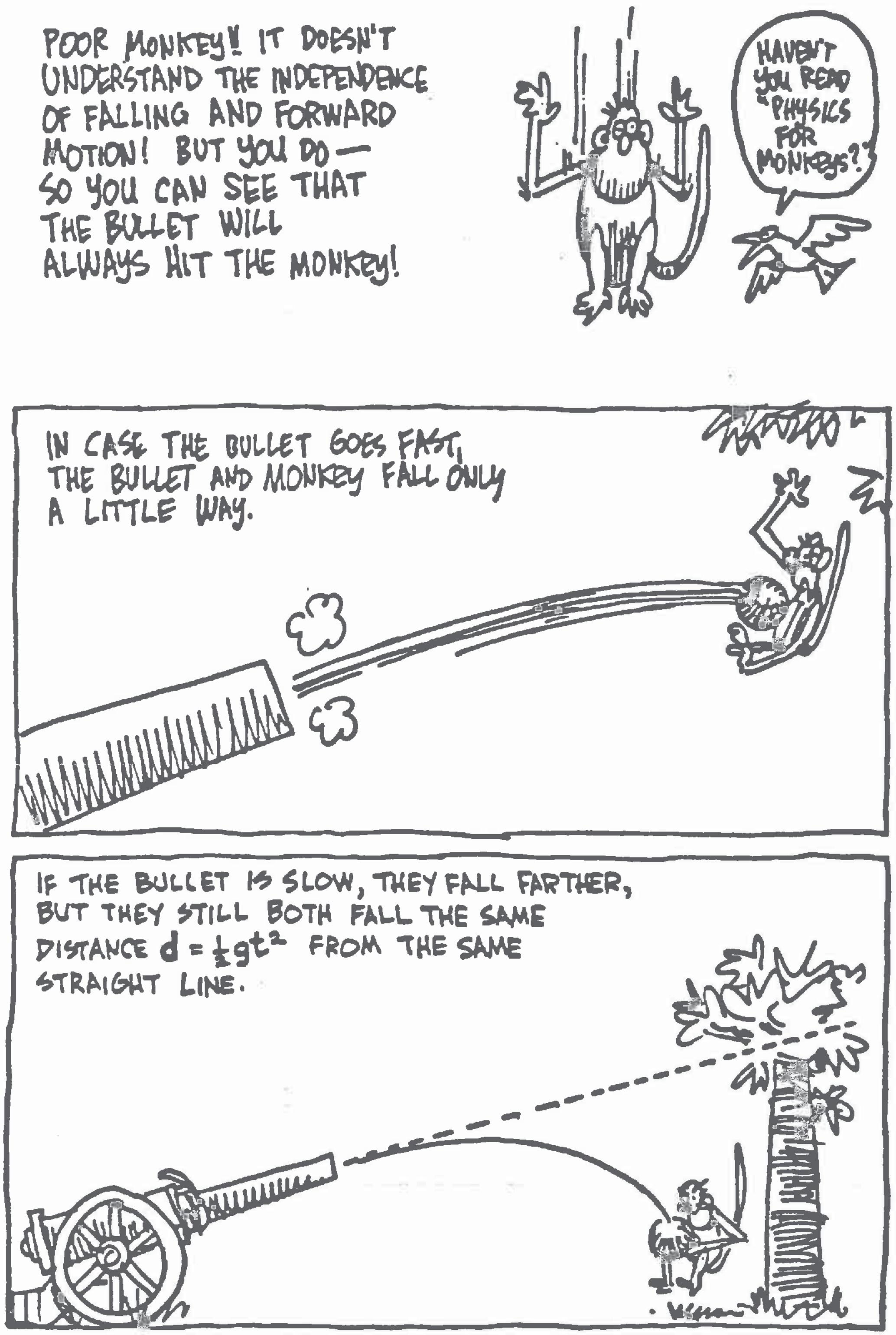
θ = ________

THE MONKEY AND THE HUNTER

An Illustrated Story

This is an old story, probably first told 400 years ago to dramatize the path of a projectile and to emphasize the effect caused by the acceleration due to gravity. This is the illustrated version of the story as written by Larry Gonick and illustrated by Art Huffman.





[1] Borrowed from THE CARTOON GUIDE TO PHYSICS by Larry Gonick and Art Huffman, Harper Perennial, 1991, p 35.

TABLE OF MASSES, DIMENSIONS, AND SPEEDS

What is the mass of a car or a polar bear? How fast can a cheetah run or what is the radius of a basketball? You may wish to know the answers to these and similar questions when thinking about the motion of real objects. This table gives the masses, dimensions, and speeds of various kinds of objects.

Object	Mass (kg)	Dimensions or other property*
ping-pong ball	2.5×10^{-3}	d = 3.78 cm
small marble	5.0×10^{-3}	d = 1.5 cm ; ρ = 2.87 g/cm^3
golf ball	4.6×10^{-2}	r = 2.18 cm
tennis ball	5.7×10^{-2}	r = 3.26 cm service ≈ 200 km/h = 56 m/s
baseball	0.145	r = 3.74 cm fast ball ≈ 38 m/s
baseball bat		max. l = 106.7 cm max. t = 7.0 cm
ice hockey puck	0.17	r = 3.8 cm; t = 2.54 cm
volley ball	0.255	r = 10.5 cm
soccer ball	0.425	r = 11.0 cm
croquet ball	0.437 mallet ≈ 1.4	r = 4.60 cm
bowling ball	7.2	r = 10.9 cm
basketball	0.625	r = 12.0 cm
curling stone	18.8	r = 14.5 cm
javelin (men's) javelin (women's)	0.800 0.600	min. l = 260 cm max. d ≈ 2.5 cm record throw ≈ 97 m
men's discus	2.0	d = 22.1 cm ; t = 4.6 cm record throw ≈ 71 m
grinding wheel	1.66	d = 19 cm ; rpm = 2600
large car wheel and tire	22	d = 71 cm
small car wheel and tire	13	d = 58 cm
human fraction of body mass: head and neck....0.07; trunk....0.43; upper arms....0.07; forearms and hands...0.06; thighs....0.23; lower legs and feet.....0.14		

mosquito	≈ 5×10^{-5}	
domestic cat	≈ 4	
Chihuahua	≈ 1.4	h = 19 cm (shoulders)
Golden Retriever	≈ 32	h = 60 cm (shoulders)
male polar bear	590	
draft horse	640 to 1140	
elephant	3800	foot d ≈ 38 cm
large blue whale	1.4×10^5	30 m
horseshoe (pitching)	1.13	
small block Chevy V-8 engine	227	
large block Chevy V-8 engine	318	
Corvette	1460	
L 1011 - 500 Lockheed airliner	2.3×10^5	wingspan = 50.1 m length = 50.0 m cruising speed = 880 km/h
box car	7×10^4	12 m
largest steam locomotive	5.4×10^5	
J F K class aircraft carrier	7.3×10^7	l = 329 m
greyhound	max. speed ≈ 64 km/h	
falcon	max. flying speed ≈ 160 km/h; max. diving speed ≈ 290 km/h	
horse	max. speed ≈ 50 km/h; for long distances ≈ 21 km/h	
human high jump	record h ≈ 2.3 m	
cheetah	max. speed ≈ 113 km/h	
lion	can jump 10 m and reach 97 km/h in a short sprint	
impala	max. jump h ≈ 2.4 m, max.jump l ≈ 9 m	

* In this table d = diameter, r = radius, l = length, t = thickness, h = height, s = speed, w =width, and ρ = density.

PROBLEM SOLVING - NEWTON'S SECOND LAW

Newton's second law tells us that the *acceleration* of an object is caused by the *net force* acting on that object. Thus, to analyze the motion of an object, we must be able to find *all* the forces that act on an object and reduce them to the net force. When solving problems in dynamics, it is very important to draw force diagrams showing all the forces that act on each object of interest. The basic method for solving 2nd law problems, summarized below, is a general method that can be applied to any 2nd law problem that you meet. Usually, the solution to a problem is not apparent at first. But rather than being lost and not knowing how to proceed, start with step 1 of this method. The steps guide you through the procedure that leads to a solution. If you can get the right force diagrams, you can usually solve the problem. As you learned in kinematics, ***the solution is in the diagram***.

General Problem Solving Method for the 2nd Law.

1. **Draw a sketch** of the situation and include what quantities you know and don't know.
2. **Isolate** the objects or objects of interest and **draw a force diagram** for each.
3. **Show** the direction of the acceleration, **a**, on each force diagram,
4. **Show** a coordinate system, if needed. **Break** the forces into their **perpendicular components**, parallel to **a** and perpendicular to **a**.
5. **Apply** the 2nd Law to each direction:

$$\sum F_x = m\,a_x \qquad\qquad \sum F_y = m\,a_y$$

6. **Substitute** the known quantities into each eqution and **solve.**

On the next page are two problems with partial solutions that illustrate this general method for solving 2nd Law problems. Work through each problem and supply the missing steps.

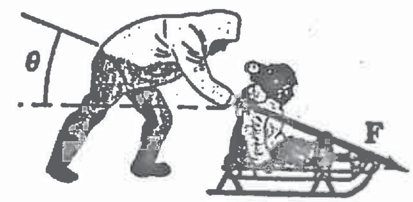
PROBLEM SOLVING - NETON'S SECOND LAW

EXAMPLES OF THE PROBLEM SOLVING METHOD

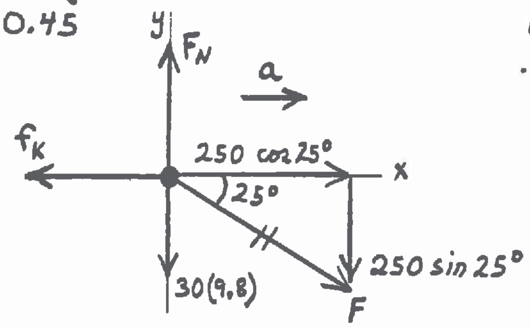
1. Your niece wants to ride in your sled. The total mass of niece and sled is 30 kg and you give her a push of 250 N directed 25° *below* the horizontal as shown. Assume that the coefficient of kinetic friction between the sled and the snow is 0.45. Find the acceleration of the sled and the normal force acting on the sled.

sketch with quantities $m = 30\ kg$ $F = 250\ N$

$\mu_K = 0.45$



force diagram
direction of acceleration
perpendicular components



second law

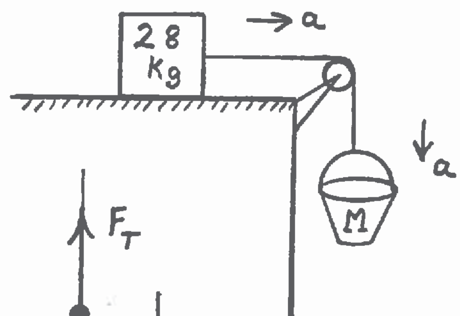
$\Sigma F_x = ma$ $\Sigma F_y = 0$ $f_K = \mu_K F_N$

$250 \cos 25° - f_K = 30a$ $F_N - 30(9.8) - 250 \sin 25° = 0$ $f_K = 0.45 F_N$

answers

$a = 1.57\ m/s^2$ $F_N = 400\ N$ Note: $F_N \neq mg$

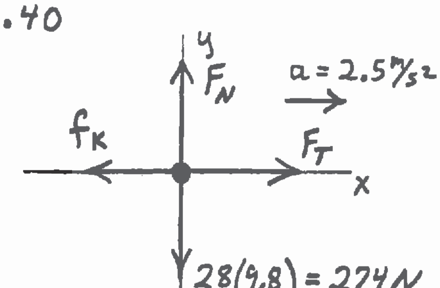
2. A 28 kg block, resting on a table surface, is connected to an empty bucket of mass 2 kg via a rope that passes over a frictionless pulley as shown below. Assuming that the coefficient of kinetic friction between the block and the surface is 0.40, what mass sand must be added to the bucket to cause the system to accelerate at 2.5 m/s^2?

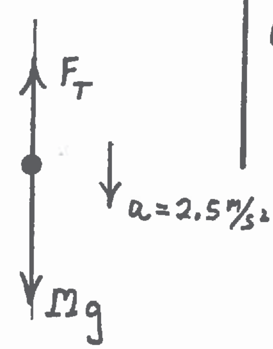


sketch with quantities $a = 2.5\ m/s^2$ $m_{sand} = M - 2$

$\mu_K = 0.40$

force diagram
direction of acceleration
perpendicular components





second law

$\Sigma F_x = ma$ $\Sigma F_y = 0$ $f_K = \mu_K F_N$ $\Sigma F_y = Ma$

$F_T - f_K = 28(2.5)$ $F_N - 274 = 0$ $f_K = 0.4 F_N$ $Mg - F_T = M(2.5)$

answer $m_{sand} = 22.7\ kg$

FORCES AND FORCE DIAGRAMS

Part 1. Drawing Force Diagrams and Identifying Forces.

A. An 80 kg person standing near a wall reaches out a hand and leans against a nearby wall as shown in the sketch below. Let the dot at the right represent the c.m. of the person. On the dot draw and label the force diagram for the person showing all the forces acting on the person.

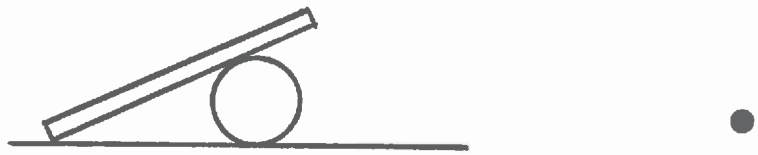
1. For each force in your force diagram, clearly identify the force by stating its *direction*, the object acted *on*, and the object *causing* the force.

2. Characterize each force by stating whether it is a contact *force* or an *action-at-a-distance* force and stating the type of force (i.e. gravitation, normal, etc.).

3. Assume that each force in your force diagram is an *action* force. For each action force, clearly identify the associated *reaction* force by stating its *direction*, the object acted *on*, and the object *causing* the force.

FORCES AND FORCE DIAGRAMS - WORKSHEET 8

B. A 5 kg plank of wood leans on a 0.15 kg basketball as shown in the sketch below. Let the dot at the right represent the c.m. of the basketball. On the dot draw and label the force diagram for the basketball showing all the forces acting on the ball. Note that the ball does not move.



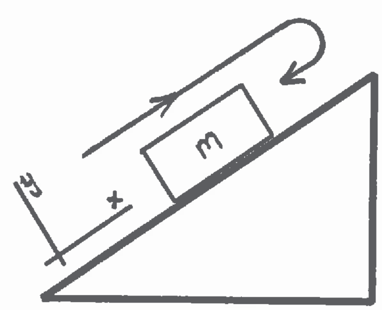
1. For each force in your force diagram, clearly identify the force by stating its *direction*, the object acted *on*, and the object *causing* the force.

2. Characterize each force by stating whether it is a contact *force* or an *action-at-a-distance* force and stating the type of force (i.e. gravitation, normal, etc.).

3. Assume that each force in your force diagram is an *action* force. For each action force, clearly identify the associated *reaction* force by stating its *direction*, the object acted *on*, and the object *causing* the force.

Part 2. Predicting Motion from Force Diagrams.

A. A block of wood is given an initial push up an inclined surface as shown. It slides up the surface, slowing down, reaches the top, turns around and slides back down the incline. Assume that friction can be neglected.



No Friction.

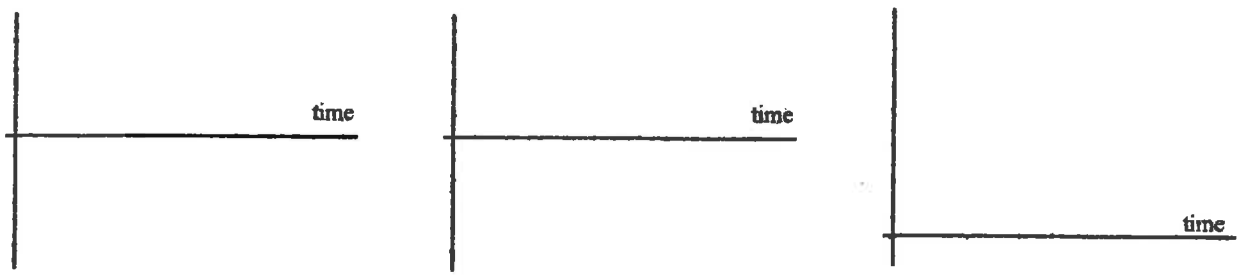
WORKSHEET 8 - FORCES AND FORCE DIAGRAMS

1. In the space below, draw and label the force diagram for the block as it moves **up** the incline (after the push) and then draw a separate force diagram for the block as it moves back **down** the incline.

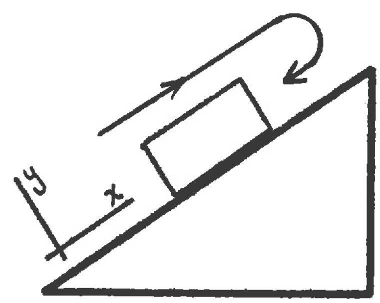
Block Moving Up | Block Moving Down

2. Sketch below the time graphs for the *entire* motion of the block (i.e. both up and down the incline).

acceleration | velocity | position



B. A block of wood is given an initial push up an inclined surface as shown. It slides up the surface, slowing down, reaches the top, turns around and slides back down the incline. There is friction between the block and the surface.



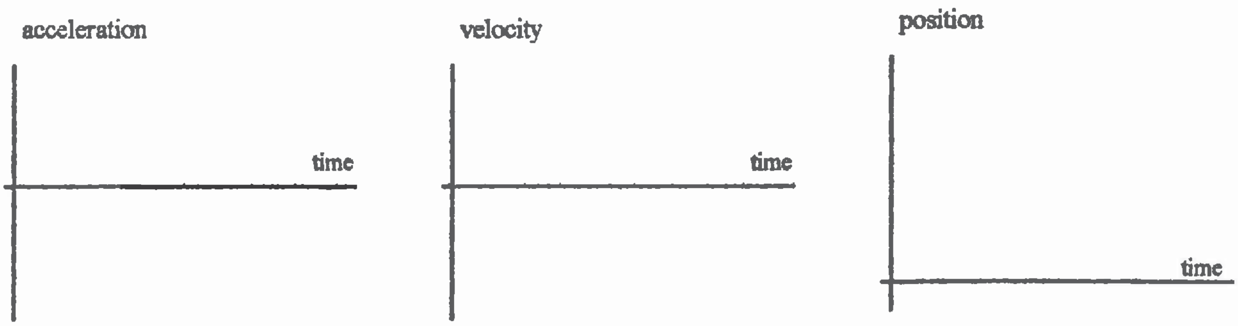
There is friction.

1. In the space below, draw and label the force diagram for the block as it moves **up** the incline (after the push) and then draw a separate force diagram for the block as it moves back **down** the incline.

Block Moving Up | Block Moving Down

FORCES AND FORCE DIAGRAMS - WORKSHEET 8

2. Sketch below the time graphs for the *entire* motion of the block (i.e. both up and down the incline).

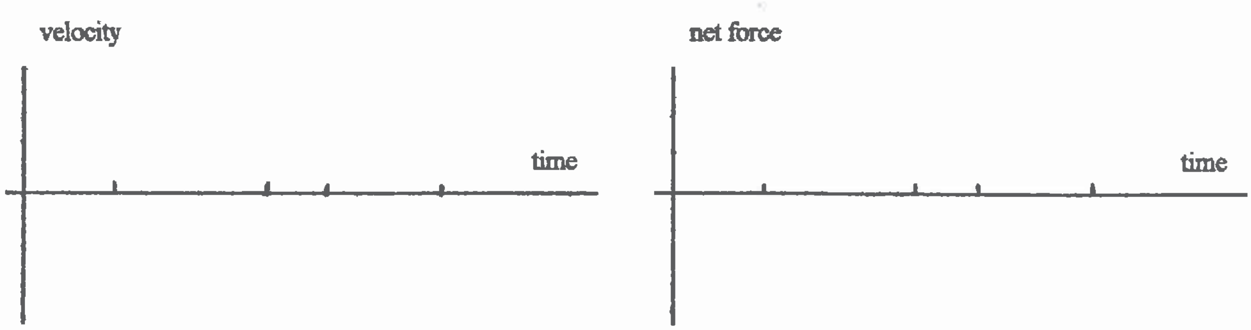


C. Suppose you have determined that the average force of friction that acts on your car when moving with a speed between zero and 12 m/s is about 2.50 kN and that the force applied to the car when braking is about 11.0 kN. Suppose further that you know that when accelerating within this speed range, the average force applied to the car via its wheels is about 10 kN. Imagine that you take your car for a drive and make the following motions: starting from rest, you speed up to 10 m/s and move with a constant velocity for awhile. Then you quickly slow down to 6 m/s to avoid hitting the car in front of you, then immediately speed up to 12 m/s and then turn off the motor and allow the car to coast to a stop.

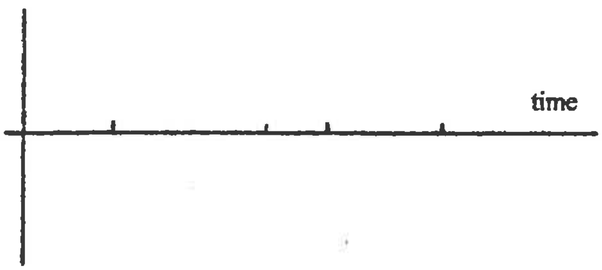
1. In the space below draw and label the force diagram for the car for each situation

Speeding Up Braking Coasting

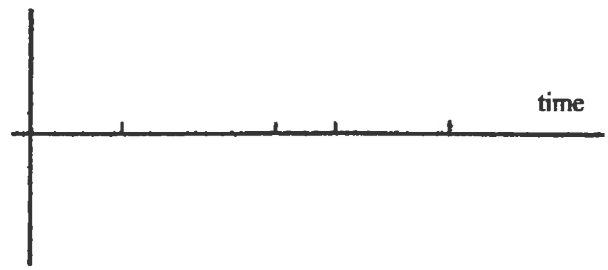
2. Sketch the time graphs for each quantity below associated with this motion.



force of friction

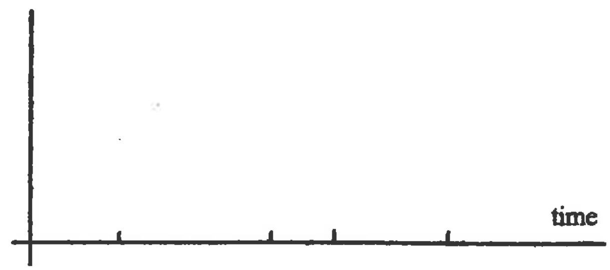


applied force on the wheels



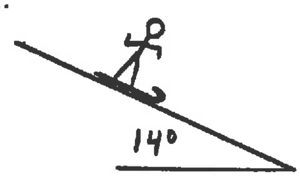
acceleration

position



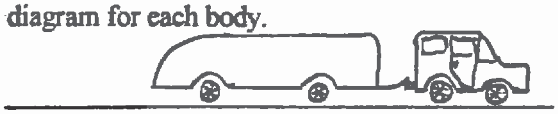
Part 3. Drawing Force Diagrams.

Force diagrams help you solve problems in dynamics. The questions below give you additional practice in drawing force diagrams. Draw and label a force diagram or diagrams for each situation below and show the direction of the acceleration for each object.

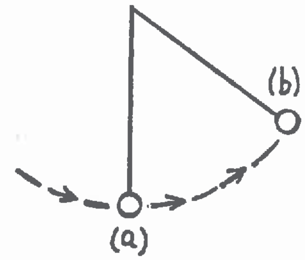
1. A sled is pulled over a rough surface. Draw the force diagram for the sled. 	2. An 80 kg skier slides down a slope where the coefficient of sliding friction is 0.4. Draw the force diagram for the skier. 

FORCES AND FORCE DIAGRAMS - WORKSHEET 8

3. A 1200 kg car pulls a 2000 kg trailer along a surface with a rolling coefficient of friction of 0.12. If the force of friction acts on both bodies, draw the force diagram for each body.

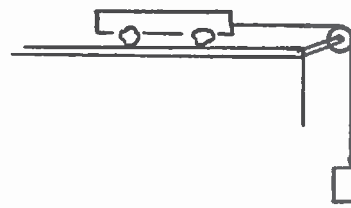


4. A 2 kg ball swings as a pendulum along an arc as shown. Draw the force diagram for the ball when (a) the ball is at the bottom of the path and (b) the ball is at the end of its arc.

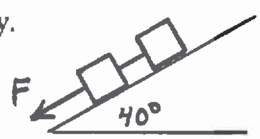


5. A 60 kg student stands on a 10 kg chair. If this is a two body problem, draw the force diagram for each body.

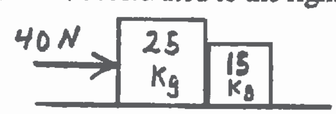
6. A 0.50 kg cart is pulled along a rough surface by a 0.080 kg weight as shown. Draw the force diagram for each body.



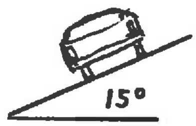
7. Two 10 N boxes, connected by a rope, are pulled down a rough inclined surface. Draw the force diagram for each body.



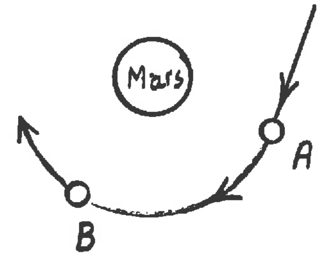
8. A 25 kg box is in contact with a 15 kg box and both sit on a rough surface. A 40 N force is applied to the 25 kg box and the system is accelerated to the right.



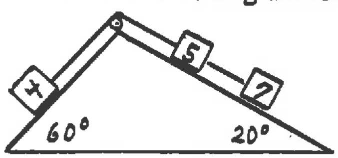
9. The diagram shows the rear view of a car rounding a corner on a banked roadway. The car is moving fast and is tending to slide up the incline on the rough surface. Draw the force diagram for the car.



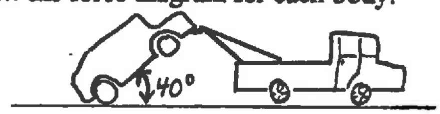
10. A Mars probe is entering the space near Mars and follows the trajectory shown. Draw the force diagram for the probe at the two positions, position A and position B.



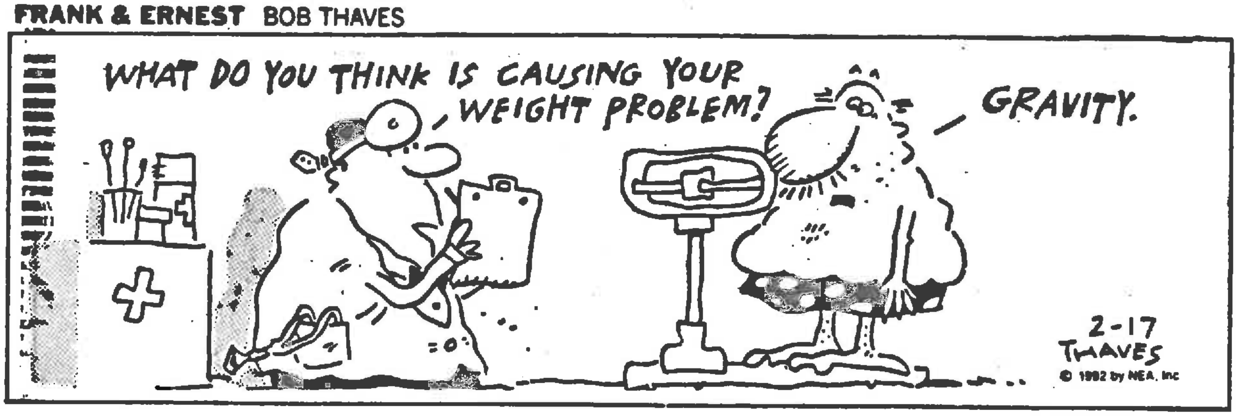
11. A 5 N box, attached to a 7 N box via a rope, is connected over a pulley to a 4 N box. The coefficient of kinetic friction is 0.3. Draw the force diagram for each body.



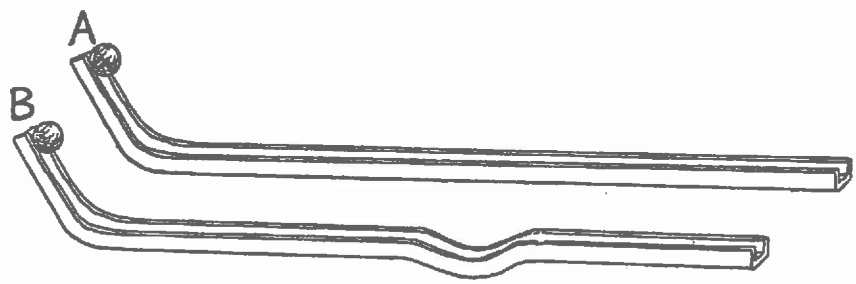
12. A tow truck, pulling a car, is accelerating to the right. A force of friction acts on both objects. Draw the force diagram for each body.



FRANK & ERNEST BOB THAVES



Figuring Physics



Tracks A and B are made from pieces of channel iron of the same length. They are bent identically except for the small dip in the middle of Track B. When balls are simultaneously released on both tracks as indicated, the ball that races to the end of the track first is on

a) Track A

b) Track B

c) ... both reach the end at the same time

Hewitt Drew it!

THE HORSE AND THE CART

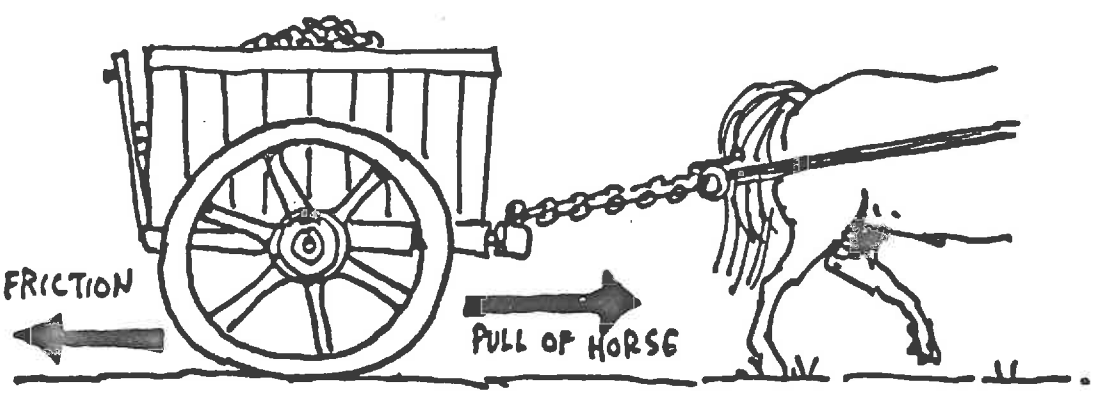
An Ancient Fable Concerning the Third Law

The Fable: A horse is urged to pull a cart. The horse refuses to try, citing Newton's third law as a defense: The pull of the horse on the car is equal and opposite to the pull of the cart on the horse. *"If I can never exert a greater force on the cart than it exerts on me, how can I ever start the cart moving?"* asks the horse.

How would you reply to the horse (assuming that you know how to talk to horses)?

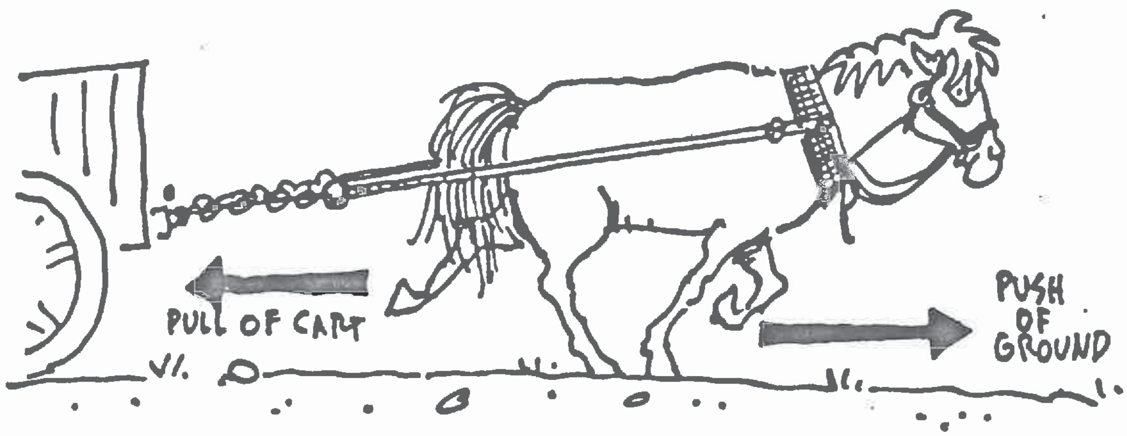
Here is an analysis as writen by Larry Gonick and illustated by Art Huffman.

HOW CAN A HORSE PULL A CART, IF THE CART PULLS BACK WITH AN EQUAL FORCE?? TO ANALYZE THIS, WE HAVE TO LOOK AT EACH OBJECT ALONE AND THE FORCES ACTING ON IT.



WHAT FORCES ACT ON THE CART? THE HORSE PULLS IT FORWARD, AND THERE IS A BACKWARD FORCE FROM THE GROUND: **FRICTION**. IF THE HORSE'S PULL EXCEEDS THE FRICTION, THE CART WILL ACCELERATE.

P.T.O.



NOW THE HORSE: THE CART PULLS IT BACKWARD, BY NEWTON'S THIRD LAW. WHAT PUSHES THE HORSE FORWARD? IT'S THE GROUND!! THE HORSE PUSHES BACKWARD ON THE GROUND, SO THE GROUND PUSHES FORWARD WITH AN EQUAL FORCE. IF THE HORSE CAN PUSH BACK AGAINST THE GROUND WITH A FORCE GREATER THAN THE CART'S RESISTING FORCE, THEN THE HORSE WILL ACCELERATE!

Borrowed from **THE CARTOON GUIDE TO PHYSICS** by Larry Gonick and Art Huffman, Harper Perennial, 1991, p 51.

CIRCULAR MOTION AND GRAVITATION

I. Key Terms and Phrases - Write a definition or description of each term. In addition,

A) write **V** in **front** of each quantity if the quantity is a **vector quantity** or write **S** if the quantity is a **scalar quantity**.

B) write the **MKS units** of the quantity in the space **behind** the quantity.

___ a) centripetal force ___
___ b) centripetal acceleration ___
___ c) weight ___
___ d) gravitational mass ___
___ e) inertial mass ___
f) uniform circular motion
g) Newton's law of gravitation
h) inverse square relationship
i) orbital speed
g) weightlessness

II. QUESTIONS

1. A car, moving with constant speed, rounds a circular corner. If it rounds the same corner with twice the speed, the **centripetal force** changes by a factor of a) one-fourth. b) one-half. c) zero. d) two. e) four.

2. A car, moving with constant speed, rounds a circular corner. If it rounds another corner of twice the radius with the same speed, the **centripetal force** changes by a factor of a) one-fourth. b) one-half. c) zero. d) two. e) four.

3. A car, moving with constant speed, rounds a circular corner. If a second car of twice the mass rounds the corner at the same speed, the **centripetal force** changes by a factor of a) one-fourth. b) one-half. c) zero. d) two. e) four.

4. A car, moving with constant speed, rounds a circular corner. The **acceleration** of the car
   a) is directed toward the front of the car.
   b) is directed toward the back of the car.
   c) is zero.
   d) is directed along the radius away from the center of the curve.
   e) is directed along the radius toward the center of the curve.

5. An off ramp from the Beltway is very dangerous because cars slide off the curve. In a redesign of this corner, which step would be the most effective?
   a) Reducing the radius to one-half its present value.
   b) Increasing the radius to twice its present value.
   c) Increasing the speed limit to twice its present value.
   d) Reducing the speed limit to one-half its present value.
   e) Either (b) or (d) because they produce identical results.

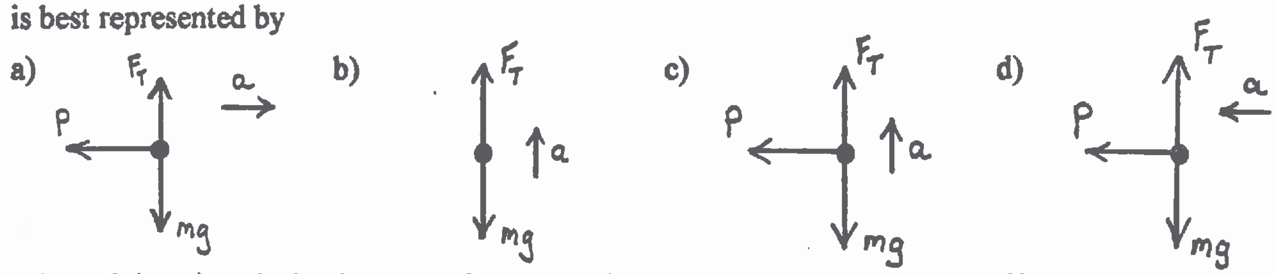
6. A ball of weight 2 N, attached to the end of a string, is whirled in a vertical circle in such a way that its speed stays constant on the circular path. At the **top of its path**, the tension in the string is a) greater than 2 N. b) less than 2 N. c) equal to 2 N. d) Cannot be determined.

CIRCULAR MOTION AND GRAVITATION - WORKSHEET 9

7. A ball of weight 2 N, attached to the end of a string, is whirled in a vertical circle in such a way that its speed stays constant on the circular path. At the **bottom of its path**, the tension in the string is a) greater than 2 N. b) less than 2 N. c) equal to 2 N. d) Cannot be determined.

8. A pendulum is swinging back and forth over the same path. At what point in its swing is the tension in the string greatest? a) At the bottom of its path. b) At either end of its path. c) About halfway between the end and the bottom of its path. d) The tension is the same at all points along its path.

9. A pendulum is swinging back and forth over the same path. At the bottom of its path, the force diagram is best represented by



10. A pendulum is swinging back and forth over the same path. At the bottom of its path, the tension in the string is (a) less than mg. (b) greater than mg. (c) equal to mg.

11. Suppose the gravitational attraction between a dime and a nickel separated by one meter is determined to be F. If a second dime is placed on the first dime, the new gravitational force of attraction is (a) 2 F. (b) 4 F. (c) 8 F. (d) F/2. (e) F/4.

12. Suppose the gravitational attraction between a dime and a nickel separated by one meter is determined to be F. If a second dime is placed on the first dime and a new nickel is placed on the first nickel, the new gravitational force of attraction is (a) 2 F. (b) 4 F. (c) 8 F. (d) F/2. (e) F/4.

13. Suppose the gravitational attraction between a dime and a nickel separated by one meter is determined to be F. A second dime is placed on the first dime and the nickel is moved to 0.25 meter from the dimes. The new gravitational force of attraction is a) 8 F. b) 16 F. c) 32 F. d) F/4. e) F/16.

14. Suppose the gravitational attraction between a dime and a nickel separated by one meter is determined to be F. A second dime is placed on the first dime and a second nickel is placed on the first nickel. The two nickels are then moved to 4 meters from the dimes. The new gravitational force of attraction is a) 8 F. b) 16 F. c) 32 F. d) F/4.

15. How does earth's rotation affect your **apparent weight?** a) It increases weight. b) It decreases weight. c) It has no effect on weight.

16. Suppose the mass of the earth doubled. Your **weight** would change by a factor of a) four. b) two. c) zero. d) one-half. e) one-quarter.

17. Suppose the radius of the earth doubled. Your **weight** would change by a factor of a) four. b) two. c) zero. d) one-half. e) one-quarter

18. Suppose your mass doubled. Your **weight** would change by a factor of a) four. b) two. c) zero. d) one-half. e) one-quarter

19. An object weighs 12 N on earth. Zantar has twice the radius and twice the mass of earth. The **weight** of the object on Zantar is a) 3 N. b) 4 N. c) 6 N. d) 12 N. e) 24 N.

20. An object weighs 12 N on earth. Mytor has twice the radius and four times the mass of earth. The **weight** of the object on Mytor is a) 3 N. b) 4 N. c) 6 N. d) 12 N. e) 24 N.

21. An object weighs 12 N on earth. Jeduk has four times the radius and four times the mass of earth. The **weight** of the object on Jeduk is a) 3 N. b) 4 N. c) 6 N. d) 12 N. e) 24 N.

22. A person who weighs 650 N on earth, only weighs 130 N on Planet X. The **acceleration due to gravity** on Planet X is a) 4.95 m/s^2. b) 3.25 m/s^2. c) 1.96 m/s^2. d) 0.82 m/s^2.

23. If Planet X has twice the mass and twice the radius of earth, the **acceleration due to gravity** on Planet X in m/s^2 is (a) 39.2. (b) 19.6. (c) 9.80. (d) 4.90. (e) 2.45.

24. If Planet X has one-half the mass and one-half the radius of earth, the **acceleration due to gravity** on Planet X in m/s^2 is (a) 39.2. (b) 19.6. (c) 9.80. (d) 4.90. (e) 2.45.

25. If Planet X has one-fourth the mass and one-fourth the radius of earth, the **acceleration due to gravity** on Planet X in m/s^2 is (a) 39.2. (b) 19.6. (c) 9.80. (d) 4.90. (e) 2.45.

26. If Planet X has four times the mass and twice the radius of earth, the **acceleration due to gravity** on Planet X in m/s^2 is (a) 39.2. (b) 19.6. (c) 9.80. (d) 4.90. (e) 2.45.

27. The net force that acts on an object in orbit around the earth is (a) its inertia. (b) zero. (c) its weight. (d) the acceleration due to gravity.

28. If the moon had twice its present mass, its **orbital speed** in its orbit would be a) greater than its present value. b) equal to its present value. c) less than its present value.

29. If the radius of the moon's orbit were doubled, its **orbital speed** would be a) greater than its present value. b) equal to its present value. c) less than its present value.

30. If the mass of the earth were doubled, the **orbital speed** of the moon would be a) greater than its present value. b) equal to its present value. c) less than its present value.

31. When the orbit of an earth satellite is increased to a larger radius, its **orbital speed** a) increases. b) decreases. c) stays the same.

32. When the mass of an earth satellite is doubled, its **orbital speed** in the same orbit a) increases. b) decreases. c) stays the same.

CIRCULAR MOTION AND GRAVITATION - WORKSHEET 9

33. In a circular orbit about the earth, the acceleration of a satellite a) points away from the earth. b) points toward the earth. c) is zero.

34. A space ship is traveling to the moon. At what point is it beyond the pull of earth's gravity? a) When it gets above earth's atmosphere. b) When it is halfway to the moon. c) When it is closer to the moon that to the earth. d) It is never beyond the pull of earth's gravity.

35. **Gravitational mass** is a measure of a) the inertia of an object. b) the weight of an object. c) the ability of an object to attract other objects. d) the ability of an object to resist changes in its velocity.

36. **Inertial mass** is a measure of a) the size of an object. b) the weight of an object. c) the ability of an object to attract other objects. d) the ability of an object to resist changes in its velocity.

37. Answer T or F.
    ___ a) An object always speeds up or slows down when a net force acts on it.
    ___ b) An object always has an acceleration when a net force acts on it.
    ___ c) An object can move with constant speed even when a net force acts on it.
    ___ d) An object moving with uniform circular motion has constant speed.
    ___ e) An object moving with uniform circular motion has constant velocity.
    ___ f) An object moving with uniform circular motion has constant acceleration.
    ___ g) The weight of an astronaut inside an orbiting space station is zero.

38. Newton showed that gravitational mass and inertial mass are (a) the same thing. (b) are always proportional to each other. (c) are always numerically equal to one another.

39. The masses in Newton's Law of Gravitation are (a) both inertial masses. (b) both gravitational masses. (c) either gravitational or inertial depending upon which mass is being attracted. (d) both measures of gravitational inertia.

40. The mass in Newton's Second Law of Motion is (a) an inertial mass. (b) a gravitational mass. (c) either a gravitational mass or an inertial mass depending on its state of motion. (d) a measure of gravitational inertia.

41. In Einstein's Principle of Gravity (a) gravitational masses do not exist. (b) gravitational forces do not exist. (c) inertial masses near the sun travel in straight lines. (d) all the above. (e) none of the above.

42. In Einstein's Principle of Gravity, the concept of gravitational mass is replaced by the concept of (a) inertial forces. (b) straight line motions in a curved space. (c) gravitational inertia. (d) all the above. (d) none of the above.

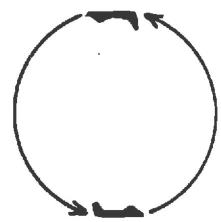
APPLICATIONS OF NEWTON'S SECOND LAW

These problems provide extra practice using Newton's second law. For each problem, draw the force diagram or diagrams, show the direction of the acceleration, find the components of the forces (if necessary) and solve.

1. An 80 kg person enters an elevator and stands on a scale that measures weight. What value does the scale show when the elevator is (a) at rest? (b) accelerating upward at 4 m/s^2?

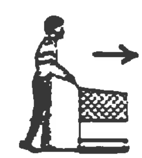
2. A 5 kg puck, given an initial speed of 12 m/s, slides 18 meters across a sheet of ice. Find the force of friction that acted on the puck as it moved.

3. An 80 kg jet pilot flies her plane in a vertical circle so that she is upside down at the top of the loop. If the radius of the circle is 2000 meters and the speed of the plane at the top of the loop is 300 m/s, compute the "g force" that acts on the pilot at the top of the loop.



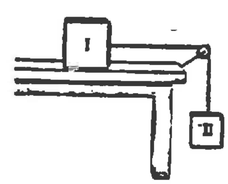
4. A 20 kg box is given an initial velocity of 9 m/s up a rough surface inclined at 15° with respect to the horizontal. If the box slides 6 meters up the incline before coming to rest, find the magnitude of the force of friction that acted on the box.

5. A person pushes an 8 kg grocery cart with a force of 90 N directed 30° below the horizontal as shown. If the acceleration of the cart is 2.5 m/s^2, find (a) the force of friction that acts on the cart and (b) the normal force that acts on the cart.

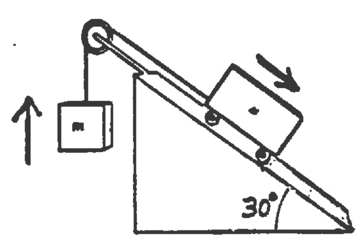


6. A 1200 kg car is used to push an 1800 kg car as shown. If the cars accelerate at 1.2 m/s^2, find the traction force exerted on the small car by the road. Assume that the forces of rolling and sliding friction are negligible.

7. A 200 kg box, placed on the top of a table, is connected by a rope to a 150 kg hanging box as shown. If the boxes experience an acceleration of 2.5 m/s^2, find the force of friction that acts on the 200 kg box as it slides across the table.



8. A 5 kg cart, placed on an inclined surface as shown, is connected to a hanging mass via a rope. If the cart accelerates down the incline at 2 m/s^2, find the magnitude of the hanging mass. Assume that the forces of rolling and sliding friction are negligible.



JAR OF FLIES

A bunch of flies are in a capped jar. You place the jar on a scale. The scale will register the most weight when the flies are

a) sitting on the bottom of the jar
b) flying around inside the jar
c) . . . weight of the jar is the same in both cases

Sir Issac Newton

1642- 1727

Newton was a genius. There is no doubt that his discoveries have become the foundations of modern science. Yet Newton, like all of us, experienced human sufferings and failings. Early in his life, he developed feelings of insecurity and rejection. These fears together with a fear of the unknown spurred him on to learn the laws of nature as he felt God had written them. The precision of his mathematical proofs gave him assurance and comfort. Those proofs and ideas, however, did not spring full-grown from his forehead, but rather were nurtured through tortuous periods of development. Newton had much difficulty relating to his colleagues and unfortunately was involved in several spiteful disputes. In later life, his autocratic domination of London's scientific community brought him some final satisfaction, but even then he seemed to be a man of little mercy and much spite.

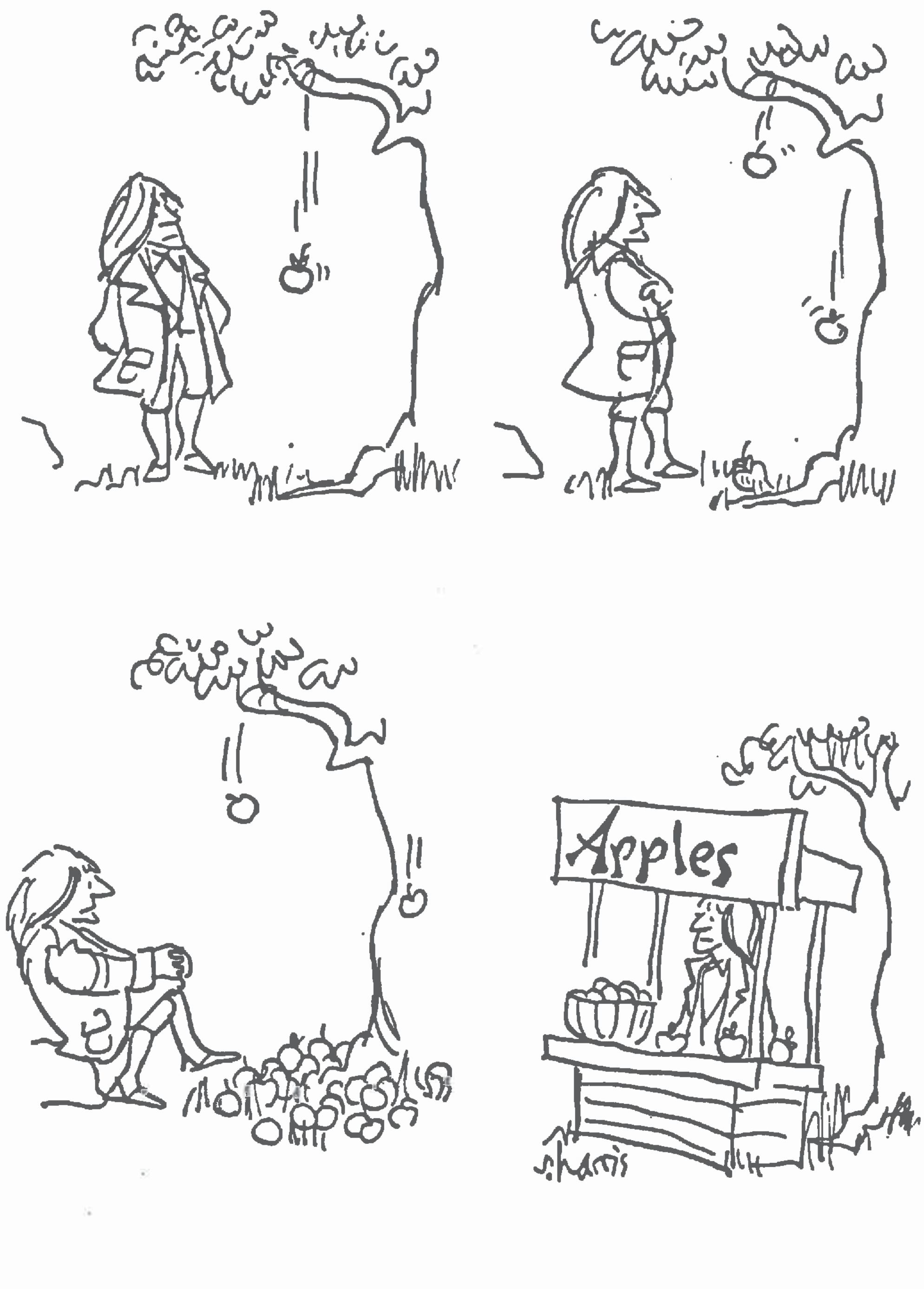
Isaac Newton was born prematurely on Christmas Day in 1642. His mother used to remark that he was small enough to fit into a quart pot. Newton's father was a common yeoman in Lincolnshire and had died before his son was born. When Issac was about three, his mother married a local pastor and moved a few miles away, leaving young Issac in the care of the housekeeper. Newton hated his stepfather for taking his mother away.

Isaac was a small child who was forever being bullied by other children. He was required to help on the farm, but slipped off as much as he could to read. In his leisure he amused himself building model windmills powered by mice, waterclocks, sundials, and kites carrying lanterns which frightened the country folk. It was said that he had the hands of a carpenter as well as the head of a mathematician. A local schoolmaster recognized Newton's abilities and helped send him to Cambridge.

In 1665, the bubonic plague was raging through the English countryside and consequently Cambridge went into recess. At about the same time there was a great fire which destroyed much of London. Many were beginning to feel it was the end of the world. Amid all the turmoil, Newton, now 23, returned to the family farm to study. From his concentration, he developed a theory of colored light and his theory of fluxions (calculus). While sitting in his garden, he dreamed up the proof for the law of gravity. This was a marvelously creative time for Newton. As he explained, "I keep the subject constantly before me, and wait till the first dawnings open slowly by little and little into the full and clear light."

Much of Newton's life was spent in seclusion. He lived an ascetic life, dressed sloppily, and rarely went to bed before 2 or 3 in the morning. He hated weeds in his garden and was an inveterate hypochondriac. There was little laughter in his life and he never married. Newton was an avid follower of the Bible and as he conducted his experiments, it was as though he were wrestling with an evil force. His studies even took him into alchemy.

A large part of Newton's life was spent quarreling with fellow scientists. Robert Hooke accused Newton of stealing some ideas about gravity and light. This touched off a dispute which lasted for years. Newton usually responded badly and tended to feel he was omnipotent. Leibnitz was another rival. Unfortunately, both Newton and Leibnitz developed calculus at about the same time. Both claimed priority and another dispute was born.


Apples
S.Harris

WORK, KINETIC ENERGY AND POWER

I. Key Terms and Phrases - Write a definition or description of each term. In addition,

A) write **V** in **front** of each quantity if the quantity is a **vector quantity** or write **S** if the quantity is a **scalar quantity**.

B) write the **MKS units** of the quantity in the space **behind** the quantity.

___ a) work ___
___ b) net work ___
___ c) kinetic energy ___
___ d) spring force ___
___ e) power ___
f) dot product
g) scalar product
h) Hooke's law
i) spring constant
j) joule
k) work-energy principle
l) watt

II. QUESTIONS

1. A 10 N object is lifted 3 meters. How much work is done on it? (a) 10 J (b) 15 J (c) 30 J (d) 60 J (e) zero

2. A 10 N object is lifted 3 meters and then returned to its original position. How much work is done on it? (a) 10 J (b) 15 J (c) 30 J (d) 60 J (e) zero

3. A 10 N object is lifted 3 meters and then carried 3 meters horizontally. How much work is done on it? (a) 10 J (b) 15 J (c) 30 J (d) 60 J (e) zero

4. A 10 N object, 3 meters above the floor, is carried 6 meters horizontally. How much work is done on it? (a) 10 J (b) 15 J (c) 30 J (d) 60 J (e) zero

5. A 10 N object is pushed 3 meters up a 30° frictionless incline. How much work is done on it? (a) 10 J (b) 15 J (c) 30 J (d) 60 J (e) zero

6. A 10 N object is held 3 meters above the floor. How much work is done on it? (a) 10 J (b) 15 J (c) 30 J (d) 60 J (e) zero

7. A 10 N barrel is rolled up a 6 meter long ramp (friction is zero) into a truck bed 3 meters above the ground. How much work is done on the barrel? (a) 10 J (b) 15 J (c) 30 J (d) 60 J (e) zero

8. A 10 N barrel, sitting on a loading dock 3 meters above the ground, is pushed off the edge of the dock and falls to the ground. How much work is done on the barrel? (a) 10 J (b) 15 J (c) 30 J (d) 60 J (e) zero

9. A 10 N barrel, sitting on a loading dock 3 meters above the ground, is allowed to roll down a ramp of length 6 meters. How much work is done on the barrel? (a) 10 J (b) 15 J (c) 30 J (d) 60 J (e) zero

10. A 10 N barrel, sitting on a loading dock 3 meters above the ground, is rolled horizontally with constant speed along the dock for 6 meters. How much work is done on the barrel? (a) 10 J (b) 15 J (c) 30 J (d) 60 J (e) zero

11. As you push harder and harder against a brick wall, the amount of work done (a) increases. (b) decreases. (c) remains constant at its original value. (d) is zero.

12. Which of the following is not a unit of energy? (a) watt (b) newton-meter (c) joule (d) kilowatt-hour (e) kg-$(m/s)^2$

13. If **A**•**B** = 0, the angle between vector **A** and vector **B** is a) 0°. b) 45°. c) 90°. d) acute. e) obtuse.

14. If **A**•**B** = 1, the angle between vector **A** and vector **B** is a) 0°. b) 45°. c) 90°. d) acute. e) obtuse.

15. If **A**•**B** = −1, the angle between vector **A** and vector **B** is a) 0°. b) 45°. c) 90°. d) 180°. e) obtuse.

16. If **A**•**B** = AB, the angle between vector **A** and vector **B** is a) 0°. b) 45°. c) 90°. d) 180°. e) obtuse.

17. If **A** = 3 **i** + 4 **j** and **A**•**B**=0, then **B** = a) 3 **i** + 4 **j**. b) 4 **i** +3 **j**. c) 4 **i** − 3 **j**. d) 3 **i** − 4 **j**.

18. **A** = 3 **i** + 4 **j** and B_x = 3. If A•B=25, then **B** = a) 3 **i** + 4 **j**. b) 4 **i** +3 **j**. c) 4 **i** − 3 **j**. d) 3 **i** − 4 **j**.

19. **A** = 3 **i** + 4 **j** and B_x = 3. If **A**•**B**=−7, then **B** = a) 3 **i** + 4 **j**. b) 4 **i** +3 **j**. c) 4 **i** − 3 **j**. d) 3 **i** − 4 **j**.

20. If **A** = 3 **i** + 4 **j** and **B** = 3 **i** − 4 **j**, the angle between **A** and **B** is a) 0°. b) 74°. c) 90°. d) 106°. e) 180°.

21. If **A** = 3 **i** + 4 **j** and **B** = −3 **i** + 4 **j**, the angle between **A** and **B** is a) 0°. b) 74°. c)90°. d) 106°. e) 180°.

22. If **A** = 3 **i** + 4 **j** and **B** = −3 **i** − 4 **j**, the angle between **A** and **B** is a) 0°. b) 74°. c) 90°. d) 106°. e) 180°.

23. If **A** = 3 **i** + 4 **j** and **B** = 4.5 **i** + 6 **j**, the angle between **A** and **B** is a) 0°. b) 74°. c) 90°. d) 106°. e) 180°.

24. A truck has *twice* the mass and the *same* speed as a car. The KE of the truck is ____ times larger than the KE of the car? (a) equal (b) 2 (c) 4 (d) 8 (d) one-half

25. A truck has the *same* mass and *twice* the speed as a car. The KE of the truck is ____ times larger than the KE of the car? (a) equal (b) 2 (c) 4 (d) 8 (d) one-half

26. A truck has *twice* the mass and *twice* the speed as a car. The KE of the truck is ____ times larger than the KE of the car? (a) equal (b) 2 (c) 4 (d) 8 (d) one-half

27. A truck has *twice* the mass and *one-half* the speed of a car. The KE of the truck is ____ times larger than the KE of the car? (a) equal (b) 2 (c) 4 (d) 8 (d) one-half

28. A truck has *four* times the mass and *one-half* the speed of a car. The KE of the truck is ____ times larger than the KE of the car? (a) equal (b) 2 (c) 4 (d) 8 (d) one-half

29. A brick and a rock are moving at speeds of 3 m/s and 5 m/s respectively. If they both have the same **kinetic energy**, the ratio of the *mass* of the brick to that of the rock is (a) 3:5 (b) 5:3 (c) 9:25 d) 25:9 (e) impossible to tell.

30. A brick and a rock are moving at speeds of 3 m/s and 5 m/s respectively. If they both have the same **mass**, the ratio of the *KE* of the brick to that of the rock is (a) 3:5 (b) 5:3 (c) 9:25 (d) 25:9 (e) impossible to tell.

31. The work required to keep a hockey puck of mass m sliding over frictionless ice at constant speed is (a) $\frac{1}{2} mv^2$. (b) mgh. (c) zero. (d) $m \Delta x$. (e) impossible to determine.

32. The speed of a 2 kg mass increases from 4 m/s to 8 m/s. The work done on the mass was a) 8 J. b) 16 J. c) 48 J. d) 64 J. e) 75 J.

33. The speed of a 2 kg mass increases from 4 m/s to 8 m/s. The increase in KE of the mass is a) 8 J.

    b) 16 J. c) 48 J. d) 64 J. e) 75 J.

34. The speed of a 2 kg mass increases from 5 m/s to 10 m/s. The increase in KE of the mass is a) 8 J. b) 16 J. c) 48 J. d) 64 J. e) 75 J.

35. If you double the work done on an object, the change in its KE a) will double. b) will quadruple. c) will increase by $\sqrt{2}$. d) will be zero. e) is impossible to determine.

36. If you double the work done on an object, the change in its speed a) will double. b) will quadruple. c) will increase by $\sqrt{2}$. d) will be zero. e) is impossible to determine.

37. During a panic stop, a car skids 30 meters before coming to rest. If the mass of the car were *twice* its original mass, the length of the skid would be (a) 15 m. (b) 30 m. (c) 60 m. (d) 90 m. (e) 120 m.

38. During a panic stop, a car skids 30 meters before coming to rest. If the stopping force (the force of friction) on the car were *twice* its original value, the length of the skid would be (a) 15 m. (b) 30 m. (c) 60 m. (d) 90 m. (e) 120 m.

39. During a panic stop, a car skids 30 meters before coming to rest. If the initial speed of the car were *twice* its original value, the length of the skid would be (a) 15 m. (b) 30 m. (c) 60 m. (d) 90 m. (e) 120 m.

40. Starting from rest, an object is pulled by an applied force for 10 meters. If the same force is allowed to pull for 20 meters, the *work done* on the object a) will double. b) will quadruple. c) will increase by $\sqrt{2}$. d) will be zero. e) is impossible to determine.

WORK, KINETIC ENERGY AND POWER - WORKSHEET 11

41. Starting from rest, an object is pulled by an applied force for 10 meters. If the applied force is doubled, the *work done* on the object a) will double. b) will quadruple. c) will increase by $\sqrt{2}$. d) will be zero. e) is impossible to determine.

42. Starting from rest, an object is pulled by an applied force for 10 meters. If the same force is allowed to pull for 20 meters, the *kinetic energy* acquired by the object a) will double. b) will quadruple. c) will increase by $\sqrt{2}$. d) will be zero. e) is impossible to determine.

43. Starting from rest, an object is pulled by an applied force for 10 meters. If the same force is allowed to pull for 20 meters, the *speed* acquired by the object a) will double. b) will quadruple. c) will increase by $\sqrt{2}$. d) will be zero. e) is impossible to determine.

44. Starting from rest, an object is pulled by an applied force for 10 meters. If the same force is allowed to pull for 40 meters, the *speed* acquired by the object a) will double. b) will quadruple. c) will increase by $\sqrt{2}$. d) will be zero. e) is impossible to determine.

45. A ball attached to the end of a string is whirled around a horizontal circle of circumference 2.5 meters. If the tension in the string is 10 Newtons, the work done on the ball is (a) 250 J. (b) 25 J. (c) 2.5 J. (d) zero. (e) cannot be determined.

46. A car rounds a corner of radius 10 m. If the force of friction responsible for pulling the car around the corner is 800 N, the work done on the car moving 1/4 of a circle is a) 13,000 J. b) 6,500 J. c) zero. d) −6,500 J. e) −13,000 J

47. Today you worked. Tomorrow you must do *twice* the work in *twice* the time. Your power output tomorrow will be how much greater than today's output? (a) One-half. (b) The same. (c) Two times. (d) Four times. (e) Nine times.

48. Today you worked. Tomorrow you must do *twice* the work in *half* the time. Your power output tomorrow will be how much greater than today's output? (a) One-half. (b) The same. (c) Two times. (d) Four times. (e) Nine times.

49. Today you worked. Tomorrow you must do *four times* the work in *twice* the time. Your power output tomorrow will be how much greater than today's output? (a) One-half. (b) The same. (c) Two times. (d) Four times. (e) Nine times.

50. Today you worked. Tomorrow you must do *three times* the work in *one-third* the time. Your power output tomorrow will be how much greater than today's output? (a) One-half. (b) The same. (c) Two times. (d) Four times. (e) Nine times.

51. A car travels 200 meters at the **constant speed** of 10 m/s. If the force of air resistance acting on the car is 100 N, the power delivered to the car is (a) 5000 W. (b) 2500 W. (c) 1000 W. (d) 500 W. (e) 100 W.

52. Which of the following statements are true?
    a) Work can only be negative.
    b) Work is a scalar.
    c) Work done by gravity is always positive.
    d) Work done by kinetic friction is always negative.
    e) Work done by a centripetal force can be either positive or negative.

Fig. 1

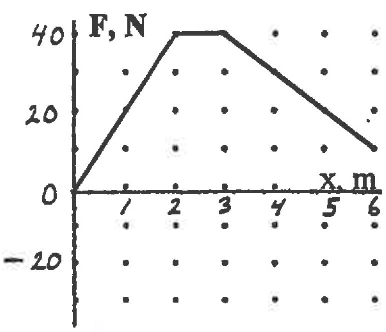


Fig. 2

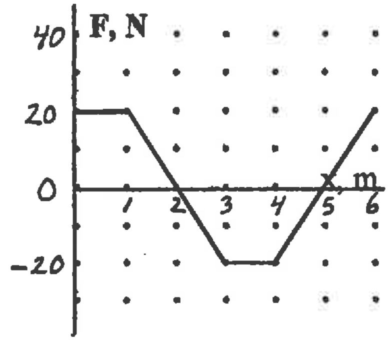
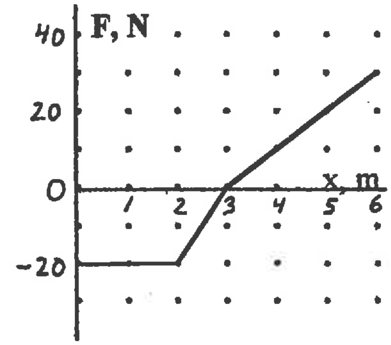


Fig. 3

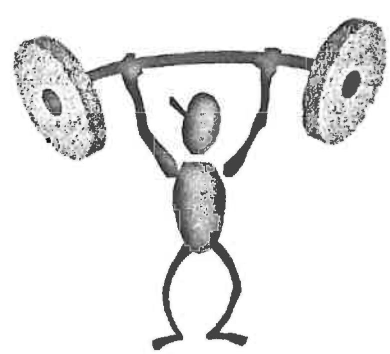


53. The force vs. position graph for a variable force is shown in Fig. 1 above. How much work does the force do in moving from x=0 to x=5 m? a) −30 J b) −5 J c) zero d) 15 J e) 140 J

54. The force vs. position graph for a variable force is shown in Fig. 2 above. How much work does the force do in moving from x=1 to x=5 m? a) −30 J b) −5 J c) zero d) 15 J e) 140 J

55. The force vs. position graph for a variable force is shown in Fig. 3 above. How much work does the force do in moving from x=0 to x=6 m? a) −30 J b) −5 J c) zero d) 15 J e) 140 J

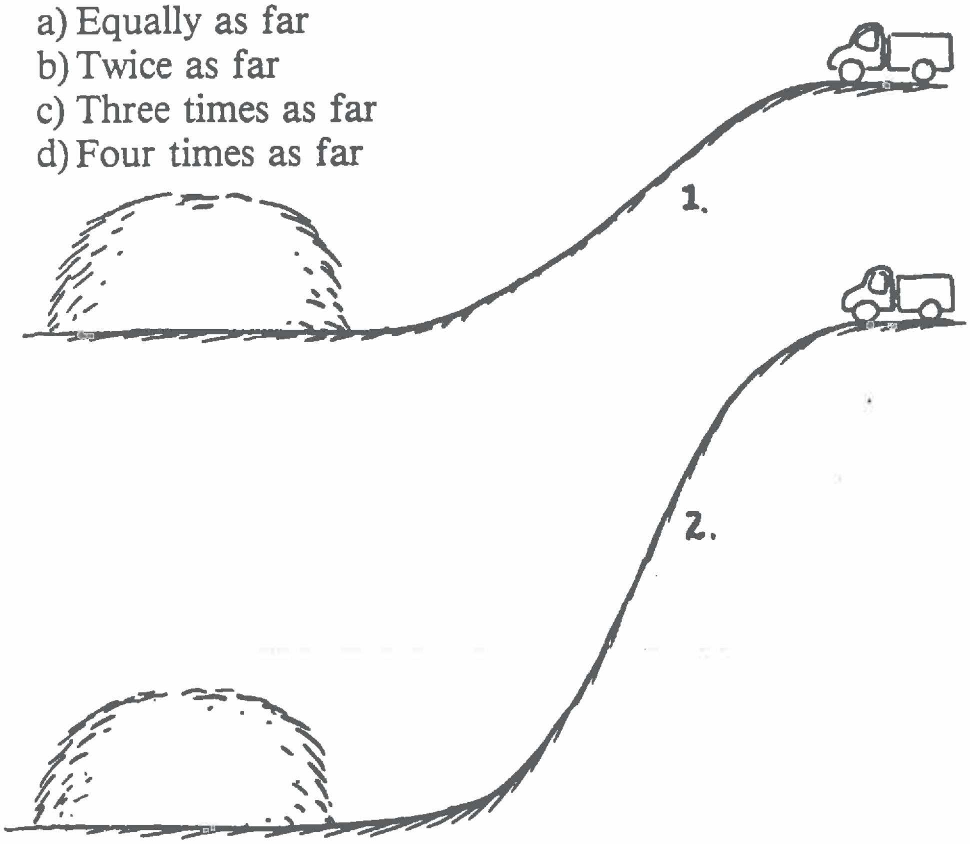
56. Which of the following statements are true?
    a) When an object experiences a *velocity change*, work is done on the object.
    b) When an object experience a *speed* change, work is done on the object.
    c) A *net force* applied to a moving object will always do work on the object.
    d) When going up stairs, you do more work if you run fast rather than walk.
    e) Pushing a box up a ramp into a truck requires less work than lifting it into the truck.



HIT THE HAYSTACK

A truck initially at rest rolls down Hill 1 into a very big haystack. Another identical truck also rolls from rest down Hill 2, twice as high, into an identical haystack. Compared to the truck on Hill 1, how much farther does the truck on Hill 2 penetrate into the stack?

a) Equally as far
b) Twice as far
c) Three times as far
d) Four times as far



Perhaps: too many questions

WORKSHEET 12

CONSERVATION OF ENERGY

I. Key Terms and Phrases - Write a definition or description of each term. In addition,

A) write **V** in **front** of the quantity if it is a **vector quantity** or write **S** if it is a **scalar quantity**.

B) write the **MKS units** of the quantity in the space **behind** the quantity.

___ a) kinetic energy ___
___ b) potential energy ___
___ c) gravitational PE ___
___ d) elastic PE ___
___ e) mechanical energy ___
___ f) thermal energy ___
g) conservative forces
h) non-conservative forces
i) dissipative forces
j) escape speed
k) work done against gravity
l) work done by gravity

II. QUESTIONS

1. A 10 N block is placed 3 meters above the floor. If placed 6 meters above the floor, its PE with respect to the floor will a) halve. b) double. c) stay the same. d) increase by $\sqrt{2}$. e) quadruple.

2. A 10 N block, pushed against a spring, compresses it 0.3 meters. If the spring is compressed 0.6 meters, its PE will a) halve. b) double. c) stay the same. d) increase by $\sqrt{2}$. e) quadruple.

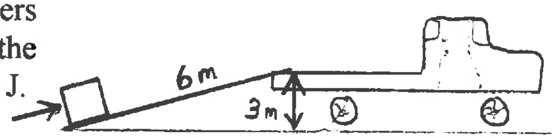
3. A 10 N block is placed 3 meters above the floor. Where should it be placed to double its PE with respect to the floor? a) 1.5 m b) 3 m c) 6 m d) $\sqrt{2}\cdot 3$ m e) 9 m

4. A 10 N block, pushed against a spring, compresses it 0.3 meters. How far should the spring be compressed to double its PE? a) 0.15 m b) 0.3 m c) 0.6 m d) $\sqrt{2}\cdot 0.3$ m e) 0.9 m

5. An object rises to height h when thrown straight upward at 3 m/s. How *high* does it rise when thrown at 6 m/s? a) 0.5 h b) h c) $\sqrt{2}\cdot$h d) 2·h e) 4·h

6. An object rises to height h when thrown straight upward at 3 m/s. How *fast* must it be thrown to rise to height 2h? a) 0.5·3 m/s b) 3 m/s c) $\sqrt{2}\cdot 3$ m/s d) 2·3 m/s e) 4·3 m/s

7. A 100 N crate must be placed onto the bed of a truck, 3 meters above the ground. If pushed up a ramp of length 6 meters, the *work* that must be done on the create is a) 300 J. b) 200 J. c) 150 J. d) 100 J. e) 50 J.

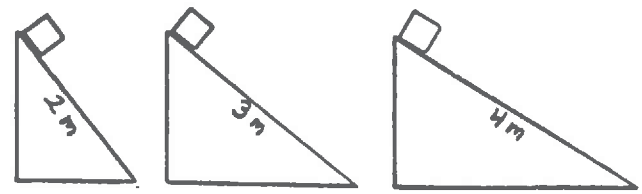


8. A 100 N crate must be placed onto the bed of a truck, 3 meters above the ground. If pushed up a ramp of length 6 meters, the *force* that must be applied on the create is a) 300 N. b) 200 N. c) 150 N. d) 100 N. e) 50 N.

9. The purpose of using a ramp to load a heavy desk onto the back of a truck is
a) to reduce the amount of work that must be done to place the desk onto the truck.
b) to reduce the force that must be applied to place the desk onto the truck.
c) to reduce both the applied force and the work done to place the desk onto the truck.
d) to increase the time so that less power is used to place the desk onto the truck.

CONSERVATION OF ENERGY - WORKSHEET 12

10. Three *frictionless* inclined planes have the same vertical height, but the length of each inclined surface is different. The length of incline A is 2m, that of incline B is 3 m, and that of incline C is 4 m. A 10 N box is placed at the top of each incline and released from rest. On which incline, if any, will the box have the greater *speed* at the bottom of the incline?
a) A b) B c) C d) The boxes have the same speed.



11. In the example above, each box is placed at the bottom of the incline and given the same initial velocity up the incline. On which incline, if any, will the box have the greater *speed* when it reaches the top of the incline? a) A b) B c) C d) The boxes will have the same speed.

12. Two *frictionless* inclined planes are identical. Mass M is placed at the top of one incline and mass 2M is placed at the top of the other incline. Both are released from rest. Which mass, if either, will have the greater *speed* at the bottom of the incline? a) M b) 2M c) Each will have the same speed.

13. Two *frictionless* inclined planes are identical. Mass M is placed at the top of one incline and mass 2M is placed at the top of the other incline. Both are released from rest. Which mass, if either, will have the greater *KE* at the bottom of the incline? a) M b) 2M c) Each will have the same KE.

14. A ball of mass m rises to height h when thrown straight upward at 3 m/s. How *high* will mass 2m rise when thrown straight upward at the same speed? a) 0.5 h b) h c) $\sqrt{2}\cdot$h d) 2·h e) 4·h

15. A ball of mass m rises to height h when thrown straight upward at 3 m/s. How *fast* must a ball of mass 2m be thrown to rise to the same height? a) 0.5·3 m/s b) 3 m/s c) $\sqrt{2}\cdot$3 m/s d) 2·3 m/s e) 4·3 m/s

16. Pushed distance d against a spring and released from rest, a block leaves the spring with a KE of 5 J. If the block is then pushed a distance 2d against the spring, it leaves the spring with a *KE* of
a) $5/\sqrt{2}$ J. b) 5 J. c) $\sqrt{2}\cdot$5 J. d) 10 J. e) 20 J.

17. Pushed distance d against a spring and released from rest, a block leaves the spring with ~~a KE~~ speed of 5 ~~J~~ m/s. If the block is then pushed a distance 2d against the spring, it leaves the spring with a *speed* of
a) $5/\sqrt{2}$ m/s. b) 5 m/s. c) $\sqrt{2}\cdot$5 m/s. d) 10 m/s. e) 20 m/s.

18. Pushed distance d against a spring and released from rest, mass m leaves the spring with a KE of 5 J. When mass 2m is pushed the same distance against the spring, it leaves the spring with a *KE* of
a) $5/\sqrt{2}$ J. b) 5 J. c) $\sqrt{2}\cdot$5 J. d) 10 J. e) 20 J.

19. Pushed distance d against a spring and released from rest, mass m leaves the spring with a speed of 5 m/s. When mass 2m is pushed the same distance d against the spring, it leaves the spring with a *speed* of a) $5/\sqrt{2}$ m/s. b) 5 m/s. c) $\sqrt{2}\cdot$5 m/s. d) 10 m/s. e) 20 m/s.

20. Pushed distance d against a spring and released from rest, mass m leaves the spring with a KE of 5 J. When mass 2m is pushed a distance 2d against the spring, it leaves the spring with a *KE* of
a) $5/\sqrt{2}$ J. b) 5 J. c) $\sqrt{2}\cdot$5 J. d) 10 J. e) 20 J.

21. Pushed distance d against a spring and released from rest, mass m leaves the spring with a speed of 5 m/s. When mass 2m is pushed a distance 2d against the spring, it leaves the spring with a *speed* of a) $5/\sqrt{2}$ m/s. b) 5 m/s. c) $\sqrt{2}\cdot 5$ m/s. d) 10 m/s. e) 20 m/s.

22. An object is *dropped* from the top of a building. If air friction is neglected, the *ratio* of the final KE just before hitting the ground to the initial P.E. is (a) greater than 1. (b) less than 1. (c) equal to 1.

23. An object is *dropped* from the top of a building. If air friction is *not neglected*, the *ratio* of the final KE just before hitting the ground to the initial P.E. is (a) greater than 1. (b) less than 1. (c) equal to 1.

24. An object is *thrown downward* from the top of a building. If air friction is neglected, the *ratio* of the final KE just before hitting the ground to the initial P.E. is (a) greater than 1. (b) less than 1. (c) equal to 1.

25. A sphere, held above the ground, has 10 J of P.E. When released, it falls toward the ground. If air friction is *neglected*, the final kinetic energy just before hitting the ground is (a) greater than 10 J. (b) less than 10 J. (c) equal to 10 J. (d) impossible to determine.

check answer →

26. A sphere, held above the ground, has 10 J of P.E. When released, it falls toward the ground. If *air friction* acts on the sphere, the final kinetic energy just before hitting the ground is (a) greater than 10 J. (b) less than 10 J. (c) equal to 10 J. (d) impossible to determine.

27. A sphere, held above the ground, has 10 J of P.E. It is thrown downward with an initial KE of 10 J. If air friction is *neglected*, the final kinetic energy just before hitting the ground is (a) greater than 20 J. (b) less than 20 J. (c) equal to 20 J. (d) impossible to determine.

28. A sphere, held above the ground, has 10 J of P.E. It is thrown downward with an initial KE of 10 J. If *air friction* acts on the sphere, the final kinetic energy just before it hits the ground is (a) greater than 20 J. (b) less than 20 J. (c) equal to 20 J. (d) impossible to determine.

29. A 10 N ball, dropped from a height of 3 meters, rebounds to a height of 2 meters. The mechanical energy transferred to thermal energy is (a) 40 J. (b) 30 J. (c) 20 J. (d) 10 J. (e) zero.

30. A 10 N ball, dropped from a height of 3 meters, rebounds to a height of 4 meters. The work done by nonconservative forces during the collision with the floor was (a) 40 J. (b) 30 J. (c) 20 J. (d) 10 J. (e) zero.

31. The bob of a pendulum of mass m and length L is pulled back until the string is *horizontal* and taut. The bob is then released from rest. What is the *KE* of the mass as it passes through the lowest point in its arc? (a) mgL (b) 2mgL (c) 3mgL (d) cannot be determined.

32. The bob of a pendulum of mass m and length L is pulled back until the string is *horizontal* and taut. The bob is then released from rest. What is the *tension* in the string as the mass passes the lowest point in its arc? (a) mg (b) 2mg (c) 3mg (d) cannot be determined.

33. Which of the following is a conservative force? a) weight b) normal c) friction d) tension e) Both (a) and (b)

CONSERVATION OF ENERGY - WORKSHEET 12

34. Which of the following is a non-conservative force? a) weight b) normal c) gravitation d) spring e) All are conservative forces.

35. If three conservative forces and one non-conservative force act on an object, how many potential energy terms are there in the expression for mechanical energy? a) 1 b) 2 c) 3 d) 4 e) 5

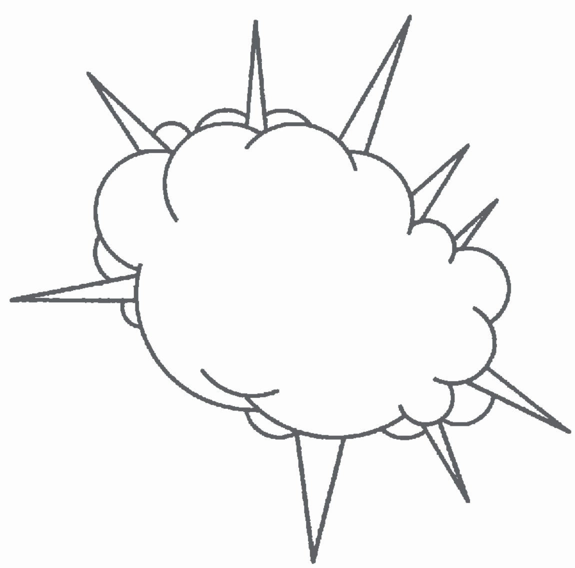
36. A box of mass m, moving at 3 m/s, is stopped by hitting and compressing a spring distance d. If the *speed* of the box is doubled, how far will the spring be compressed? a) 0.5 d b) d c) $\sqrt{2}\cdot$d d) 2d e) 4d

37. A box of mass m, moving at 3 m/s, is stopped by hitting and compressing a spring distance d. If the *KE* of the box is doubled, how far will the spring be compressed? a) 0.5 d b) d c) $\sqrt{2}\cdot$d d) 2d e) 4d

38. A box of mass m, moving at 3 m/s, is stopped by hitting and compressing a spring distance d. If the *mass* of the box is doubled, how far will the spring be compressed? a) 0.5 d b) d c) $\sqrt{2}\cdot$d d) 2d e) 4d

39. A box of mass m, moving at 3 m/s, is stopped by hitting and compressing a spring distance d. If the *spring constant* of the spring is halved, how far will the spring be compressed? a) 0.5 d b) d c) $\sqrt{2}\cdot$d d) 2d e) 4d

40. A box of mass m, moving at 3 m/s, is stopped by hitting and compressing a spring distance d. If the *mass* of the box is doubled and the *spring constant* is doubled, how far will the spring be compressed? a) 0.5 d b) d c) $\sqrt{2}\cdot$d d) 2d e) 4d



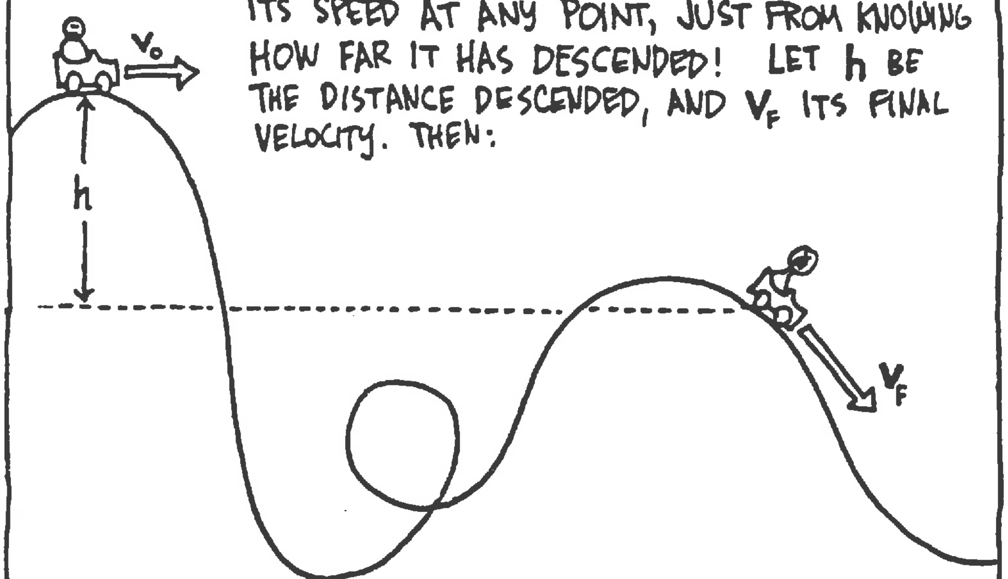
THIS EQUALITY $\frac{1}{2}mv^2 = mgh$ IS AN EXAMPLE OF

☆ CONSERVATION OF ENERGY. ☆

AS THE CONCEPT OF ENERGY WAS DEVELOPED, PHYSICISTS GRADUALLY REALIZED THAT ENERGY, LIKE MOMENTUM, IS CONSERVED.

(THE CONFUSING PART WAS THAT ENERGY, UNLIKE MOMENTUM, APPEARS IN MANY DISGUISES, SUCH AS HEAT, AS WE'LL SEE.)

HERE'S AN APPLICATION OF ENERGY CONSERVATION. IF V_0 IS THE INITIAL SPEED OF THIS ROLLER COASTER, WE CAN COMPUTE ITS SPEED AT ANY POINT, JUST FROM KNOWING HOW FAR IT HAS DESCENDED! LET h BE THE DISTANCE DESCENDED, AND V_F ITS FINAL VELOCITY. THEN:



INITIAL ENERGY $= \frac{1}{2}mv_0^2 + mgh$

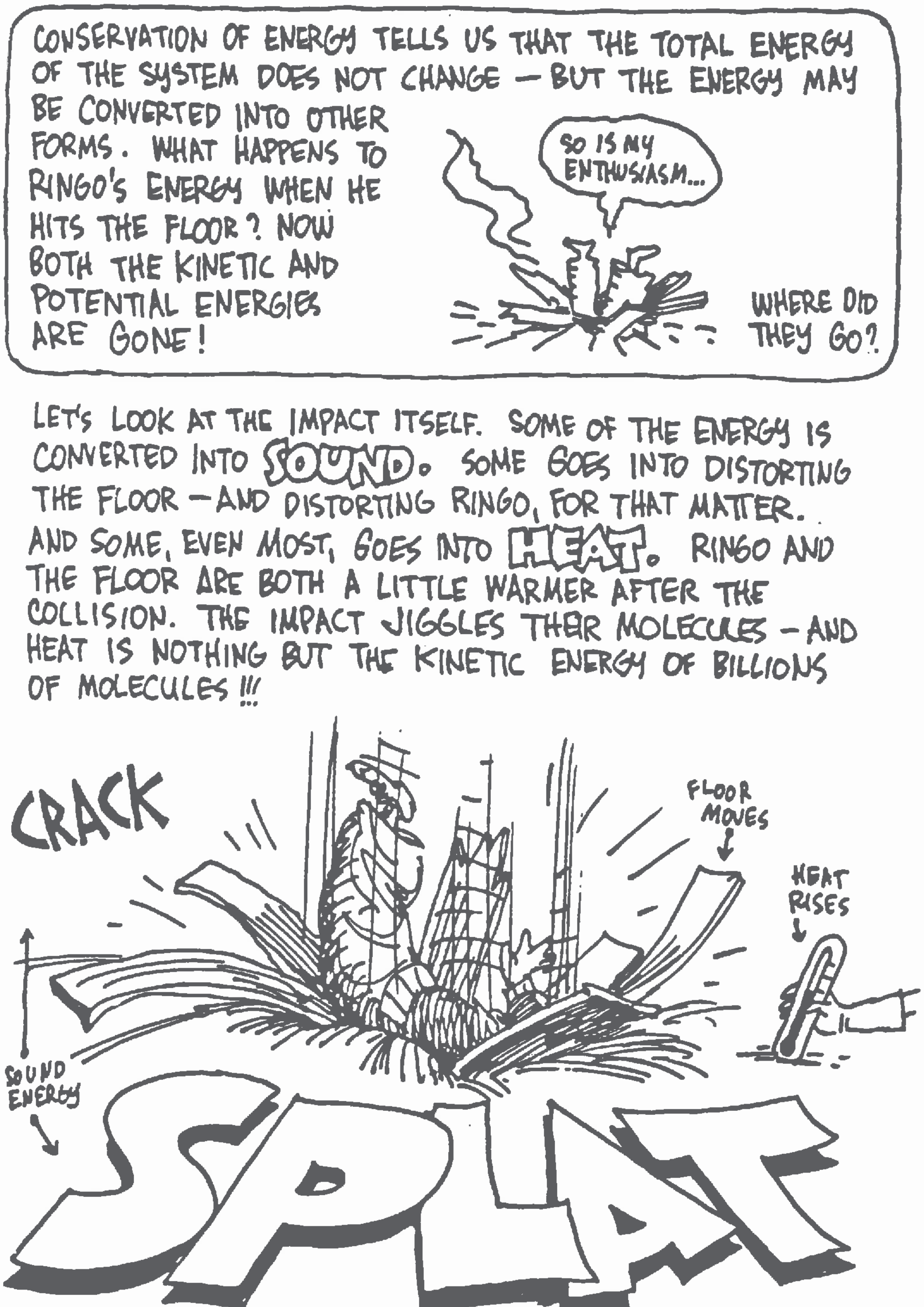
FINAL ENERGY $= \frac{1}{2}mv_F^2$

THESE ARE EQUAL, BY CONSERVATION OF ENERGY.

$\frac{1}{2}mv_F = \frac{1}{2}mv_0^2 + mgh$, SO

$$V_F = \sqrt{V_0^2 + 2gh}$$

P.T.O.



Borrowed from **THE CARTOON GUIDE TO PHYSICS** by Larry Gonick and Art Huffmanh, Harper Perennial, 1991, p 79.

IMPULSE, MOMENTUM, AND COLLISIONS

I. Key Terms and Phrases - Write a definition or description of each term. In addition,

A) write **V** in **front** of the quantity if it is a **vector quantity** or write **S** if it is a **scalar quantity**.

B) write the **MKS units** of the quantity in the space **behind** the quantity.

___ a) momentum___
___ b) impulse ___
___ c) momentum change ___
d) internal forces
e) external forces
f) two body system
g) recoil
h) inelastic collision
i) perfectly inelastic collision
j) elastic collision
k) 2nd law - impulse/momentum form
l) law of conservation of momentum

II. QUESTIONS

1. A 2 kg arrow, moving at 12 m/s, *passes through* a pumpkin and emerges from the other side at 7 m/s. The *impulse* that acted on the arrow is a) −7 N·s. b) −10 N·s. c) −24 N·s. d)−38 N·s. e) −48 N·s.

2. A 2 kg arrow, moving at 12 m/s, hits and *sticks* in a pumpkin. The *impulse* that acted on the arrow is a) −7 N·s. b) −10 N·s. c) −24 N·s. d)−38 N·s. e) −48 N·s.

3. A 2 kg arrow, moving at 12 m/s, hits a tough pumpkin and *rebounds* at 7 m/s. The *impulse* that acted on the arrow is a) −7 N·s. b) −10 N·s. c) −24 N·s. d)−38 N·s. e) −48 N·s.

4. A 2 kg arrow, moving at 12 m/s, hits a really tough pumpkin and *rebounds* elastically at 12 m/s. The *impulse* that acted on the arrow is a) −7 N·s. b) −10 N·s. c) −24 N·s. d)−38 N·s. e) −48 N·s.

5. A constant force of 6 N acts for 4 seconds on a 12 kg mass. What *impulse* acts on the mass? a) 2 N·s b) 10 N·s c) 24 N·s d) 48 N·s e) 72 N·s

6. A constant force of 6 N acted for 4 seconds on a 12 kg mass. What is the *change in momentum* of the mass? a) 2 kg·m/s b) 10 kg·m/s c) 24 kg·m/s d) 48 kg·m/s e) 72 kg·m/s

7. A constant force of 6 N acts for 4 seconds on a 12 kg mass. What is the *change in velocity* of the mass? a) 2 m/s b) 10 m/s c) 24 m/s d) 48 m/s e) 72 m/s

8. A force, acting for 3 seconds on a 6 kg mass, causes a momentum change of 18 kg·m/s. What *impulse* acts on the mass? a) 3 N·s b) 6 N·s c) 12 N·s d) 18 N·s e) 24

9. A force, acting for 3 seconds on a 6 kg mass, causes a momentum change of 18 kg·m/s. What *force* acts on the mass? a) 3 N b) 6 N c) 12 N d) 18 N e) 24 N

10. A force, acting for 3 seconds on a 6 kg mass, causes a momentum change of 18 kg·m/s. What is the *change in velocity* of the mass? a) 3 m/s b) 6 m/s c) 12 m/s d) 18 m/s e) 24 m/s

11. An impulse of 48 N·s acts for 4 seconds on a 12 kg mass. What is the *change in momentum* of the mass? a) 4 kg·m/s b) 12 kg·m/s c) 24 kg·m/s d) 48 kg·m/s e) 72 kg·m/s

IMPULSE, MOMENTUM AND COLLISIONS - WORKSHEET 13

12. An impulse of 48 N·s acts for 4 seconds on a 12 kg mass. What *average force* acts on the mass?
    a) 4 N b) 12 N c) 24 N d) 48 N e) 72 N

13. An impulse of 48 N·s acts for 4 seconds on a 12 kg mass. What is the *change in velocity* of the mass?
    a) 4 m/s b) 12 m/s c) 24 m/s d) 48 m/s e) 72 m/s

14. A 5 kg object falls from a table onto the floor. It hits the floor with a *velocity* of −3 m/s and does not rebound. What is the *change in momentum* of the object? a) +15 kg·m/s b) +25 kg·m/s c) −15 kg·m/s d) −30 kg·m/s e) Cannot determine from the information given.

15. A 5 kg object falls from a table onto the floor. It hits the floor with a *velocity* of −3 m/s and does not rebound. What *impulse* acts on the object *due to the floor*? a) +15 N·s b) +25 N·s c) −15 N·s d) −30 N·s e) Cannot determine from the information given.

16. A 5 kg object falls from a table onto the floor. It hits the floor with a *velocity* of −3 m/s and does not rebound. What *average force* does the object apply to the floor? a) +15 N b) +25 N c) −15 N d) −30 N e) Cannot determine from the information given.

17. A 5 kg object falls from a table onto the floor. It hits the floor with a *velocity* of −3 m/s and rebounds upward with a *velocity* of 2 m/s. What *impulse* acts on the object *due to the floor*? a) +15 N·s b) +25 N·s c) −15 N·s d) −30 N·s e) Cannot determine from the information given.

18. A constant force of 2 N acts for 3 seconds on an object and then the force abruptly *increases* to 10 N in the same direction for an additional second. What is the *change in momentum* of the object during this time? a) 16 kg·m/s b) 10 kg·m/s c) 25 kg·m/s d) 48 kg·m/s e) 32 kg·m/s

19. A constant force of 2 N acts for 3 seconds on an object and then the force abruptly *increases* to 10 N in the same direction for an additional second. What *average force* acted on the object during this time? a) 8 N b) 6 N c) 5 N d) 4 N e) 3 N

20. A hockey puck is moving with constant momentum across frictionless ice. The *impulse* that keeps it moving is a) its weight. b) its inertia. c) zero. d) mv. F Δt.

21. When two objects of *different* mass are dropped from the same height, they hit the floor with the same (circle all that are true) a) speed. b) momentum. c) kinetic energy. d) impulse. e) force.

22. When two objects of the *same* mass are dropped from the same height, they hit the floor with the same (circle all that are true) a) speed. b) momentum. c) kinetic energy. d) impulse. e) force.

23. A 2 kg mass and a 12 kg mass have the same *momentum*. What mass has the larger kinetic energy?
    a) 2 kg b) 12 kg c) They have the same KE.

24. A 2 kg mass and a 12 kg mass have the same *kinetic energy*. What mass has the larger kinetic energy?
    a) 2 kg b) 12 kg c) They have the same KE.

25. A 2 kg **red** box is moving at 10 m/s and a 10 kg **blue** box is moving at 2 m/s. If both boxes are stopped by the same force, which box stops in the longer time interval? a) red box b) blue box. c) Both stop in the same time.

26. A 2 kg **red** box is moving at 10 m/s and a 10 kg **blue** box is moving at 2 m/s. If both boxes are stopped by the same force, which box stops in the shorter distance? a) **red** box b) **blue** box. c) Both stop in the same distance.

27. A 2 kg **red** box is moving at 10 m/s and a 50 kg **blue** box is moving at 2 m/s. If both boxes are stopped by the same force, which box stops in the longer time interval? a) **red** box b) **blue** box. c) Both stop in the same time.

28. A 2 kg **red** box is moving at 10 m/s and a 50 kg **blue** box is moving at 2 m/s. If both boxes are stopped by the same force, which box stops in the shorter distance? a) **red** box b) **blue** box. c) Both stop in the same distance.

29. A 2000 kg car, moving at 15 m/s, hits a brick wall and comes to rest in 0.20 seconds. Which is hit harder, the wall or the car? a) The wall. b) The car. c) Both are hit with the same magnitude force.

30. A 2000 kg car, moving at 15 m/s, hits a brick wall and comes to rest in 0.20 seconds. The *impulse* that acted on the car was a) –4000 N·s. b) –6000 N·s. c) –30,000 N·s. d) –40,000 N·s. e)–150,000 N·s.

31. A 2000 kg car, moving at 15 m/s, hits a brick wall and comes to rest in 0.20 seconds. The magnitude of the *average force* that acted on the car was a) 4000 N. b) 6000 N. c) 30,000 N. d) 40,000 N. e)150,000 N.

32. A 2000 kg car, moving at 15 m/s, hits a brick wall, remains in contact with the wall for 0.20 seconds, and then rebounds backwards at 5 m/s. The *impulse* that acted on the car was a) –4000 N·s. b) –6000 N·s. c) –30,000 N·s. d) –40,000 N·s. e)–150,000 N·s.

33. A lump of clay and a tennis ball of the same mass are each thrown at the same speed toward a brick wall. The lump of clay sticks to the wall while the tennis al bounces back with one-half its original speed. Which of the two delivers the greater *impulse* to the wall? a) The tennis ball. b) The lump of clay. c) Each delivers the same impulse. d) Can't tell because Δt is unknown.

34. A **blue** ball and a **red** ball of the same mass are both released from rest from the same height above the floor. Both balls rebound from the floor, the blue ball bouncing back to 7/8 its original height and the red ball bouncing back to 5/8 its original height. Which ball delivered the greater *impulse* to the floor? a) The **blue** ball. b) The **red** ball. c) Each delivers the same impulse. d) Can't tell because Δt is unknown.

35. A small car has a head-on collision with a *large* truck. During the collision, a) the truck experiences the larger *force*. b) the car experiences the larger force. c) both vehicles experience the same force. d) Can't tell from the information given.

IMPULSE, MOMENTUM AND COLLISIONS - WORKSHEET 13

36. A small car has a head-on collision with a *large* truck. During the collision, a) the truck experiences the larger *impulse*. b) the car experiences the larger impulse. c) both vehicles experience the same impulse. d) Can't tell from the information given.

37. A small car has a head-on collision with a *large* truck. During the collision, a) the truck experiences the larger *momentum change*. b) the car experiences the larger momentum change. c) both vehicles experience the same momentum change. d) Can't tell from the information given.

38. A small car, moving toward the right smashes into the rear of a stationary *large* truck. Which vehicle experiences the larger collision force? a) The car. b) The truck. c) Both vehicles experience the same impulse. d) Can't tell from the information given.

39. A *large* truck, moving toward the right smashes into the rear of a stationary small car. Which vehicle experiences the larger collision force? a) The truck. b) The car. c) Both vehicles experience the same impulse. d) Can't tell from the information given.

40. A golf ball with momentum 5 kg·m/s collides head-on with a stationary bowling ball. If the golf ball bounces back with a momentum of 4 kg·m/s, which ball had the greater *impulse* acting on it. a) The golf ball. b) The bowling ball. c) The impulse is the same on both.

41. A golf ball with momentum 5 kg·m/s collides head-on with a stationary bowling ball. If the golf ball bounces back with a momentum of 4 kg·m/s, the *momentum* change of the golf ball is a) −4 kg·m/s. b) −9 kg·m/s. c) −1 kg·m/s. d) −5 kg·m/s. e) −6 kg·m/s.

42. A golf ball with momentum 5 kg·m/s collides head-on with a stationary bowling ball. If the golf ball bounces back with a momentum of 4 kg·m/s, the *momentum* change of the bowling ball is a) 4 kg·m/s. b) 9 kg·m/s. c) 1 kg·m/s. d) 5 kg·m/s. e) 6 kg·m/s.

43. A 3 kg block, moving to the right at 4 m/s, collides head-on with a 6 kg block moving to the left at 2 m/s. If the collision is *elastic*, the total KE after the collision is a) 36 J. b) 12 J. c) 24 J. d) 72 J. e) zero.

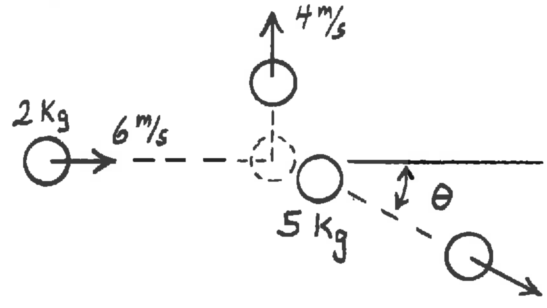
44. A 3 kg block, moving to the right at 4 m/s, collides head-on with a 6 kg block moving to the left at 2 m/s. If the collision is *elastic*, the total momentum after the collision is a) 36 J. b) 12 J. c) 24 J. d) 72 J. e) zero.

45. A 3 kg block, moving to the right at 4 m/s, collides head-on with a 6 kg block moving to the left at 2 m/s. If the collision is *perfectly inelastic*, the total KE after the collision is a) 36 J. b) 12 J. c) 24 J. d) 72 J. e) zero.

46. A 3 kg block, moving to the right at 4 m/s, collides head-on with a 6 kg block moving to the left at 2 m/s. If the collision is *perfectly inelastic*, the velocity of the 3 kg block after the collision is a) 2 m/s. b) −2 m/s. c) 3 m/s. d) −3 m/s. e) zero.

47. An object, traveling *east* with momentum 12 kg·m/s, collides and sticks to an object traveling *north* with momentum 5 kg·m/s. The magnitude of the final *momentum* is a) 17 kg·m/s. b) 7 kg·m/s. c) 13 kg·m/s. d) 12 kg·m/s. e) 5 kg·m/s.

The following questions, 48 through 52, refer to the two dimensional collision shown at the right. A 2 kg puck, moving at 6 m/s along the x-axis, makes a glancing collision with a stationary 5 kg puck. After the collision, the 2 kg puck is observed moving along the y-axis at 4 m/s while the 5 kg puck is observed moving with an unknown speed at angle θ with respect to the x-axis.



48. The *x-component* of momentum of the 5 kg puck after the collision is a) 2 kg·m/s. b) 4 kg·m/s. c) 6 kg·m/s. d) 8 kg·m/s. e) 12 kg·m/s.

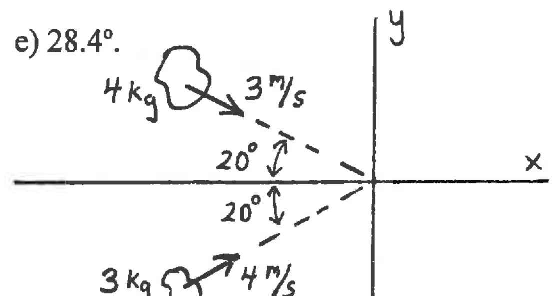
49. The *y-component* of momentum of the 5 kg puck after the collision is a) 2 kg·m/s. b) 4 kg·m/s. c) 6 kg·m/s. d) 8 kg·m/s. e) 12 kg·m/s.

50. The *x-component* of velocity of the 5 kg puck after the collision is a) 0.8 m/s. b) 1.2 m/s. c) 1.6 m/s. d) 2.4 m/s. e) 3.6 m/s.

51. The *y-component* of velocity of the 5 kg puck after the collision is a) 0.8 m/s. b) 1.2 m/s. c) 1.6 m/s. d) 2.4 m/s. e) 3.6 m/s.

52. The angle θ is a) 24.2°. b) 72.8°. c) 56.2°. d) 33.7°. e) 28.4°.

Questions 53 through 55 refer to the collision shown at the right. Two lumps of clay, one of mass 4 kg moving at 3 m/s and the other of mass 3 kg moving at 4 m/s, are each heading for the origin where they collide and stick together.



53. The *x-component* of velocity of the lump after the collision is a) 4.10 m/s. b) 3.22 m/s. c) 2.05 m/s. d) 1.41 m/s. e) zero.

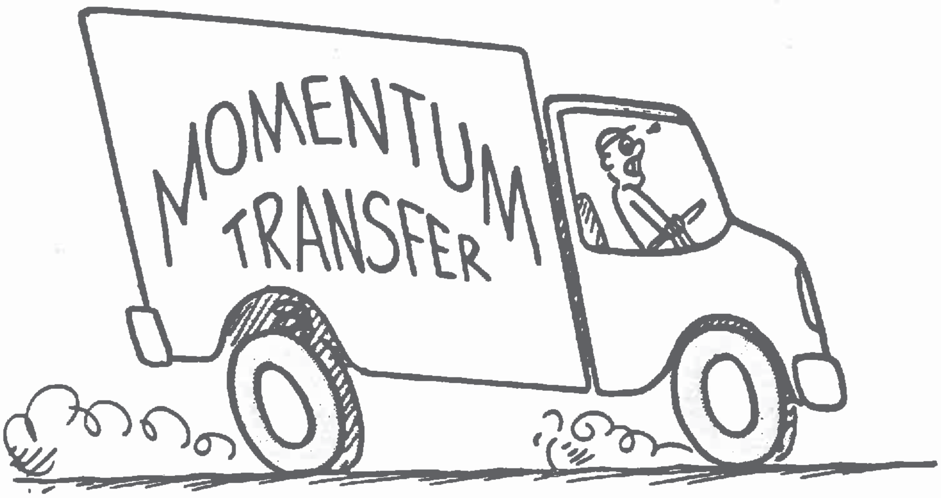
54. The *y-component* of velocity of the lump after the collision is a) 4.10 m/s. b) 3.22 m/s. c) 2.05 m/s. d) 1.41 m/s. e) zero.

55. Is energy conserved in this collision? a) Yes b) No c) Can't tell from the information provided.

56. An explosion occurs, dividing a 8 kg mass into two pieces. One piece of 5 kg is observed to fly along the y-axis at 3 m/s. What is the speed of the other piece? a) 2 m/s b) 3 m/s c) 5 m/s d) 8 m/s e) zero

57. Is energy conserved in the explosion? a) Yes b) No c) Can't tell from the information provided

FIGURING PHYSICS



The brakes are slammed on a speeding truck and it skids to a stop. If the truck were heavily loaded so it had twice the mass, the skidding time would be

a) the same.
b) 1½ times as long.
c) twice as long.
d) four times as long.

Hewitt Drew it!

CONSERVATION OF MOMENTUM

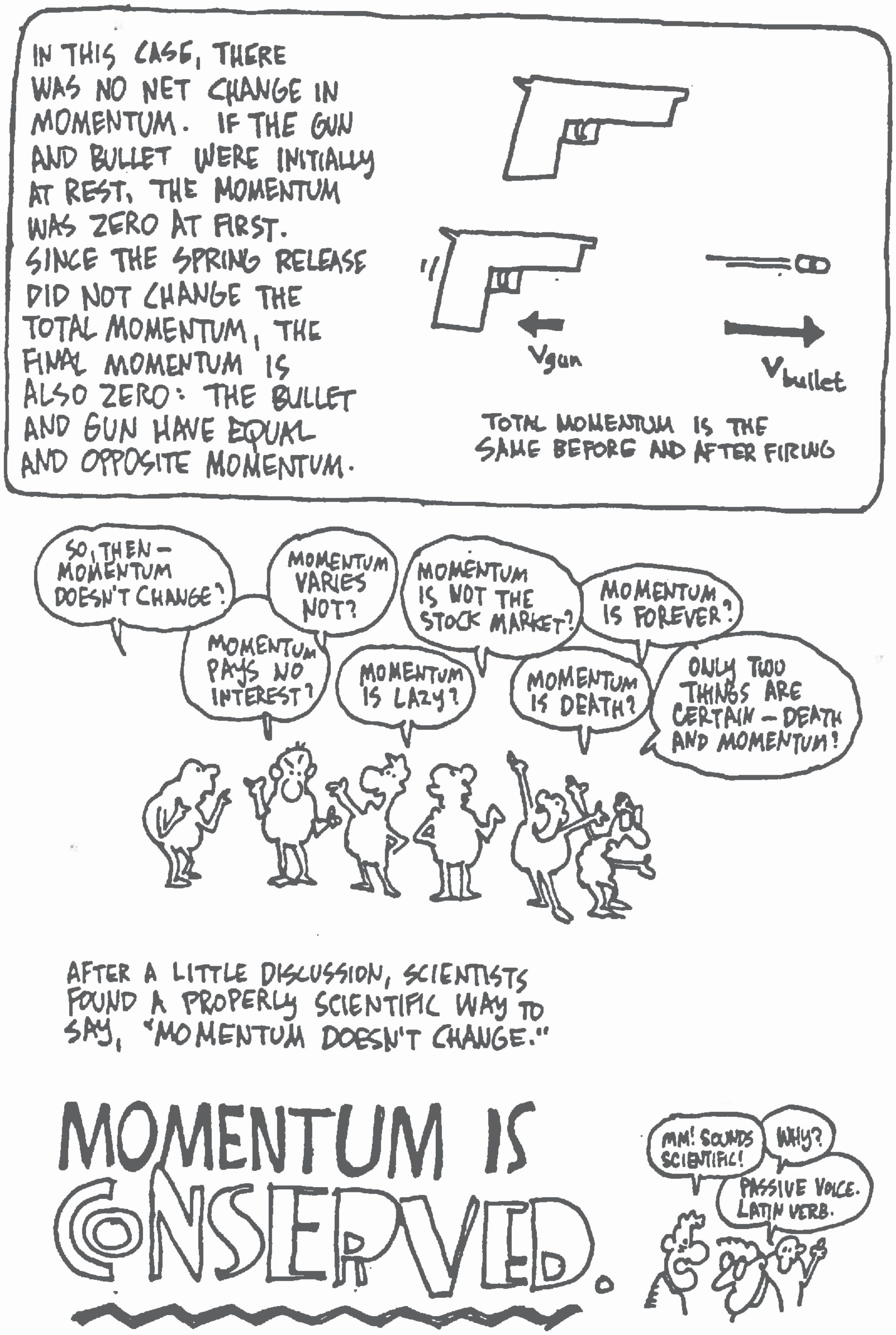
LET'S LOOK FOR A MINUTE AT COLLISIONS AND EXPLOSIONS. BY THIS WE MEAN ANY SITUATION WHERE THINGS ARE COMING TOGETHER OR FLYING APART.

COLLISION ABOUT TO HAPPEN

EXPLOSION ABOUT TO HAPPEN

FOR EXAMPLE, CONSIDER SHOOTING A GUN. THIS IS AN EXPLOSION, IN THE GENERAL SENSE THAT THE BULLET GOES ONE WAY AND THE GUN RECOILS THE OTHER. SUPPOSE, FOR THE SAKE OF SIMPLIFYING THE ARGUMENT, THAT THE BULLET IS EJECTED BY MEANS OF A SPRING:

WHEN THE SPRING IS RELEASED, IT EXERTS A FORCE ON THE BULLET. BY NEWTON'S THIRD LAW, THE BULLET EXERTS AN EQUAL BUT OPPOSITE FORCE ON THE SPRING/GUN SYSTEM. THESE FORCES PRODUCE EQUAL BUT OPPOSITE CHANGES IN MOMENTUM. SINCE THE GUN IS MORE MASSIVE THAN THE BULLET, IT RECOILS AT A VELOCITY MUCH SMALLER THAN THE BULLET'S VELOCITY.



Borrowed from **THE CARTOON GUIDE TO PHYSICS** by Larry Gonick and Art Huffmanh, Harper Perennial, 1991, p 68.

ROTATIONAL KINEMATICS

I. Key Terms and Phrases - Write a definition or description of each term. In addition,

A) write **V** in **front** of each quantity if the quantity is a **vector quantity** or write **S** if the quantity is a **scalar quantity**.

B) write the **MKS units** of the quantity in the space **behind** the quantity.

___ a) radius vector ___
___ b) angular position ___
___ c) arc length ___
___ d) angular speed___
___ e) angular displacement ___
___ f) tangential speed ___
___ g) angular acceleration ___
___ h) tangential acceleration ___
___ i) centripetal acceleration ____
j) axis of rotation
k) radian measure

II. QUESTIONS

1. How many radians is 120° ? a) 2.09 b) 1.36 c) 0.572 d) 3.78 e) 40.0

2. How many degrees is 4.50 radians? a) 165° b) 345° c) 258° d) 315° e) 120°

Questions 3 through 6 refer to the following situation: Imagine a boy and girl riding on a merry-go-round. The merry-go-round is rotating at a *constant* rate. The boy is riding a zebra *near the axis of rotation* and the girl is riding a tiger *near the outer rim.*

3. Which has the greater **angular speed**? a) The boy. b) The girl. c) Their speeds are equal. d) Their speeds are zero.

4. Which has the greater **tangential speed**? a) The boy. b) The girl. c) Their speeds are equal. d)Their speeds are zero.

5. Which has the greater **centripetal acceleration**? a) The boy. b) The girl. c) Their accelerations are equal. d) Their accelerations are zero.

6. Which has the greater **tangential acceleration**? a) The boy. b) The girl. c) Their accelerations are equal. d)Their accelerations are zero.

7. A wheel of radius 30 cm (0.30 m) turning at 1200 rpm has an **angular speed** of a) 37.7 rad/s. b) 62.8 rad/s. c) 94.3 rad/s. d) 126 rad/s. e) 314 rad/s.

8. A wheel of radius 30 cm (0.30 m) turning at 1200 rpm has a **tangential speed** at its rim of a) 37.7 m/s. b) 62.8 m/s. c) 94.3 m/s. d) 126 m/s. e) 314 m/s.

9. A wheel of radius 30 cm (0.30 m) is turning at 1200 rpm. Through what **angle** does it turn in one second? a) 37.7 rad b) 62.8 rad c) 94.3 rad d) 126 rad e) 314 rad

10. A wheel of radius 30 cm (0.30 m) is turning at 1200 rpm. How **far** does a point on its rim travel in one second? a) 37.7 m b) 62.8 m c) 94.3 m d) 126 m e) 314 m

11. A wheel of radius 30 cm (0.30 m) is turning at 1200 rpm. How **long** does it take for the wheel to rotate through 100 revolutions? a) 3.77 s b) 5.0 s c) 9.43 s d) 12.6 s e) 15.8 s

12. A car rounds a corner of radius 80 meters moving with a constant speed of 20 m/s. What is the **angular speed** of the car? a) zero b) 4 rad/s c) 1 rad/s d) 0.25 rad /s e) 0.1 rad/s

13. A car has 20 cm radius tires. If the tires are rotating with an angular speed of 60 rad/s, the **speed** of the car is a) 18 m/s. b) 20 m/s. c) 10 m/s. d) 12 m/s. e) 60 m/s.

14. A car has 20 cm radius tires. If the car is moving with a speed of 20 m/s, the **angular speed** of its tires is a) 18 rad/s. b) 20 rad/s. c) 100 rad/s. d) 120 rad/s. e) 60 rad/s.

15. A car has 20 cm radius tires. If the car is moving with a speed of 20 m/s, the **tangential speed** of the rim of each tire is (with respect to its axis) a) 18 m/s. b) 20 m/s. c) 10 m/s. d) 120 m/s. e) 60 m/s.

16. A car has tires of radius 20 cm. If the car moves 180 meters, each point of the rim has moved along the arc (with respect to the axis) a **distance** of a) 180 m. b) 200 m. c) 100 m. d) 120 m. e) 60 m.

17. A car has 20 cm radius tires. If the car is moving with a speed of 20 m/s, the **centripetal acceleration** of each point on the rim of a tire is a) 1800 m/s^2. b) 2000 m/s^2. c) 1000 m/s^2. d) 1200 m/s^2. e) 600 m/s^2.

18. A car has 20 cm radius tires. If the car is accelerating at 1.2 m/s^2, the **angular acceleration** of each tire is a) 18 rad/s^2. b) 20 rad/s^2. c) 10 rad/s^2. d) 12 rad/s^2. e) 6 rad/s^2.

19. If the tires on your car are replaced by tires of larger diameter, the speedometer of your car will register a speed a) faster than the true speed. b) slower than the true speed. c) the same as the true speed.

    d) The speedometer will not work with larger tires.

Questions 20 through 23 refer to a 50 cm (0.50 m) radius wheel that starts from rest and accelerates uniformly with an **angular acceleration** of 4 rad/s^2.

20. Through what **angle** does it turn in 3 seconds? a) 6 rad b) 12 rad c) 18 rad d) 9 rad e) 24 rad

21. How **far** does a point on its rim travel (with respect to the axis) in 3 seconds? a) 6 m b) 12 m c) 18 m d) 9 m e) 24 m

22. What is the **angular speed** of the wheel after 3 seconds? a) 6 rad/s b) 12 rad/s c) 18 rad/s d) 9 rad/s e) 24 rad/s

23. What is the **tangential speed** of a point on its rim (with respect to the axis) after 3 seconds? a) 6 m/s b) 12 m/s c) 18 m/s d) 9 m/s e) 24 m/s

ROTATION ABOUT A FIXED AXIS

I. Key Terms and Phrases - Write a definition or description of each term. In addition,

A) write **V** in **front** of each quantity if the quantity is a **vector quantity** or write **S** if the quantity is a **scalar quantity**.

B) write the **MKS units** of the quantity in the space **behind** the quantity.

___ a) torque ___
___ b) application distance ___
___ c) moment arm ___
___ d) moment of inertia
___ e) rotational KE___
___ f) rotational work
g) rotational 2nd law
h) line of action
i) axis of rotation
j) right hand rule
k) center of gravity
l) parallel-axis theorem

II. QUESTIONS

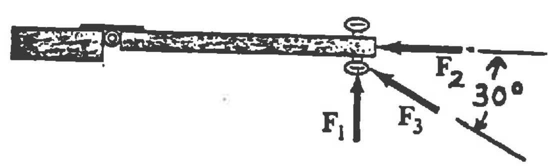
1. You twist a doorknob in the counterclockwise direction. The *direction* of this torque is a) in toward the door. b) out from the door. c) to your left. d) to your right. e) up.

2. You reach out and twist the key in your ignition clockwise. The *direction* of this torque is a) in toward the key. b) out from key. c) to your left. d) to your right. e) up.

3. You open a door hinged on your left by pushing it away from you. The *direction* of this torque is a) in toward the door. b) out from the door. c) to your left. d) to your right. e) up.

4. As you face a clock, the direction of its angular velocity is a) in toward the clock face. b) out from the clock face. c) to your left. d) to your right. e) up.

Questions 5 through 10 refer to the sketch at the right which shows a top view of a door hinged on the left. The door opens by pushing away from you. The distance between hinges and doorknob is 0.80 meters and the magnitude of each force is 20 N.



5. The *magnitude* of the torque due to force $\mathbf{F_1}$ is a) zero. b) 8 N·m. c) 12.5 N·m. d) 13.87 N·m. e) 16.0 N·m.

6. The *magnitude* of the torque due to force $\mathbf{F_2}$ is a) zero. b) 8 N·m. c) 12.5 N·m. d) 13.87 N·m. e) 16.0 N·m.

7. The *magnitude* of the torque due to force $\mathbf{F_3}$ is a) zero. b) 8 N·m. c) 12.5 N·m. d) 13.87 N·m. e) 16.0 N·m.

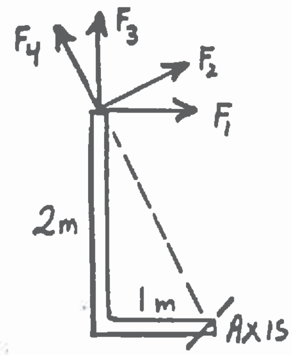
8. The *moment arm* of $\mathbf{F_1}$ is a) zero. b) 0.4 m. c) 0.693 m. d) 0.725 m. e) 0.80 m.

9. The *moment arm* of $\mathbf{F_2}$ is a) zero. b) 0.4 m. c) 0.693 m. d) 0.725 m. e) 0.80 m.

10. The *moment arm* of $\mathbf{F_3}$ is a) zero. b) 0.4 m. c) 0.693 m. d) 0.725 m. e) 0.80 m.

ROTATION ABOUT A FIXED AXIS - WORKSHEET 15

Questions 11 through 14 refer to the "L shaped" arm shown below. Four possible forces that can act on the arm are also shown. The magnitude of each force is 20 N.



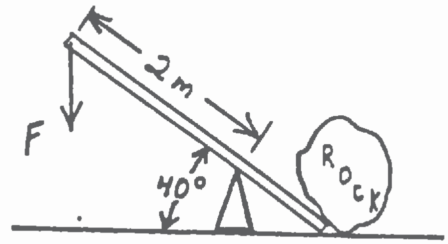
11. The *magnitude* of the torque due to $\mathbf{F_1}$ is a) zero. b) 20 N·m. c) 40 N·m. d) 44.7 N·m. e) 60 N·m.

12. The *magnitude* of the torque due to $\mathbf{F_2}$ is a) zero. b) 20 N·m. c) 40 N·m. d) 44.7 N·m. e) 60 N·m

13. The *magnitude* of the torque due to $\mathbf{F_3}$ is a) zero. b) 20 N·m. c) 40 N·m. d) 44.7 N·m. e) 60 N·m

14. The *magnitude* of the torque due to $\mathbf{F_4}$ is a) zero. b) 20 N·m. c) 40 N·m. d) 44.7 N·m. e) 60 N·m

15. Using a steel bar of length 3.0 meters, you attempt to move a large rock as shown in the sketch at the right. Your applied force at the end of the lever is straight down. The *moment arm* of the applied force is a) 1.29 m. b) 1.0 m. c) 1.53 m. d) 2 m. e) 3 m.



16. A boy and a girl of equal mass are riding on a merry-go-round. The boy is twice as far from the axis of rotation as the girl. The *moment of inertia* of the boy is a) equal to that of the girl. b) twice that of the girl. c) three times that of the girl. d) four times that of the girl.

17. A boy and a girl are riding on a merry-go-round. They are both the same distance from the axis of rotation, but the boy has twice the mass as the girl. The *moment of inertia* of the boy is a) equal to that of the girl. b) twice that of the girl. c) three times that of the girl. d) four times that of the girl.

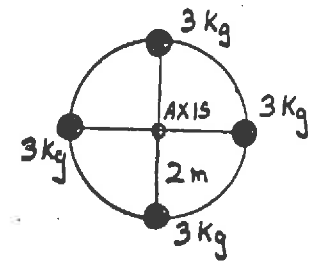
18. A boy and a girl are riding on a merry-go-round. The girl has one-fourth the mass of the boy and is twice as far from the axis of rotation as the boy. The *moment of inertia* of the boy is a) equal to that of the girl. b) twice that of the girl. c) three times that of the girl. d) four times that of the girl.

19. A solid cylinder of mass **4 kg** and a hollow cylinder of mass **4 kg** both have the same radius. Which has the greater *moment of inertia*? a) The solid cylinder. b) The hollow cylinder. c) Both have the same value.

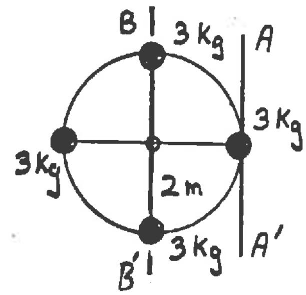
20. A solid cylinder of mass **4 kg** and a hollow cylinder of mass **2 kg** both have the same radius. Which has the greater *moment of inertia*? a) The solid cylinder. b) The hollow cylinder. c) Both have the same value.

21. A solid cylinder of mass **4 kg** has radius R while a hollow cylinder of mass **1 kg** has radius 2R. Which has the greater *moment of inertia*? a) The solid cylinder. b) The hollow cylinder. c) Both have the same value.

22. A solid cylinder of length **L** has the same mass and radius R as a solid cylinder of length **2L**. Which has the greater *moment of inertia*?
a) cylinder **L** b) cylinder **2L** c) Both have the same value

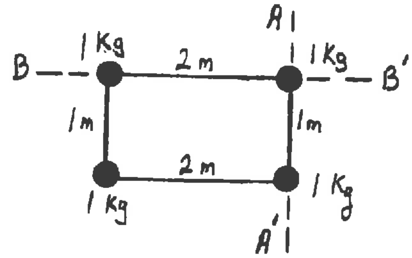


23. Four 3 kg masses are connected together by light rods as shown in the sketch at the right. Each mass is 2 m from the axis of rotation. If the system rotates about an axis through its center (directed into the page), the moment of inertia of the system is a) 72 kg·m^2.
b) 12 kg·m^2. c) 24 kg·m^2. d) 36 kg·m^2. e) 48 kg·m^2.



24. Four 3 kg masses are connected together by light rods as shown in the sketch at the right. Each mass is 2 m from the center. If the system rotates about the axis <u>AA'</u>, the moment of inertia of the system is a) 72 kg·m^2. b) 12 kg·m^2. c) 24 kg·m^2. d) 36 kg·m^2.
e) 48 kg·m^2.

25. Four 3 kg masses are connected together by light rods as shown in the sketch above. Each mass is 2 m from the center. If the system rotates about the axis <u>BB'</u>, the moment of inertia of the system is a) 72 kg·m^2. b) 12 kg·m^2. c) 24 kg·m^2. d) 36 kg·m^2. e) 48 kg·m^2

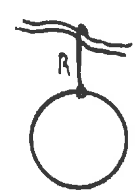


26. Four 1 kg masses are connected together in the shape of a rectangle as shown in the sketch at the right. If the masses rotate about the axis <u>AA'</u>, the *moment of inertia* of the system is a) 2 kg·m^2.
b) 4 kg·m^2. c) 8 kg·m^2. d) 16 kg·m^2. e) 32 kg·m^2.

27. Four 1 kg masses are connected together in the shape of a rectangle as shown above. If the masses rotate about the axis <u>BB'</u>, the *moment of inertia* of the system is a) 2 kg·m^2. b) 4 kg·m^2. c) 8 kg·m^2.
d) 16 kg·m^2. e) 32 kg·m^2.

28. If both the mass and radius of a uniform sphere are doubled, the *moment of inertia* of the sphere about its center will increase by a factor of a) 1. b) 2. c) 4. d) 8. e) 16.

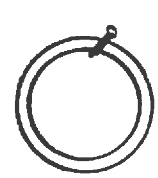
29. What is the *moment of inertia* of a meter stick of mass M about its 40 cm position? a) 0.12 M
b) 0.08 M c) 0.062 M d) 0.051 M e) 0.093 M



30. A hook of length R is attached to the surface of a <u>solid</u> spherical Xmas tree ornament of radius R and mass M. If the ornament is hung from a tree limb as shown, what is the *moment of inertia* of the ornament about the limb?
a) 6.2 MR^2 b) 4.7 MR^2 c) 4.4 MR^2 d) 3.8 MR^2 e) 3.2 MR^2

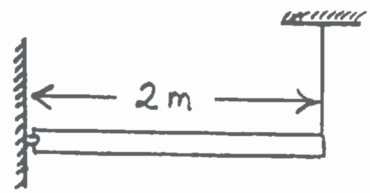
31. A hook of length R is attached to the surface of a <u>hollow</u> spherical Xmas tree ornament of radius R and mass M. If the ornament is hung from a tree limb as shown above, what is the *moment of inertia* of the ornament about the limb? a) 6.2 MR^2 b) 4.7 MR^2 c) 4.4 MR^2 d) 3.8 MR^2 e) 3.2 MR^2

32. A hoop of mass M and radius R is hung on a nail as shown. What is its *moment of inertia* about the nail? a) 2 MR^2 b) 1.8 MR^2 c) 1.5 MR^2 d) MR^2 e) 0.5 MR^2

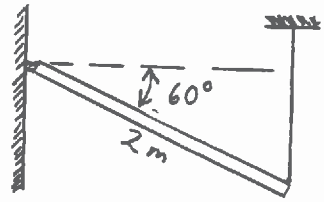


ROTATION ABOUT A FIXED AXIS - WORKSHEET 15

33. A uniform rod of weight 40 N and length two meters is attached to a wall by a hinge. A vertical string attached to the other end holds the rod horizontal as shown. If the string is cut, the initial *torque* exerted on the rod is a) 10 N·m. b) 20 N·m. c) 36.4 N·m. d) 40 N·m. e) 80 N·m.



34. A uniform rod of weight 40 N and length two meters is attached to a wall by a hinge. A vertical string attached to the other end holds the rod at an angle of 60° below the horizontal as shown. If the string is cut, the initial *torque* exerted on the rod is a) 10 N·m. b) 20 N·m. c) 36.4 N·m. d) 40 N·m. e) 80 N·m.



35. If the *mass* of a spinning disk were doubled, its *rotational KE* would a) halve. b) stay the same. c) double. d) quadruple.

36. If the *angular speed* of a spinning disk were doubled, its *rotational KE* would a) halve. b) stay the same. c) double. d) quadruple.

37. If the *radius* of a spinning disk were doubled, its *rotational KE* would a) halve. b) stay the same.

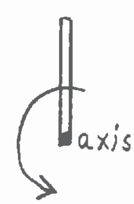
    c) double. d) quadruple.

38. If the *radius* of a spinning disk were doubled and its *angular speed* reduced by one-half, its *rotational KE* would a) halve. b) stay the same. c) double. d) quadruple.

39. If the *mass* of a spinning disk were doubled and its *angular speed* reduced by one-half, its *rotational KE* would a) halve. b) stay the same. c) double. d) quadruple.

40. A rod of mass M and length L is free to rotate about one end as shown. If released from rest in the horizontal position, as it passes through its lowest point, its *KE* is a) MgL. b) 0.5 MgL. c) 0.25 MgL. d) 2MgL. e) 4MgL.

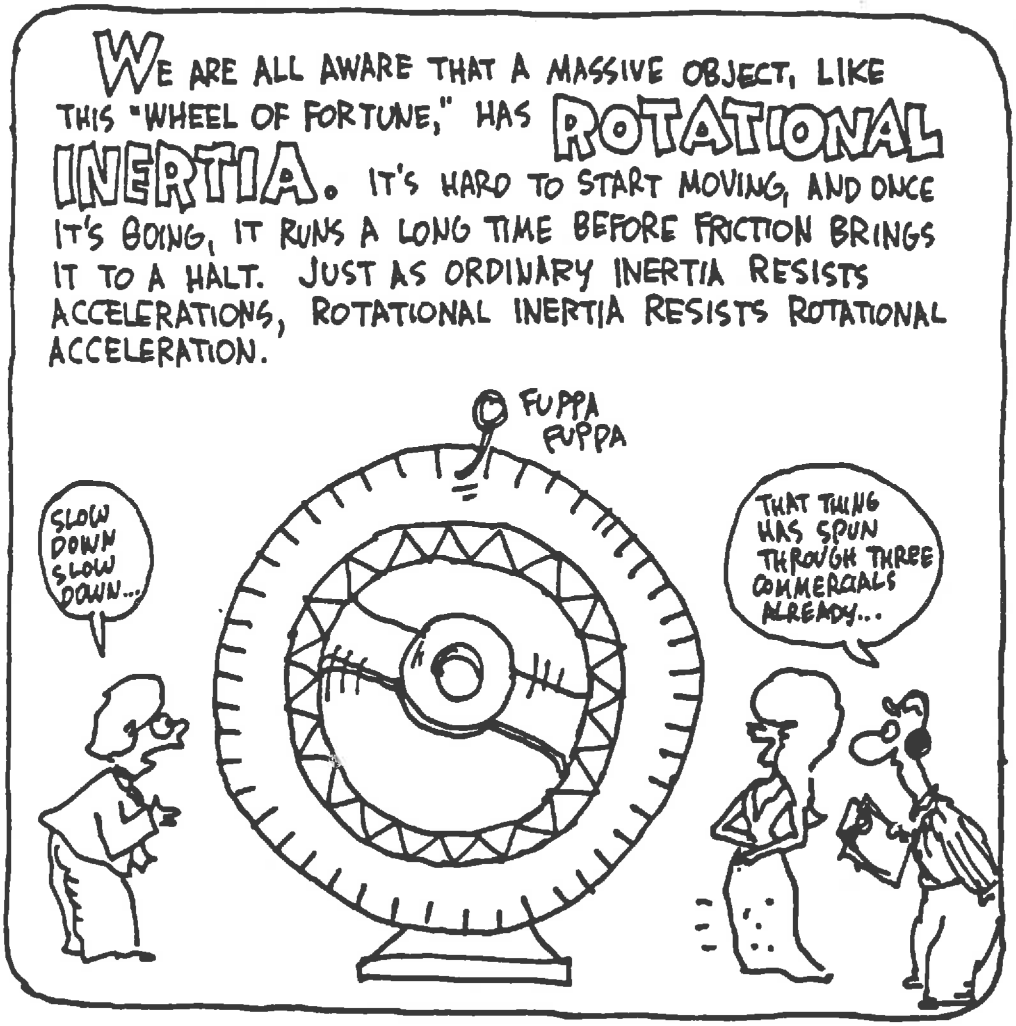
41. A rod of mass M and length L is free to rotate about one end as shown. If released from rest in an upright position, as it passes through its lowest point, its *KE* is a) MgL. b) 0.5 MgL. c) 0.25 MgL. d) 2MgL. e) 4MgL.



42. The torque that keeps a wheel spinning with *constant* angular speed is a) zero. b) its weight. c) its moment of inertia. d) its rotational torque. e) cannot be determined.

43. A *nonzero* torque is required to a) produce a change in angular velocity. b) maintain a constant angular velocity. c) produce a linear acceleration. d) produce a constant angular displacement. e) Both (a) and (c) are correct.

ROTATIONAL INERTIA



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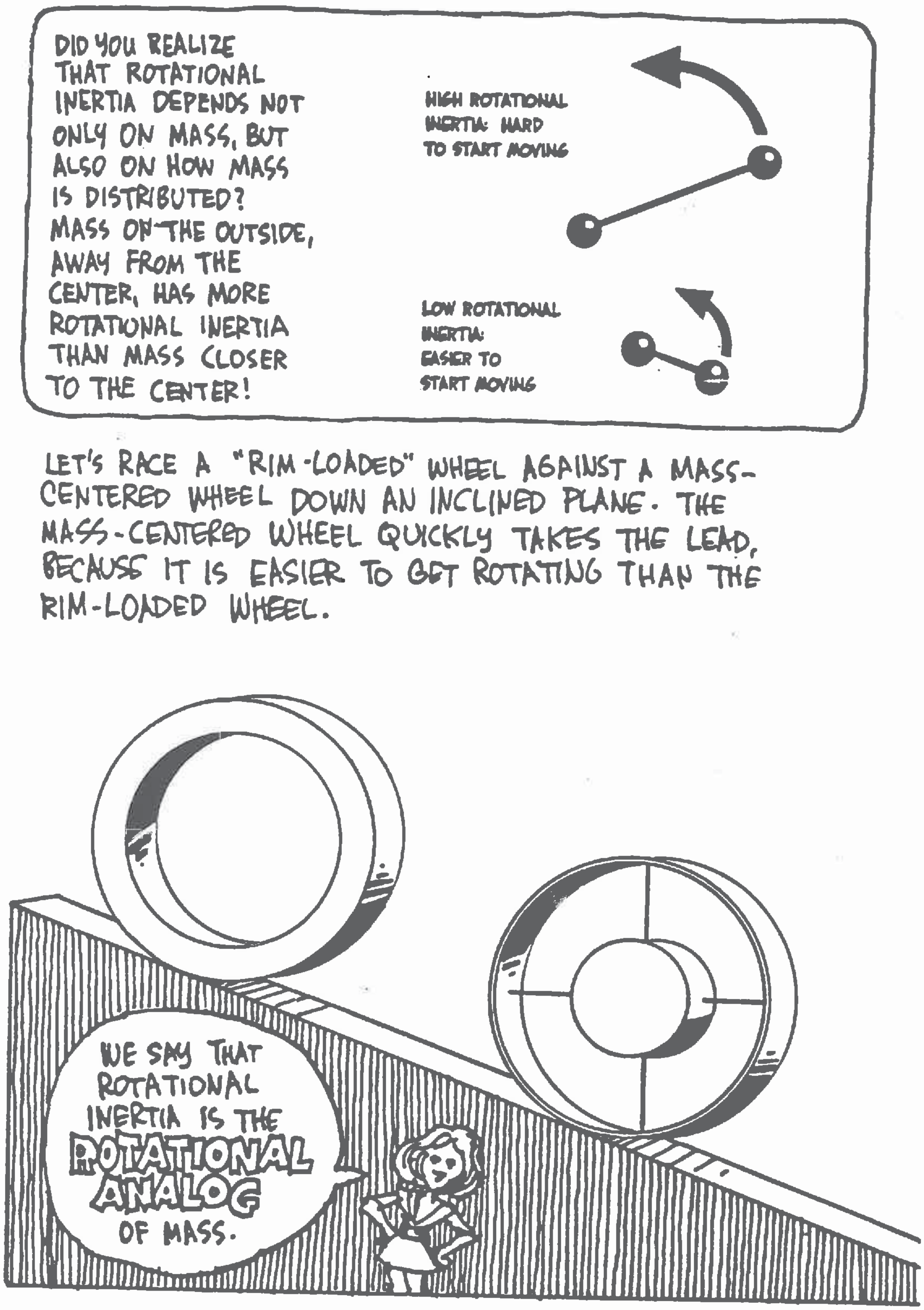
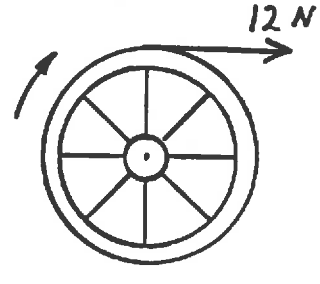


Borrowed from **THE CARTOON GUIDE TO PHYSICS** by Larry Gonick and Art Huffman, Harper Perennial, 1991, p 90.

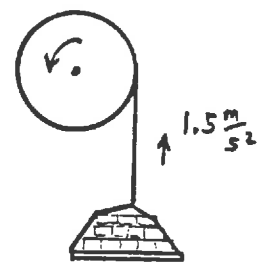
ROTATION ABOUT A FIXED AXIS - PROBLEMS

The problems below are *typical problems* than can be solved using the 2nd law for rotation about a fixed axis and the principle of the conservation of energy for rotational systems. For each problem, draw a relevant sketch including a force diagram if necessary, write down the principles or laws related to the motion, substitute the proper quantities, and solve.

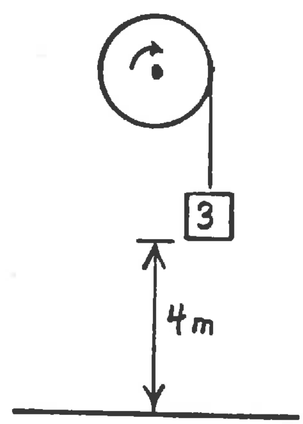
1. A wheel of moment of inertia 5.00 kg·m² and radius 80 cm is accelerated from rest by a 12.0 N force applied to its rim as shown. If the wheel obtains a final speed of 4.00 rad/s in 8 seconds, find the magnitude of the *frictional torque* that acted on the wheel as it accelerated.



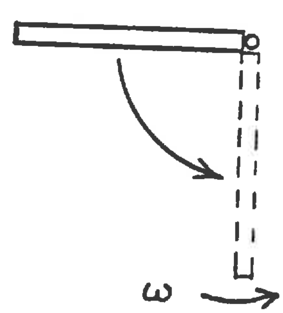
2. Bricks are lifted up to the third floor at a building site using a simple elevator consisting of a motor connected to a large pulley of radius 12 cm and mass 40 kg. A cable is wrapped around the pulley and connected to a platform containing the bricks. If the platform plus bricks have a mass of 120 kg and the elevator must be accelerated upward at 1.5 m/s², find the *torque* that must be applied on the pulley by the motor. Assume the pulley is a uniform disk.



3. This problem illustrates how the moment of inertia for a round object can be measured in the lab. Suppose you have a nonuniform cylindrical drum of radius 0.200 meters and you wish to know its moment of inertia about its axis. The drum is attached to low friction bearings and a cord is wrapped around the drum. The other end of the cord is attached to a 3.00 kg mass as shown. The height of the mass is adjusted to 4.00 meters from the floor, and released from rest. You measure 4.00 seconds for the mass to hit the floor. Use this data to find the *moment of inertia* of the drum.



4. A long uniform rod of mass 2 kg and length 120 cm is pivoted about one end as shown. Its lower end is raised so that the rod is horizontal. From this position, the rod is released from rest. (a) What is the *angular velocity* of the rod as it passes through the bottom of its swing? (b) What is the *tangential velocity* of the end of the rod at this position?



TRYING TO DO THE JOB ALONE

The True Story Behind the Accident Report

Dear Sir:

I am writing in response to your request for additional information. In block number 3 of the accident reporting form, I put "trying to do the job alone," as the cause of my accident. You said in your letter that I should explain more fully, and I trust that the following details will be sufficient.

I am a bricklayer by trade. On the day of the accident I was working alone on the roof of a new six-story building. When I completed my work, I discovered that I had about 500 pounds of brick left over. Rather than carry the bricks down by hand, I decided to lower them in a barrel by using a pulley which, fortunately, was attached to the side of the building at the sixth floor.

Securing the rope at ground level, I went up to the roof, swung the barrel out and loaded the brick into it. Then, I went back to the ground and untied the rope, holding it tightly to insure a slow descent of the 500 pounds of bricks. You will note in block number 11 of the accident report form that I weigh 135 pounds.

Due to my surprise of being jerked off the ground so suddenly, I lost presence of mind and forgot to let go of the rope. Needless to say, I proceeded at a rather rapid rate up the side of the building. In the vicinity of the third floor, I met the barrel coming down. This explains the fractured skull and broken collarbone. Slowed only slightly, I continued my rapid ascent, not stopping until the fingers of my right hand were two-knuckles deep into the pulley.

Fortunately, by this time I regained my presence of my mind and was able to hold tightly to the rope in spite of my pain. At approximately the same time, however, the barrel of bricks hit the ground--and the bottom fell out of the barrel. Devoid of the weight of the bricks, the barrel now weighed approximately 50 pounds. I refer you again to my weight in block number 11. As you might imagine, I began a rapid descent down the side of the building. In the vicinity of the third floor I met the barrel coming up. This accounts for the two fractured ankles and the lacerations of my legs and lower body.

The encounter with the barrel slowed me enough to lessen my injuries when I fell onto the pile of bricks and, fortunately, only three vertebrae were cracked.

I am sorry to report, however, that as I lay there on the bricks--in pain, unable to stand, and watching the empty barrel six stories above me--I again lost my presence of mind.

I LET GO OF THE ROPE.

OUR FINAL ROTATIONAL ANALOG IS

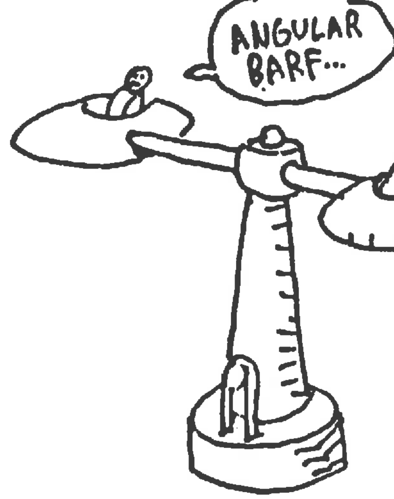
ANGULAR MOMENTUM.

BY ANALOGY WITH LINEAR MOMENTUM (MASS TIMES VELOCITY), ANGULAR MOMENTUM IS DEFINED AS

ROTATIONAL INERTIA

×

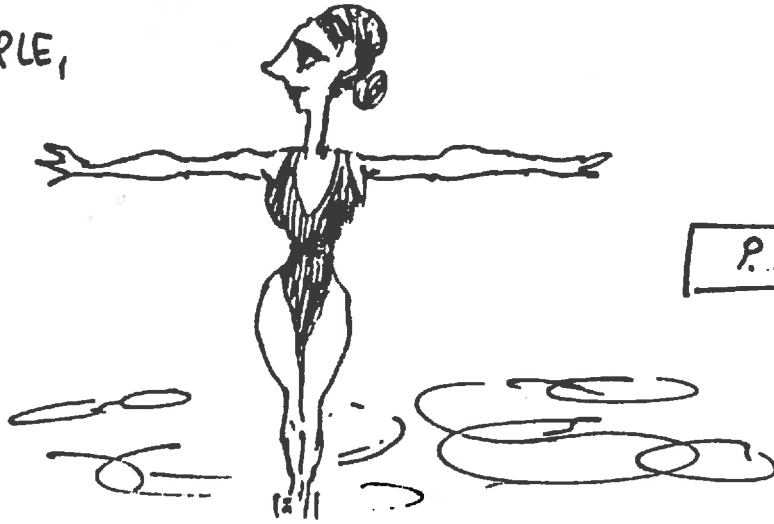
ANGULAR VELOCITY.



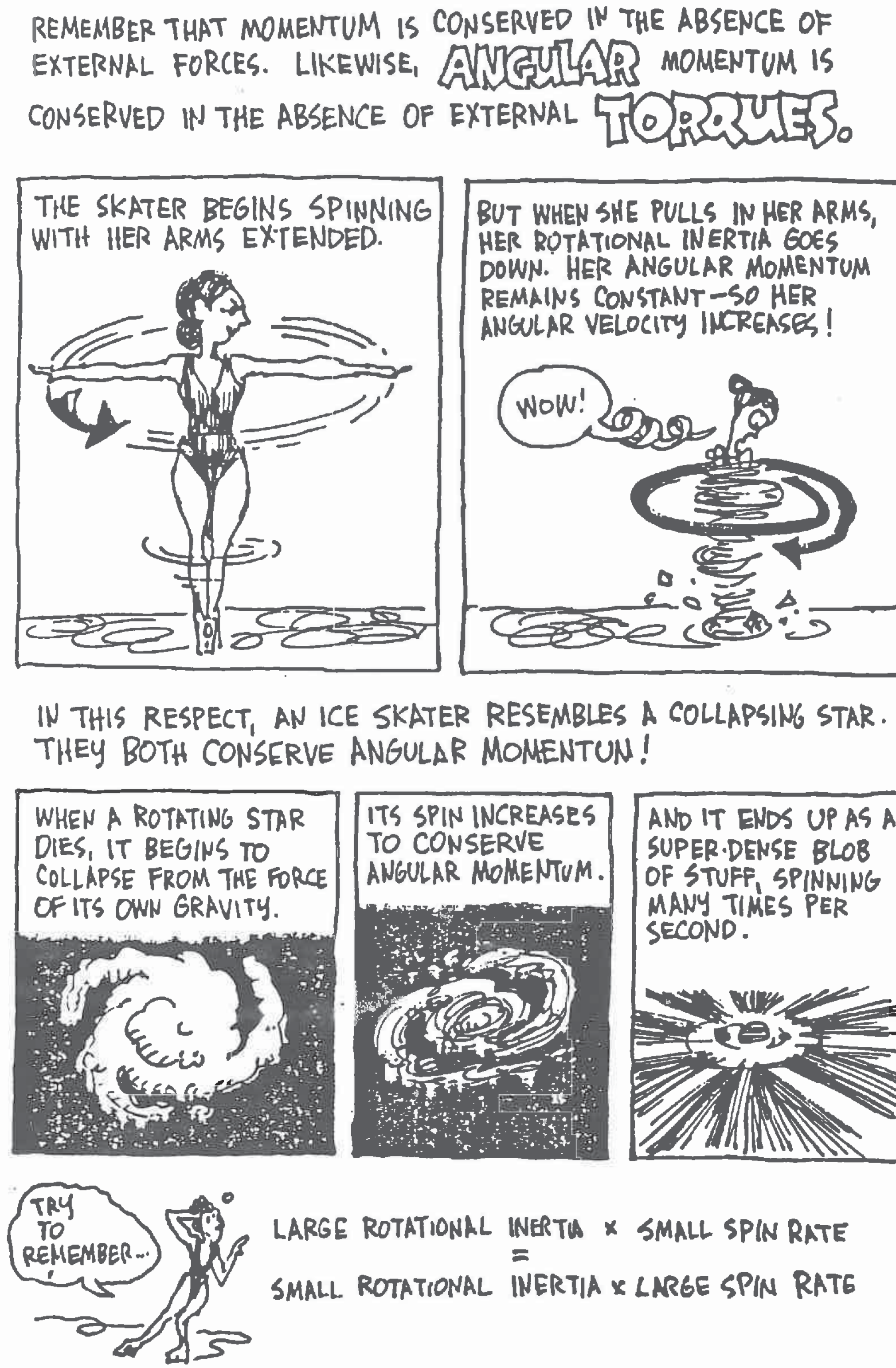
(ANGULAR VELOCITY IS JUST THE TURNING RATE. IT CAN BE EXPRESSED IN REVOLUTIONS PER SECOND.)

UNLIKE MASS, THE AMOUNT OF ROTATIONAL INERTIA CAN BE CHANGED "IN MID-FLIGHT" BY REARRANGING THE MASS. THIS MAKES ROTATIONAL MOTION MORE COMPLICATED THAN LINEAR MOTION.

TAKE, FOR EXAMPLE, THE CASE OF THE SPINNING ICE SKATER...



P.T.O.



Borrowed from **THE CARTOON GUIDE TO PHYSICS** by Larry Gonick and Art Huffman, Harper Perennial, 1991, p 94.

ROLLING AND ANGULAR MOMENTUM

I. Key Terms and Phrases - Write a definition or description of each term. In addition,
A) write **V** in **front** of the quantity if it is a **vector quantity** or write **S** if it is a **scalar quantity**.
B) write the **MKS units** of the quantity in the space **behind** the quantity.

___ a) angular momentum ___
___ b) angular impulse ___
___ c) total kinetic energy ___
___ d) net external torque ___
e) pure rolling
f) center of mass
g) vector cross product
h) right hand rule
i) moment of momentum
j) conservation of angular momentum
k) precession

II. QUESTIONS

1. A 2 kg sphere of radius 0.25 m is rolling with a speed of 10 m/s. Its *angular speed* with respect to its axis of rotation is a) 0.50 rad/s. b) 40 rad/s. c) 20 rad/s. d) 10 rad/s. e) 5 rad/s.

2. A 2 kg sphere of radius 0.25 m is rolling with a speed of 10 m/s. Its *transitional kinetic energy* is a) 10 J. b) 20 J. c) 40 J. d) 100 J. e) 140 J.

3. A 2 kg sphere of radius 0.25 m is rolling with a speed of 10 m/s. Its *rotational kinetic energy* is a) 10 J. b) 20 J. c) 40 J. d) 100 J. e) 140 J.

4. A 2 kg sphere of radius 0.25 m is rolling with a speed of 10 m/s. Its *total kinetic energy* is a) 10 J. b) 20 J. c) 40 J. d) 100 J. e) 140 J.

5. A hollow sphere and a solid sphere of the same mass and radius are placed side by side on an incline and simultaneously start rolling from rest. At the bottom, which has the larger *speed*?
a) The hollow sphere. b) The solid sphere. c) The speeds are equal.

6. A hollow sphere and a solid sphere of the same mass and radius are placed side by side on an incline and simultaneously start rolling from rest. At the bottom, which has the larger *translational KE*?
a) The hollow sphere. b) The solid sphere. c) The energies are equal.

7. A hollow sphere and a solid sphere of the same mass and radius are placed side by side on an incline and simultaneously start rolling from rest. At the bottom, which has the larger *rotational KE*?
a) The hollow sphere. b) The solid sphere. c) The energies are equal.

8. A hollow sphere and a solid sphere of the same mass and radius are placed side by side on an incline and simultaneously start rolling from rest. At the bottom, which has the larger *total kinetic energy*?
a) The hollow sphere. b) The solid sphere. c) The energies are equal.

9. A hollow sphere and a solid sphere of the same mass and radius are placed side by side on an incline and simultaneously start rolling from rest. As they roll down, which has the larger *acceleration*?
a) The hollow sphere. b) The solid sphere. c) The accelerations are equal.

10. A *cylinder* is rolling without slipping with constant speed. The *ratio* of its rotational KE to its translational KE is a) 1:1. b) 1:2. c) 2:3. d) 1:3. e) 2:5.

11. A *solid sphere* is rolling without slipping with constant speed. The *ratio* of its rotational KE to its translational KE is a) 1:1. b) 1:2. c) 2:3. d) 1:3. e) 2:5.

12. Two solid spheres are placed side by side on an incline and simultaneously start rolling from rest. The **blue** sphere has twice the radius and twice the mass of the **red** sphere. Which *reaches* the bottom first? a) The blue sphere. b) The red sphere. c) They arrive at the same time.

13. Two solid spheres are placed side by side on an incline and simultaneously start rolling from rest. The **blue** sphere has twice the radius and twice the mass of the **red** sphere. Which has the largest *translational speed* at the bottom? a) The blue sphere. b) The red sphere. c) They have the same speed.

14. Two solid spheres are placed side by side on an incline and simultaneously start rolling from rest. The **blue** sphere has twice the radius and twice the mass of the **red** sphere. Which has the greater *total kinetic energy at the bottom*? a) The blue sphere. b) The red sphere. c) They have the same total kinetic energy.

15. If $\mathbf{a} = 3\,\mathbf{i} - 4\,\mathbf{j}$ and $\mathbf{b} = 4\,\mathbf{i} - 3\,\mathbf{j}$, then $\mathbf{a} \times \mathbf{b} =$ a) $5\,\mathbf{k}$. b) $2\,\mathbf{i} - \mathbf{k}$. c) $6\,\mathbf{j}$. d) $12\,\mathbf{k}$. e) $6\,\mathbf{j} + 3\,\mathbf{k}$.

16. A force $\mathbf{F} = 2\,\mathbf{i} - 4\,\mathbf{j} + 3\,\mathbf{k}$ N acts at the position $\mathbf{r} = 3\,\mathbf{i} + 4\,\mathbf{j} - 2\,\mathbf{k}$ m. Find the magnitude of the torque about the origin due to this force. a) 15.3 N·m b) 18.5 N·m c) 24.2 N·m d) 34.8 N·m

17. As you face a clock, in which *direction* is its angular momentum? a) To the right. b) To the left. c) Out from the clock. d) In toward the clock. e) Up toward the ceiling. f) Down toward the floor.

18. As you ride a bicycle, what is the *direction* of the angular momentum of its front tire? a) To your right. b) To your left. c) To your front. d) Down toward the ground. e) Up toward the sky.

19. If you make a *right* turn while driving your car, what is the *direction* of its angular momentum with respect to the center of the turning circle? a) To your right. b) To your left. c) To your front. d) Down toward the ground. e) Up toward the sky.

20. A 2 kg particle travels at 10 m/s along the line $\mathbf{x} = 3$ m. What is its *angular momentum* with respect to the origin? a) $60\,\mathbf{k}$ kg·m^2/s b) $-30\,\mathbf{k}$ kg·m^2/s c) $20\,\mathbf{j}$ kg·m^2/s d) $-10\,\mathbf{i}$ kg·m^2/s e) $40\,\mathbf{j}$ kg·m^2/s

21. A 2 kg particle travels with uniform circular motion at 10 m/s along a circular path of radius 2 meters. The magnitude of its *angular momentum* with respect to the center of the circle is a) 60 kg·m^2/s b) 30 kg·m^2/s c) 20 kg·m^2/s d) 10 kg·m^2/s e) 40 kg·m^2/s

22. A 2 kg *hoop* of radius 50 cm (0.50 m) is rolling along a level surface at 8 m/s. Its *angular momentum* is a) 4 kg·m^2/s. b) 8 kg·m^2/s. c) 12 kg·m^2/s. d) 16 kg·m^2/s. e) 24 kg·m^2/s.

23. A 2 kg *disk* of radius 50 cm (0.50 m) is rolling along a level surface at 8 m/s. Its *angular momentum* is a) 4 kg·m^2/s. b) 8 kg·m^2/s. c) 12 kg·m^2/s. d) 16 kg·m^2/s. e) 24 kg·m^2/s.

24. A solid sphere and a hollow sphere of the same mass are spinning with the same angular velocity. Which sphere, if either, has the greater *angular momentum*? a) The hollow sphere. b) The solid sphere. c) Both spheres have the same angular momentum. d) Impossible to tell from the given information.

25. An object's angular momentum changes by 12 kg·m²/s in 2 seconds. The *average torque* that acted on the object was a) 40 N·m. b) 20 N·m. c) 2.5 N·m. d) 6 N·m. e) 24 N·m.

26. When a net external *torque* acts on a system, must its total angular momentum change? a) Yes, always. b) No, never. c) Sometimes. It depends upon the magnitude of the torque. d) Sometimes. It depends upon the point of application of the torque.

27. When a net external *force* acts on a system, must its total angular momentum change? a) Yes, always. b) No, never. c) Sometimes. It depends upon the magnitude of the force. d) Sometimes. It depends upon the point of application of the force.

28. A spinning ice skater pulls in his outstretched arms. His *moment of inertia* a) increases. b) decreases. c) remains the same.

29. A spinning ice skater pulls in his outstretched arms. His *angular momentum* a) increases. b) decreases. c) remains the same.

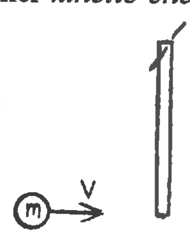
30. A spinning ice skater pulls in his outstretched arms. His *rotational kinetic energy* a) increases. b) decreases. c) remains the same.

31. A woman stands on a rotating platform with a large mass in each outstretched hand. When the masses are pulled in toward her body, her angular speed *doubles*. By what factor does her *moment of inertia* change? a) 2 b) 4 c) zero d) ½ e) 1/4

32. A woman stands on a rotating platform with a large mass in each outstretched hand. When the masses are pulled in toward her body, her angular speed *doubles*. By what factor does her *angular momentum* change? a) 2 b) 4 c) zero d) ½ e) 1/4

33. A woman stands on a rotating platform with a large mass in each outstretched hand. When the masses are pulled in toward her body, her angular speed *doubles*. By what factor does her *kinetic energy* change? a) 2 b) 4 c) zero d) ½ e) 1/4

34. A 0.20 kg mass, moving at 10 m/s as shown, strikes and sticks to the end of a 0.30 kg meter stick pivoted at the other end of the stick. What is the *angular momentum* of the system just after the collision? a) 1 kg·m²/s b) 2 kg·m²/s c) 4 kg·m²/s d) 5 kg·m²/s

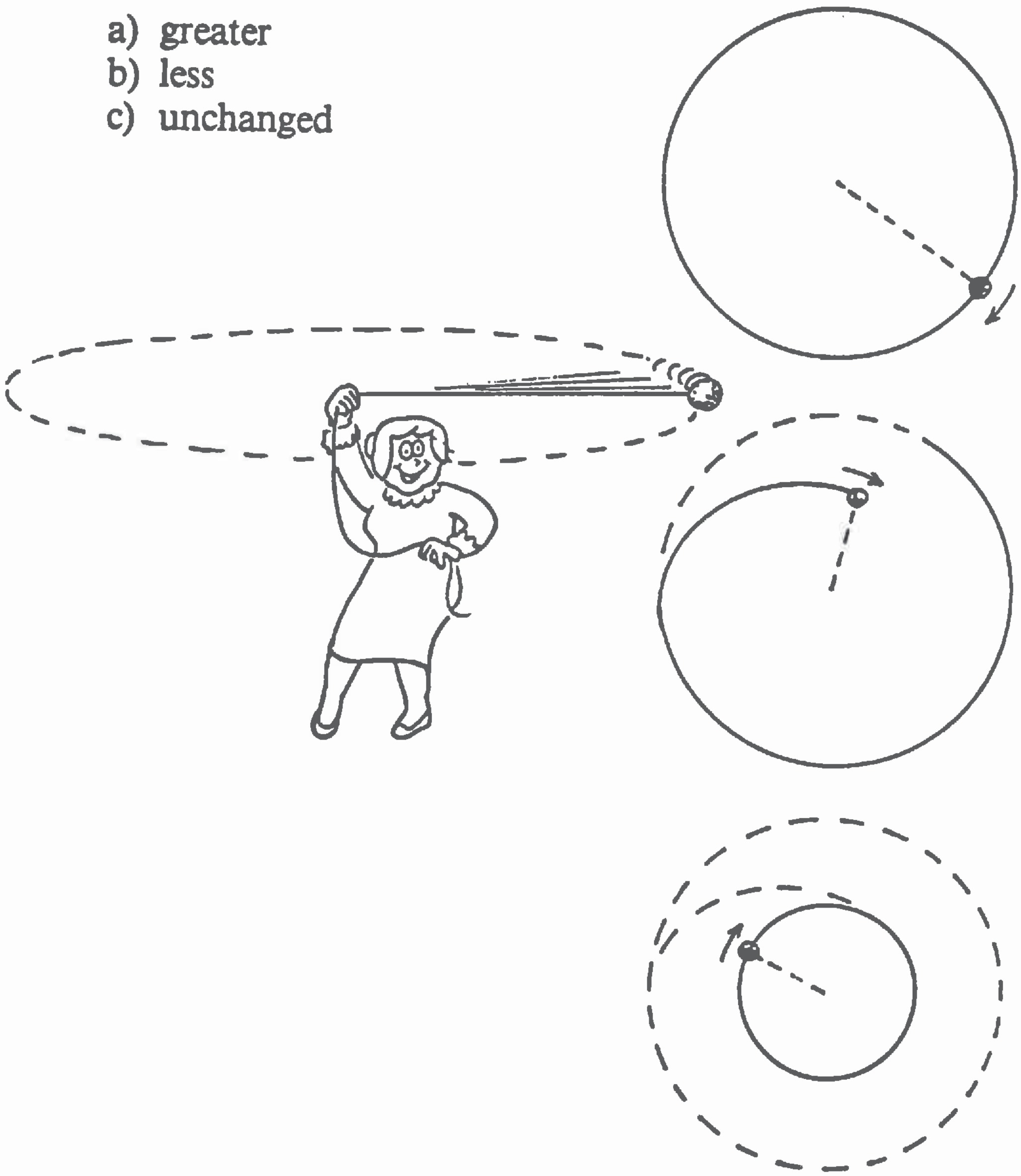


35. After the collision described above, what is the *moment of inertia* of the rotating system? a) 0.1 kg·m² b) 0.2 kg·m² c) 0.3 kg·m² d) 0.5 kg·m² e) 0.6 kg·m²

BALL ON A STRING

A ball held by a string is coasting around in a large horizontal circle. The string is then pulled in so the ball coasts in a smaller circle. When it is coasting in the smaller circle its speed is

a) greater
b) less
c) unchanged

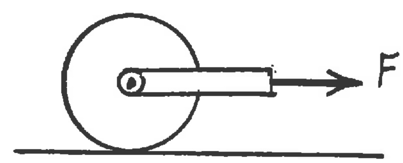


ROLLING AND ANGULAR MOMENTUM - PROBLEMS

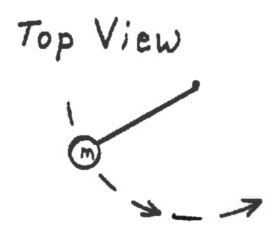
The problems below are *typical* problems associated with the concepts of rolling, rotation combined with translation, and angular momentum. For each problem, draw a relevant sketch including a force diagram if necessary, write down the principles or laws related to the motion, substitute the proper quantities, and solve.

1. A bowling ball of mass 4 kg and radius 12 cm is rolled at 2 m/s toward an incline. (a) How high in the vertical direction is the ball when it comes to rest? (b) If a small hoop of the same mass and radius is rolled at the same speed toward the incline, will it roll to the same vertical height, a lesser height, or a greater height? (c) Find the height for the hoop.

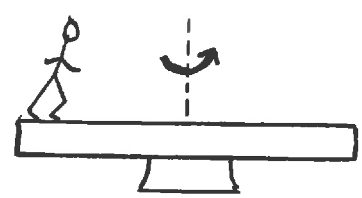
2. A constant force F is applied to a lawn roller having the form of a uniform solid cylinder of radius R and mass M. If the roller rolls without slipping on a horizontal surface, show that the *minimum* coefficient of static friction that prevents slipping is given by F/(3Mg).



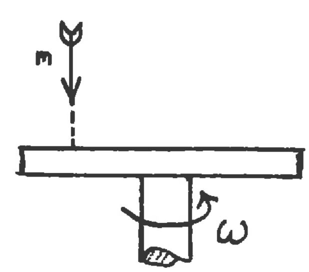
3. A 0.200 kg puck moves at the end of a 0.50 meter string in a circular path on a frictionless air table. The puck's initial tangential speed is 1.0 m/s. As the puck moves, the string is pulled inward reducing the radius of rotation. (a) What is the final *tangential speed* of the puck when the radius is 0.20 meter? (b) How much *work* was done on the puck to change its radius?



4. A large disk shaped platform of mass 120 kg and radius 5.00 meters can rotate about a center axle. A 60 kg woman stands at rest 4 meters from the center of the platform. The platform is also initially at rest. The woman starts running on the platform staying 4 m from the center and soon attains a speed of 2 m/s relative to the ground. As she runs, what is the *angular speed* of the platform?



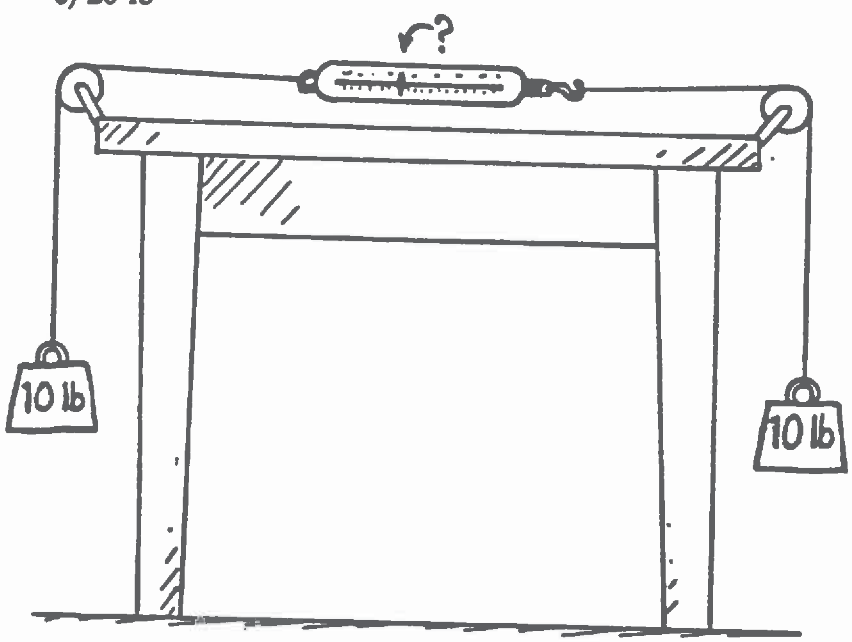
5. A wooden disk of mass 0.400 kg and radius 0.200 meters is rotating freely at 8 rad/s about an axis through its center. A dart of mass 0.120 kg is held vertically above the disk at a distance of 0.10 m from the axis of the disk and dropped. It falls and sticks into the disk. What is the final *angular speed* of the system?



STRETCH

What does the scale read?

a) 0 lb
b) 10 lb
c) 20 lb

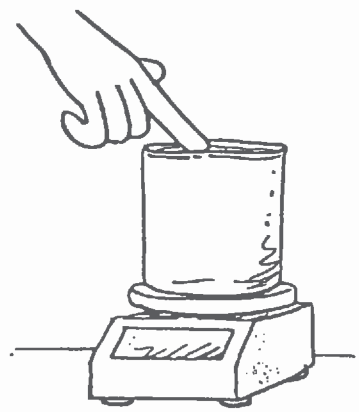


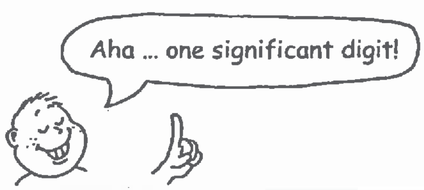
ANSWERS TO THE WORKSHEET QUESTIONS

Figuring Physics

Gently push down on the pan of the scale and the display shows an increase in force. Likewise if you do the same on the rim of the beaker. But what if you immerse your fingertip in the water, without touching the beaker? Then the scale reading

a) doesn't change.
b) shows an increase.
c) shows a decrease.





Thanx to Peter Hopkinson

ANSWERS TO THE WORKSHEET QUESTIONS

WORKSHEET 1 - AVERAGE SPEED

1. 48 mph
2. 67 mph
3. 75 mph
4. 43 mph
5. 52 mph
6. 57 mph

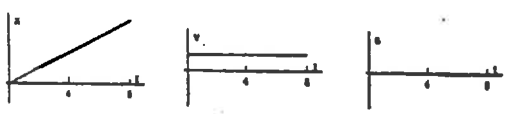
WORKSHEET 2 - GRAPHICAL ANALYSIS I - Interpretation of Graphs

1. (a) B, (b) v_A=2.5 m/s, v_B=5 m/s, (c) B, (d) 10s, each car at 55 m
2. (a) -15 m/s, (b) -45 m, (c) +25 m, (d) 1.67 s
3. (a) 5-6 s, (b) 1-3 s, (c) 40 m, 60m, (d) +20 m, (e) 20 m, (f) 16 m/s, (g) -8 m/s, (h) 0, 10 m/s
4. (a) 2-4 s, (b) 4-5 s, (c) 5 m, -20 m, (d) -45 m, (e) 55 m, (f) 15 m/s, (g) -5 m/s, (h) 5 m/s, -25 m/s
5. (a) 100 m, 300 m/s, (b) 625 m, (c) 1.5 s, 3 s, 5 s, (d) -200 m, (e) 100 m/s, (f) -37.5 m/s, (g) approx 160 m/s

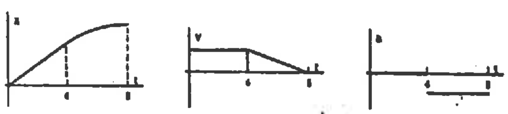
WORKSHEET 3 - GRAPHICAL ANALYSIS II - Sketching Graphs

1.

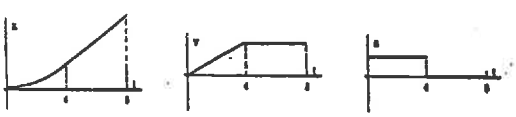
a)



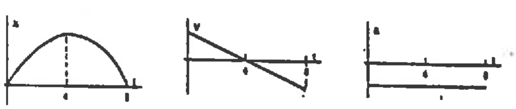
b)



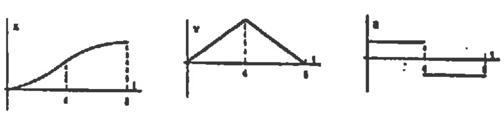
c)



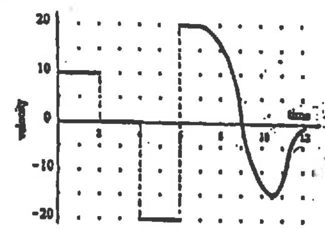
d)



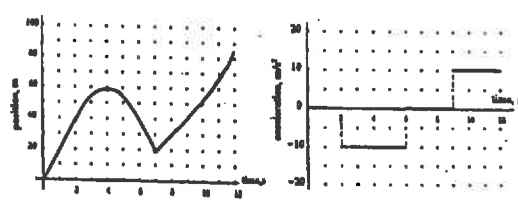
e)



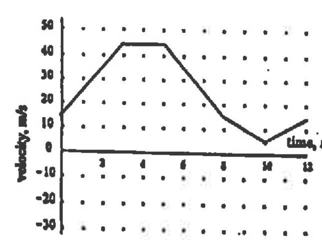
2.



3.



4.



WORKSHEET 4 -KINEMATICS - ONE DIMENSIONAL MOTION

1. e	4. e	7. e	10. b	13. e	16. a,b,d,e	19. b	22. c	25. c	28. a
2. b	5. c	8. c	11. c	14. b	17. c	20. c	23. c	26. a	29. c
3. b	6. d	9. a	12. e	15. Y,Y,Y,Y	18. a	21. a	24. b	27. c	

ANSWERS TO THE WORKSHEET QUESTIONS

WORKSHEET 5 - VECTOR ALGEBRA

1. d	3. b	5. b	7. Y,N,N,N,N,Y	9. c	11. d	13. a	15. b	17. c	19. a
2. d	4. e	6. e	8. e	10. b	12. b	14. e	16. d	18. c	

Questions. 1. 20.92 m, 126.4° 2. 28.87 N, −15.2° 3. 48.23 m/s, −140.0°, 4. 55.97 N, −134.8°

WORKSHEET 6 - KINEMATICS - TWO DIMENSIONAL MOTION

1. b	4. c	6. d	8. b	10. a	12. c	14. b	16. c	18. c	20. a	22. d
2. c	5. a	7. e	9. a	11. d	13. e	15. d	17. a	19. d	21. c	23. M at top of trajectory

3. (A) d (B) a (C) c (D) d (E) e

24. H at height of 30

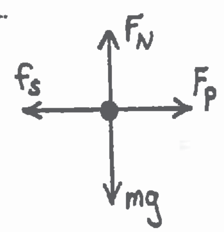
WORKSHEET 7 - NEWTON'S LAWS OF MOTION

1. a	4. d	7. c	10. d	13. a	16. b	19. b	22. d	25. d	28. c	31. a	34. c	37. d
2. c	5. b	8. a	11. a	14. a	17. a	20. a	23. e	26. c	29. b	32. a	35. e	38. c
3. e	6. c	9. e	12. c	15. b	18. c	21. c	24. b	27. b	30. b	33. d	36. e	

WORKSHEET 8 - FORCES AND FORCE DIAGRAMS

PART 1. Drawing Force Diagrams and Identifying Forces.

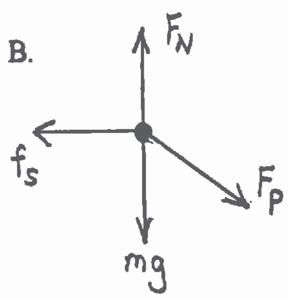
A.



1,2. F_N: force up on person due to floor, (contact, normal force)
F_p: force to right on person due to wall, (contact, normal force)
mg: force down on person due to gravity of earth, (action-at-a distance, gravitational force)
f_s: force to left on person due to floor, (contact, friction force)

3. F_N: force down on floor due to person, (reaction to normal force)
F_p: force to left on wall due to person, (reaction to normal force)
mg: force up on earth due to gravity of person, (reaction to gravitational force)
f_s: force to right on floor due to person, (reaction to friction force)

B.

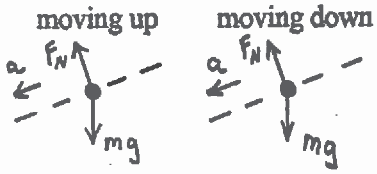


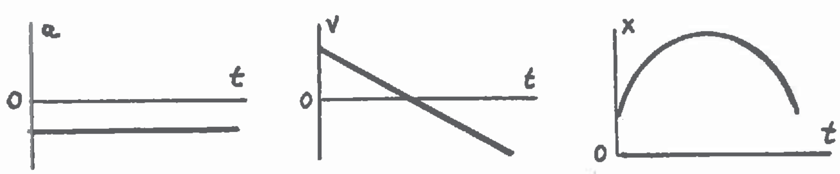
1,2. F_N: force up on ball due to floor, (contact, normal force)
F_p: force down and to the right on ball due to plank, (contact, normal force)
mg: force down on ball due to gravity of earth, (action-at-a-distance, gravitational force)
f_s: force to left on ball due to floor, (contact, friction force)

3. F_N: force down on floor due to ball, (reaction to normal force)
F_p: force up and to the left on plank due to ball, (reaction to normal force)
mg: force up on earth due to gravity of ball, (reaction to gravitational force)
f_s: force to right on floor due to ball, (reaction to friction force)

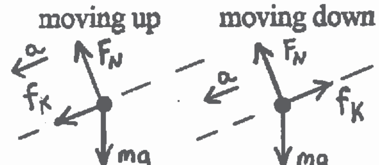
PART 2. Predicting Motion from Force Diagrams.

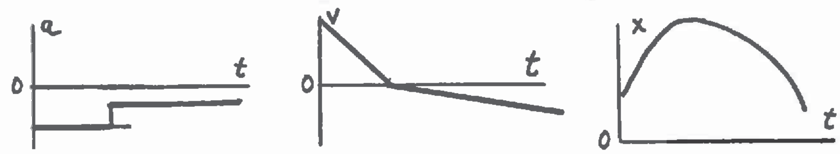
A. moving up moving down





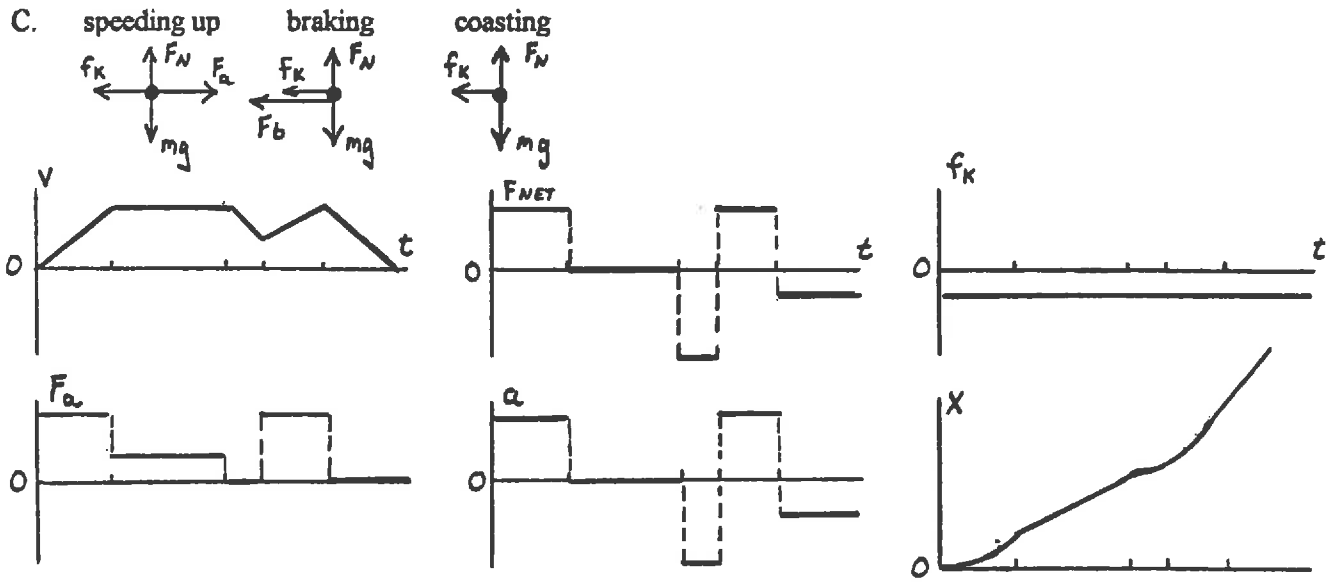
B. moving up moving down



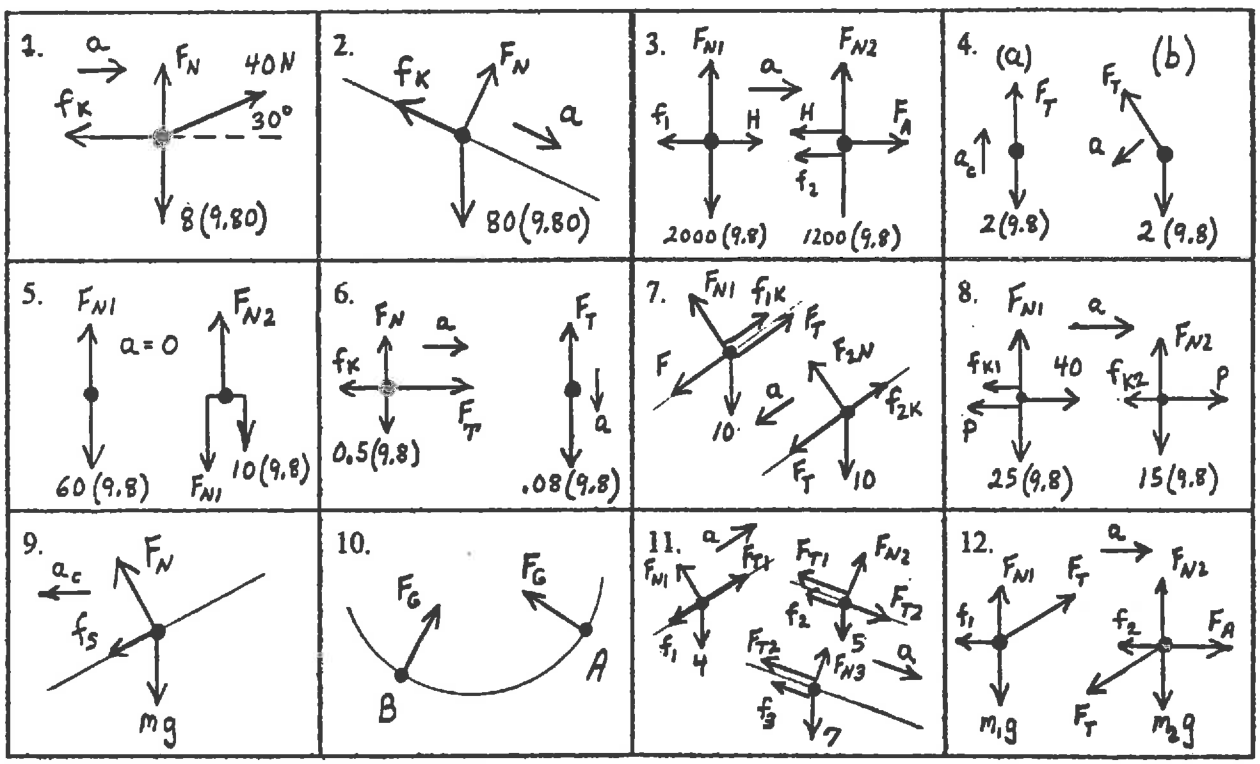


Note that the block has a larger deceleration as it moves up the incline compared to its acceleration as it moves down the incline.

C.



PART 3. Drawing Force Diagrams.

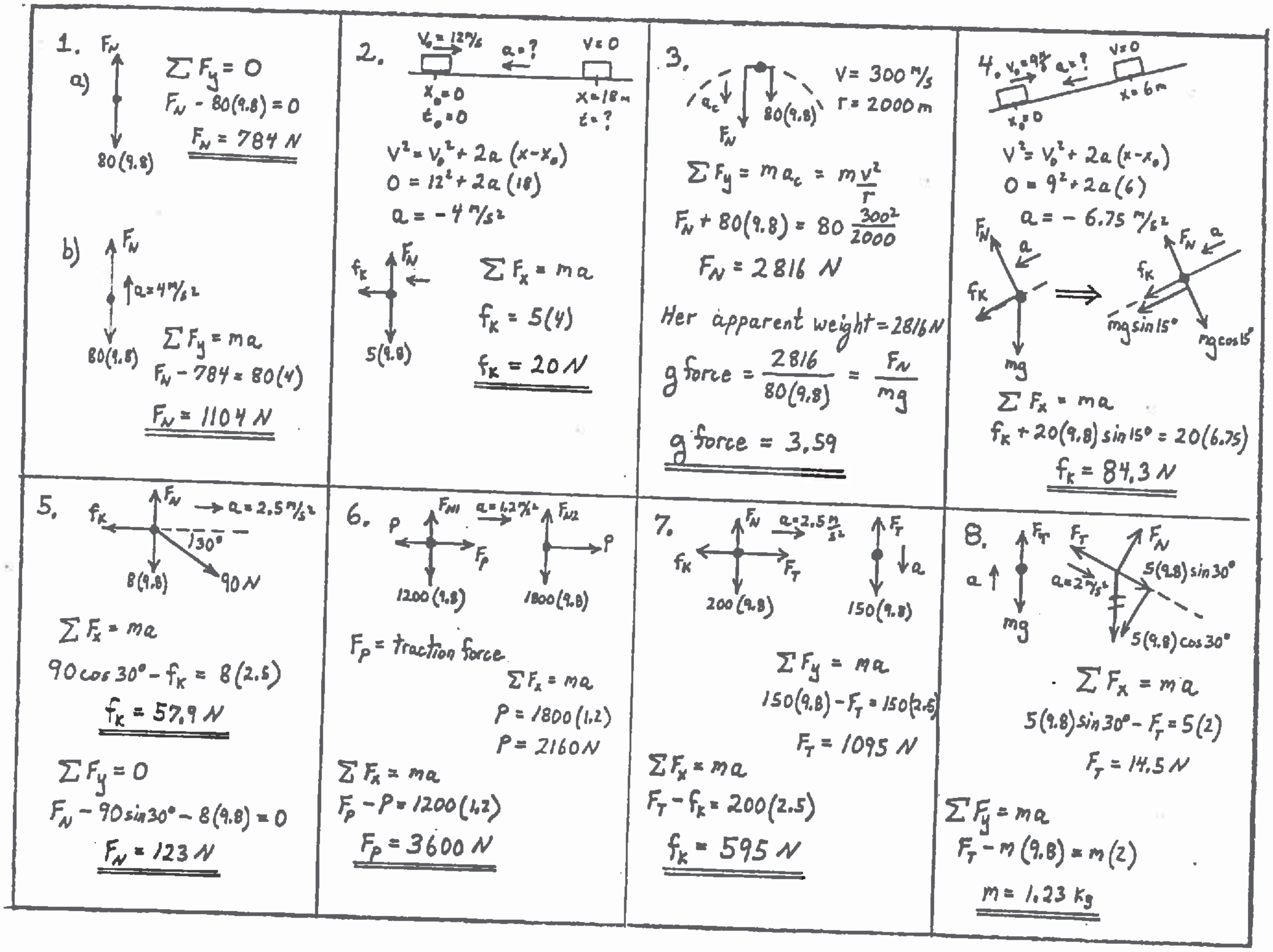


WORKSHEET 9 - CIRCULAR MOTION AND GRAVITATION

1. e	5. d	9. b	13. c	17. e	21. a	25. a	29. c	33. b	37. F,T,T,T,F,F,F	
2. b	6. d	10. b	14. d	18. b	22. c	26. c	30. a	34. d	38. c	41. a
3. d	7. a	11. a	15. b	19. c	23. d	27. c	31. b	35. c	39. b	42. b
4. e	8. a	12. b	16. b	20. d	24. b	28. b	32. c	36. d	40. a	

ANSWERS TO THE WORKSHEET QUESTIONS

WORKSHEET 10 - APPLICATIONS OF NEWTON'S SECOND LAW



WORKSHEET 11 - WORK, KINETIC ENERGY AND POWER

1. c	5. b	9. c	13. c	17. c	21. b	25. c	29. d	33. c	37. c	41. a	45. d	49. c	53. e
2. e	6. e	10. e	14. a	18. a	22. e	26. d	30. c	34. e	38. a	42. a	46. c	50. e	54. a
3. c	7. c	11. d	15. d	19. d	23. a	27. d	31. c	35. a	39. e	43. c	47. b	51. c	55. b
4. e	8. c	12. a	16. a	20. d	24. b	28. a	32. c	36. c	40. a	44. a	48. d	52. b	56. b

WORKSHEET 12 - CONSERVATION OF ENERGY

1. b	4. d	7. a	10. d	13. b	16. e	19. a	22. c	25. c	28. e	31. a	34. b	37. c	40. b
2. e	5. e	8. e	11. d	14. b	17. d	20. e	23. b	26. b	29. d	32. c	35. c	38. c	
3. c	6. c	9. b	12. c	15. b	18. b	21. c	24. a	27. c	30. d	33. a	36. d	39. c	

WORKSHEET 13 - IMPULSE, MOMENTUM AND COLLISIONS

1. b	5. c	9. b	13. a	17. b	21. a	25. c	29. c	33. a	37. c	41. b	45. e	49. d	53. b	56. b
2. c	6. c	10. a	14. a	18. a	22. a,b,c	26. b	30. c	34. a	38. c	42. b	46. e	50. d	54. e	
3. d	7. a	11. d	15. a	19. d	23. a	27. b	31. e	35. c	39. c	43. a	47. c	51. c	55. b	
4. e	8. d	12. b	16. e	20. c	24. b	28. c	32. d	36. c	40. c	44. e	48. e	52. d	56. c	

WORKSHEET 14 - ROTATIONAL KINEMATICS

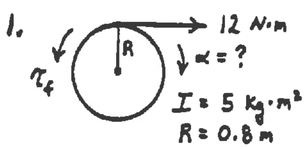
1. a	3. c	5. b	7. d	9. d	11. b	13. d	15. b	17. b	19. b	21. d	23. a
2. c	4. b	6. d	8. a	10. a	12. d	14. c	16. a	18. e	20. c	22. b	

WORKSHEET 15 - ROTATION ABOUT A FIXED AXIS

1. b	4. a	7. b	10. b	13. b	16. d	19. b	22. c	25. c	28. d	31. b	34. b	37. d	40. b	43. a
2. a	5. e	8. e	11. c	14. a	17. b	20. c	23. e	26. c	29. e	32. a	35. c	38. b	41. a	
3. e	6. a	9. a	12. d	15. c	18. a	21. b	24. a	27. a	30. c	33. d	36. d	39. a	42. a	

WORKSHEET 16 - ROTATION ABOUT A FIXED AXIS - PROBLEMS

1.



Find α.

$\omega_f = \omega_0 + \alpha t$

$4 = 0 + \alpha(8)$

$\alpha = 0.5\ rad/s^2$

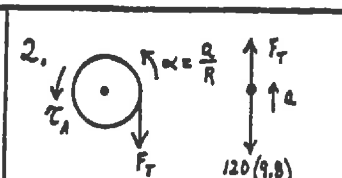
$\Sigma\tau = I\alpha$

$FR - \tau_f = 5(.5)$

$\tau_f = 12(.8) - 2.5$

$\tau_f = 7.1\ N\cdot m$

2.



$I = \frac{1}{2}MR^2 = \frac{40}{2}(.12)^2 = 0.288\ kg\cdot m^2$

$\Sigma F_y = ma$

$F_T - 120(9.8) = 120(1.5)$

$F_T = 1356\ N$

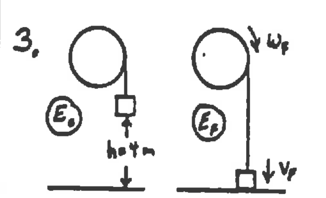
$\Sigma\tau = I\alpha$

$\tau_A - F_T R = I\alpha$

$\tau_A = (0.288)\frac{1.5}{.12} + 1356(.12)$

$\tau_A = 166.3\ N\cdot m$

3.



Find v_f.

$y = y_0 + v_0 t + \frac{1}{2}at^2$

$4 = 0 + \frac{1}{2}a(4)^2 \quad a = 0.5\ m/s^2$

$v_f = v_0 + at = 0 + (0.5)(4)$

$v_f = 2\ m/s \qquad \omega = \frac{v}{R}$

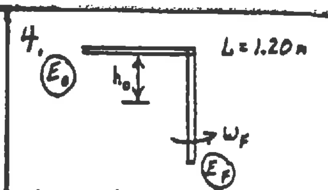
$E_0 = E_f$

$mgh_0 = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

$3(9.8)4 = \frac{3}{2}(2)^2 + \frac{I}{2}\left(\frac{2}{.12}\right)^2$

$I = 2.23\ kg\cdot m^2$

4.



h_0 = initial height of cm

$E_0 = E_f$

$mgh_0 = \frac{1}{2}I\omega^2$

(a) $m(9.8)(0.60) = \frac{1}{2}\left[\frac{1}{3}m\,1.2^2\right]\omega^2$

$\omega = 4.95\ rad/s$

(b) $v_T = r\omega = (1.2)4.95$

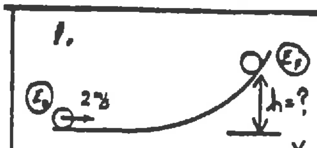
$v_T = 5.94\ m/s$

WORKSHEET 17 - ROLLING AND ANGULAR MOMENTUM

1. b	4. e	7. a	10. b	13. c	16. c	19. d	22. b	25. d	28. b	31. d	34. b
2. d	5. b	8. c	11. e	14. a	17. d	20. a	23. a	26. a	29. c	32. c	35. c
3. c	6. b	9. b	12. c	15. a	18. b	21. e	24. a	27. d	30. a	33. a	

WORKSHEET 18- ROLLING AND ANGULAR MOMENTUM- PROBLEMS

1.



(a) $E_0 = E_f \qquad \omega = \frac{v}{R}$

$\frac{1}{2}mv_0^2 + \frac{1}{2}I\omega_0^2 = mgh_f$

$\frac{7}{10}v_0^2 = gh_f$

$h_f = 0.286\ m$

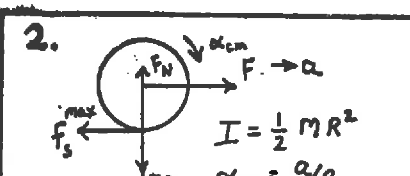
(b) Rolling hoop has more energy and will go higher.

(c) $\frac{1}{2}mv_0^2 + \frac{1}{2}I\omega_0^2 = mgh_f$

$v_0^2 = gh_f$

$h_f = 0.408\ m$

2.



$I = \frac{1}{2}MR^2$

$\alpha_{cm} = a/R$

$\Sigma F_x = ma \qquad \Sigma\tau_{cm} = I\alpha_{cm}$

$F - f_s^{max} = Ma \qquad f_s^{max}R = I\frac{a}{R}$

$\Sigma F_y = 0 \Rightarrow F_N = mg$

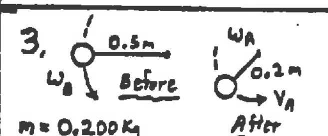
$f_s^{max}R = \frac{1}{2}MR^2 a$

$a = \frac{2f_s^{max}}{M}$

$F - f_s^{max} = 2f_s^{max}$

$\Rightarrow f_s^{max} = \frac{F}{3} \qquad \mu_s = \frac{f_s^{max}}{F_N} = \frac{F}{3mg}$

3.



$m = 0.200\ kg$

$v_B = 1\ m/s \qquad \omega = \frac{v}{r}$

(a) $L_A = L_B$

$I_A\omega_A = I_B\omega_B$

$m(.2)^2\frac{v_A}{.2} = m(.5)^2\frac{v_B}{.5}$

$v_A = 2.5\ m/s$

(b) $W = \Delta K = \frac{1}{2}mv_A^2 - \frac{1}{2}mv_B^2$

$= \frac{1}{2}(.2)\left[2.5^2 - 1^2\right]$

$W = 0.525\ J$

WORKSHEET 18 - ROLLING AND ANGULAR MOMENTUM, continued

4. Before $L_B = 0$

After (Top View) I, $2\ m/s$

$\Sigma L_A = \Sigma L_B \qquad \omega = \frac{v}{R}$

$(I\omega)_{woman} - (I\omega)_{DISK} = 0$

$[mR^2]\frac{2}{R} - [\frac{1}{2}(120)5^2]\omega = 0$

$60(4)(2) - 1500\,\omega = 0$

$\omega = 0.320\ \frac{rad}{s}$

5. Before $\omega_B = 8\ \frac{rad}{s}$

After $\omega_A = ?$

$\Sigma L_A = \Sigma L_B$

$[I_{DISK} + I_{Arrow}]\omega_A = I_{DISK}\,\omega_B$

$I_{DISK} = \frac{1}{2}(.4)(.2)^2 = .008\ kg{\cdot}m^2$

$I_{Arrow} = (.120)(.1)^2 = .0012$

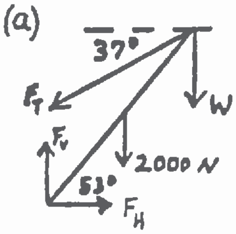
$[.008 + .0012]\omega_A = .008(8)$

$\omega_A = 6.96\ \frac{rad}{s}$

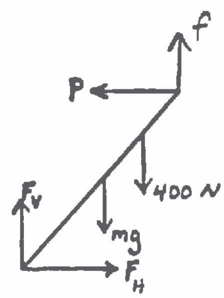
WORKSHEET 19 - EQUILIBRIUM

1. b	4. a	7. c	10. c	12. → (a)
2. c	5. c	8. a	11. b	13. a
3. c	6. a	9. d		14. d

(a)

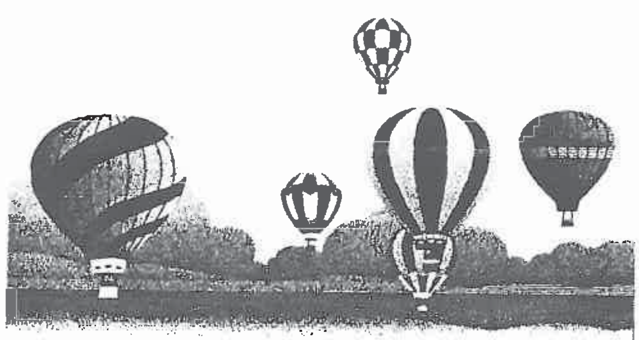


(b)



ANSWERS TO THE REVIEW EXAM, Part II, p. 59

1. c	9. b	17. b	25. d	33. b	41. e	49. c	57. d	65. b	74. c	82. c
2. d	10. b	18. e	26. a	34. a	42. b	50. a	58. d	66. a	75. a	83. a
3. b	11. b	19. a	27. a	35. a	43. c	51. e	59. b	67. c	76. b	84. d
4. c	12. b	20. a	28. d	36. c	44. d	52. e	60. c	68. b	77. a	85. d
5. d	13. c	21. d	29. a	37. c	45. d	53. c	61. a	70. c	78. d	86. b
6. b	14. a	22. b	30. c	38. e	46. e	54. c	62. c	71. a	79. d	
7. a	15. c	23. a	31. a	39. c	47. d	55. c	63. c	72. e	80. c	
8. d	16. d	24. c	32. a	40. a	48. d	56. d	64. c	73. e	81. c	

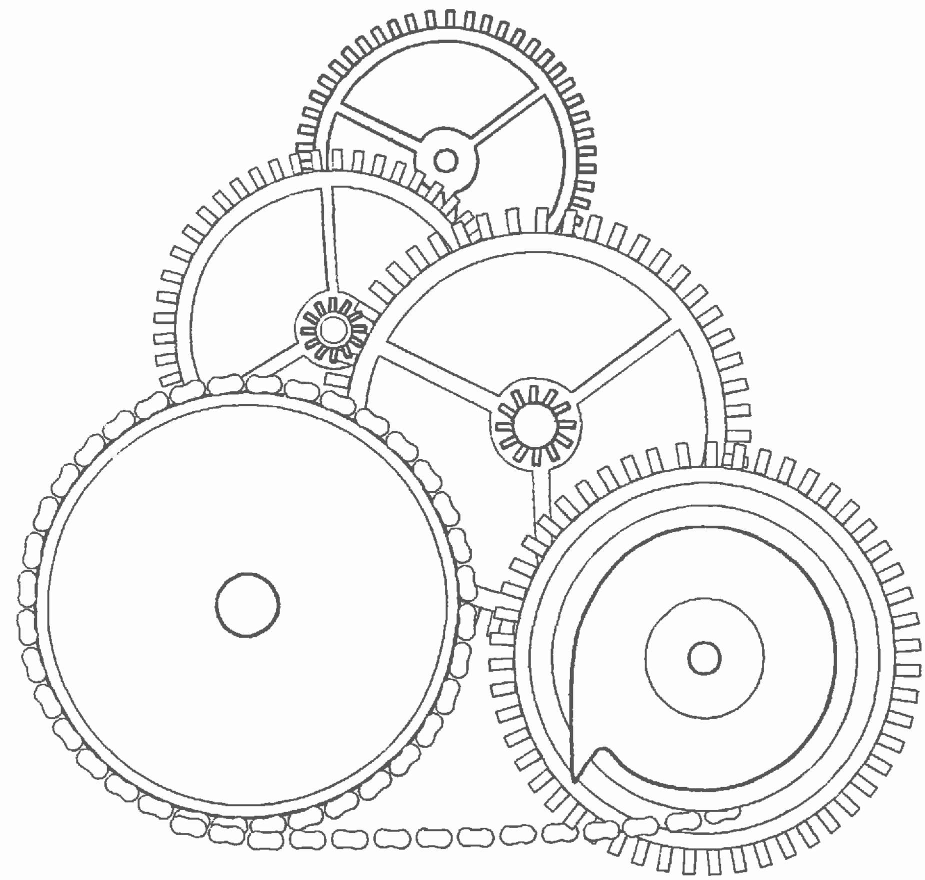


REVIEW PROBLEMS FROM

GEORGIA TECH

This section of your workbook contains review problems in mechanics taken from physics exams given to engineering students at Georgia Tech. These problems were written to accompany the Serway textbook, *PHYSICS For Scientists and Engineers*. The problems were originally written in the form of multiple choice questions, but are presented here as problem statements with the correct answer in parenthesis. Read each problem, draw a sketch, determine the known and unknown quantities, review your basic physics knowledge, select a starting point, and solve.

In square brackets [ ] just after each problem number is a numerical value which represents the fraction of answers that were correctly chosen when that question was used on an exam. Thus, a value of [0.8] indicates that 80% of those taking the exam obtained a correct answer.



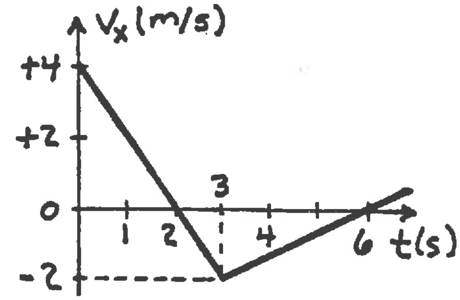
KINEMATICS AND VECTORS

1. [0.9] A bullet is fired through a board, 0.14 m thick, with its line of motion perpendicular to the face of the board. If it enters with a speed of 450 m/s and emerges with a speed of 220 m/s, what is the *magnitude* of the bullet's acceleration as it passes through the board? (-550×10^3 m/s^2)

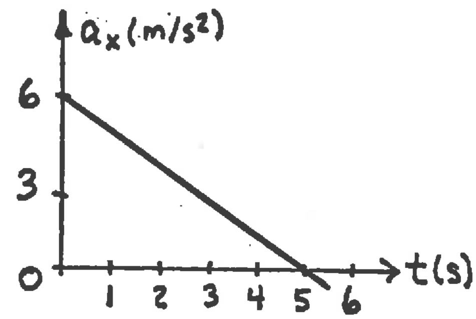
2. [0.4] The position of a particle moving along the x-axis is given by $x(t) = 6t^2 - t^3$, where x is in meters and t is in seconds. What is the position of the particle when it achieves its maximum speed in the *positive* x direction? (16 m)

3. [0.7] The position of a particle moving along the x-axis is given by $x(t) = 4t + 6t^2 - t^3$, where x is in meters and t is in seconds. What is the *maximum* speed of the particle during the time interval $0 < t < 4$ seconds? (16 m/s)

4. [0.5] The velocity of a particle moving along the x-axis is shown in the plot at the right. If x = 2.0 m when t = 1.0 s, what is the *position* of the particle at t = 6 s? (-1.0 m)



5. [0.5] The initial position and velocity of a particle is $x_o = 25$ m and $v_o = +15$ m/s, respectively. The acceleration varies with time as shown in the plot at the right. What is the *velocity* of the particle at t = 5.0 s? (+30 m/s)



6. [0.8] A particle, moving with constant acceleration, has a velocity of 20 m/s when its position is x = 10 m. If its position 7.0 seconds later is x = -30 m, what is the acceleration of the particle? (-7.3 m/s^2)

7. [0.5] An object is thrown vertically upward with an unknown velocity. When it reaches one-fourth of its maximum height above its launch point, its velocity is 18 m/s. What was its initial velocity? (21 m/s)

8. [0.7] A rock is thrown straight downward from the top of a building with an initial speed of 10 m/s. If it strikes the ground 3 seconds later, find the height of the building. (74 m)

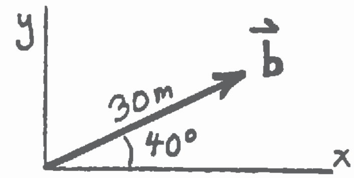
9. [0.8] At t = 0, a particle starts from the origin with an initial velocity of $\mathbf{v}_o = 8.0\,\mathbf{j}$ m/s. It moves in the xy plane with the constant acceleration $\mathbf{a} = 4.0\,\mathbf{i} + 2.0\,\mathbf{j}$ m/s^2. At the instant the x coordinate of the particle is x = 29 m, what is the value of its y coordinate? (45 m)

10. [0.6] The initial velocity of a particle is $\mathbf{v}_o = 6.0\,\mathbf{i}$ m/s. It moves in the xy plane with the constant acceleration $\mathbf{a} = -2.0\,\mathbf{i} + 4.0\,\mathbf{j}$ m/s^2. At the instant the particle achieves its *maximum positive* x coordinate, how far is it from the origin? (20 m)

11. [0.8] A stone is thrown with an initial velocity of 30 m/s in the *horizontal* direction from the top of a building 30 meters high. How fast is the stone moving just before it hits the ground? (39 m/s)

12. [0.9] A rifle is aimed horizontally at a small target nailed to the truck of a tree 60 meters away. If the initial speed of the bullet is 240 m/s, how far below the center of the target does the bullet hit the tree trunk? (0.31 m)

13. [0.8] If **a** = 24 m @ 160°, and **b** is as shown, what is the *magnitude* of 2 **a** + **b**? (42 m)



14. [0.8] If vector **B** is added to vector **A**, the resultant is 6 **i** + **j**. If **B** is subtracted from **A**, the resultant is −4 **i** + 7 **j**. What is the magnitude of **A**? (4.1)

15. [0.5] A vector **A** is added to **B** = 6 **i** − 8 **j**. The resultant vector is directed along the positive x-axis and has a magnitude equal to **A**. What is the magnitude of **A**? (8.3)

ACCELERATION AT THE TOP

A stone is thrown straight upward and at the tippity top of its path its velocity is momentarily zero. What is its acceleration at this point?

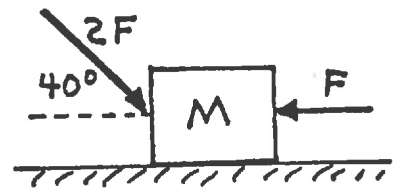
a) Zero
b) 32 ft/s²
c) Greater than zero, but less than 32 ft/s²

APPLICATIONS OF THE SECOND LAW

Note: These problems do not include examples of circular motion. Circular motion problems are included in the next Georgia Tech Problems section.

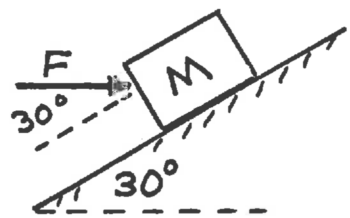
1. [0.7] At an instant when the acceleration of a 4.0 kg object is given by **a** = 5 **i** + 3 **j** m/s², one of the two forces acting on the object is known to be $\mathbf{F}_1$ = 12 **i** + 22 **j** N. What is the magnitude of the other force? (13 N)

2. [0.9] Shown at the right, the horizontal surface under a block of mass M = 3.0 kg is frictionless. If F = 30 N, find the horizontal acceleration of the block. (5.3 m/s²)



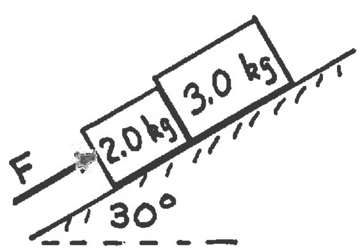
3. [0.6] Two forces, one of magnitude 3.0 N and the other with magnitude 4.0 N are the only forces acting on a 2.0 kg object. If the acceleration of the object has a magnitude of 3.0 m/s², what is the angle between the two forces? (63°)

4. [0.8] A block of mass M = 3.0 kg is pushed up a frictionless incline by a *horizontally* applied force of 25 N as shown at the right. Determine the acceleration of the block up the incline. (2.3 m/s²)

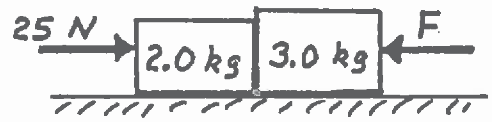


5. [0.8] A 5,0 kg mass is suspended by a string from the ceiling of an elevator that is moving *upward*, but is *slowing down* at a rate of 2.0 m/s². Determine the tension that acts within the string. (39 N)

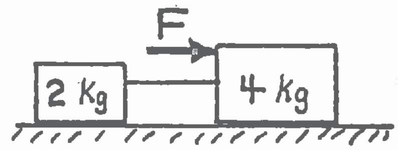
6. [0.4] Assume that the surface of the incline shown at the right is frictionless. If F is 30 N, find the magnitude of the force exerted *on* the 3.0 kg block *by* the 2.0 kg block. (18 N)



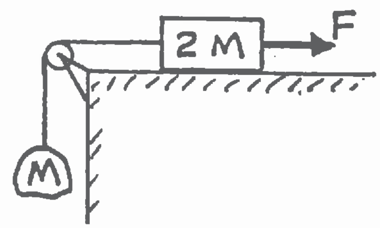
7. [0.4] As shown at the right, if F = 5.0 N, determine the magnitude of the force exerted on the 2.0 kg block by the 3.0 kg block. Assume the surface is frictionless. (17 N)



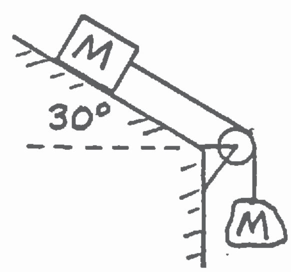
8. [0.8] Two blocks, sliding on a frictionless surface, are connected together by a string as shown at the right. When force F pushes on the 4 kg block, the tension in the connecting string is 3.0 N. Determine the magnitude of force F. (9.0 N)



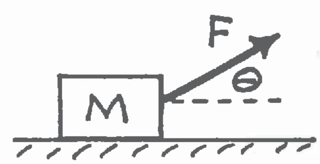
9. [0.4] Two masses are connected together by a string as shown at the right. Determine the tension in the string if force F = 40 N and M = 1.5 kg. Assume the horizontal surface is frictionless. (23 N)



10. [0.6] Two masses are connected together by a string as shown at the right. Determine the tension in the string if M = 2.2 kg. Assume the surface is frictionless. (5.4 N)

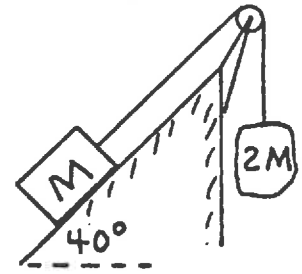


11. [0.5] A block of M = 5 kg is pulled across a *rough* surface by force F = 14 N acting 35° above the horizontal as shown at the right. If the speed of the block is *constant*, determine the coefficient of kinetic friction between the block and the surface. (0.28)

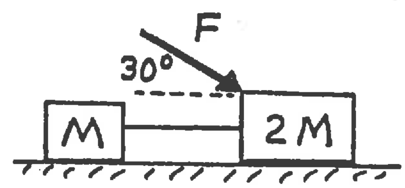


12. [0.9] A 4.0 kg block is pushed up a rough inclined surface at *constant speed* by a force of magnitude 31 N applied parallel to the surface. If the incline makes an angle of 36° with respect to the horizontal, what magnitude of applied force would lower the block down the incline with a constant speed? (15 N)

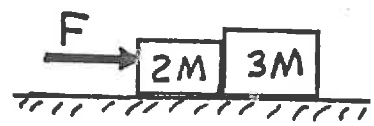
13. [0.6] The coefficient of kinetic friction between the block and the incline is 0.40. Determine the acceleration of the suspended block, 2M, as it falls. (3.4 m/s^2)



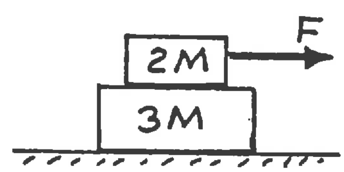
14. [0.7] Two blocks connected by a string are pushed across a *rough* horizontal surface by an applied force F = 20 N as show at the right. The coefficient of kinetic friction between the blocks and the surface is 0.20. If M = 1.5 kg, what is the tension in the connecting string? (5.1 N)

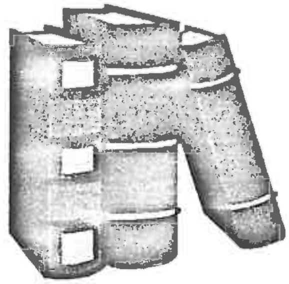


15. [0.9] The coefficient of kinetic friction between the larger block 3M and the surface is 0.25 and the coefficient of kinetic friction between the smaller block 2M and the surface is 0.40. A force F = 22 N is applied to the smaller block as shown at the right. If M = 1.0 kg, what is the magnitude of the acceleration of the system? (1.4 m/s^2)



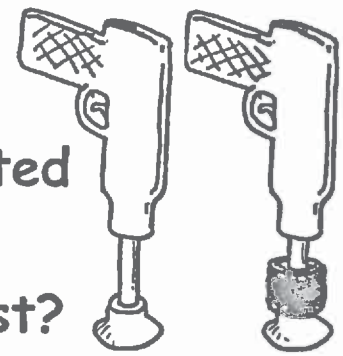
16. [0.5] A smaller block is placed on top of a larger block and the system is accelerated to the right across a horizontal *frictionless surface* by force F = 1.2 N as shown at the right. If M = 1.0 kg, determine the force of friction that acts on the lower block due to the upper block. (0.72 N)





FIGURING PHYSICS

Two identical spring-loaded dart guns are simultaneously fired straight downward. One fires a regular dart; the other a weighted dart.



Which dart hits the ground first?

a) The regular dart.
b) The weighted dart.
c) It's a tie.

Thanx to Dean Baird

Hewitt Drew it!

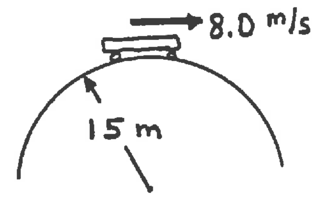
CIRCULAR MOTION AND GRAVITATION

1. [0.8] A 4.0 kg mass on the end of a string rotates in circular motion on a *horizontal* frictionless table. If the mass is moving with a constant speed of 2.0 m/s along the arc of a circle of radius 0.80 meters, determine the magnitude of the *resultant force* that acts on the mass. (20 N)

2. [0.4] A highway curve has a radius of 140 meters and is unbanked. A car of weight 12,000 N goes around the curve with a constant speed of 24 m/s without slipping. Determine the magnitude of the force on the car due to the road.. (13,000 N)

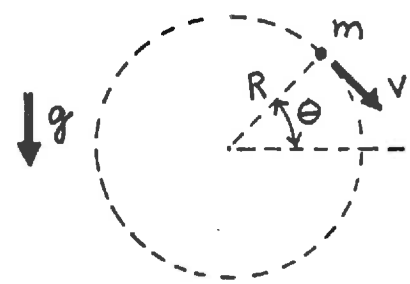
3. [0.8] A rock, attached to a string, swings in a *vertical* circle. At the *highest point* of its motion, (circle the correct answer) (a)
   a) two forces act on the rock and their resultant is *not* zero.
   b) only one force acts on the rock.
   c) two forces act on the rock and their resultant *is* zero.
   d) three forces act on the rock.

4. [0.6] A roller-coaster car has a mass of 500 kg when fully loaded with passengers. The car passes over a hill of radius 15 m as shown. If the car has a speed of 8.00 m/s at the *top* of the hill, what is the magnitude of the force that acts on the car due to the track (2800 N upward)



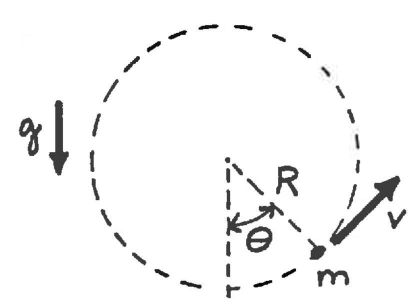
5. [0.5] An amusement ride consists of a car moving in a *vertical* circle on the end of a rigid boom of radius10 meters. The speed of the car on its circular path is 4.00 m/s. If the combined weight of the car and riders is 8000 N, what force acts on the boom due to the car when the car is at the *bottom* of the circle? (9300 N downward)

6. [[0.5] An object of mass m, attached to the end of a string, is whirled in a *vertical* circle of radius 1.20 meters as shown. At the instant when angle $\theta = 30°$, the speed of the object is 5.00 m/s and the tension in the string is 20 N. Determine the mass of the object. (1.30 kg)

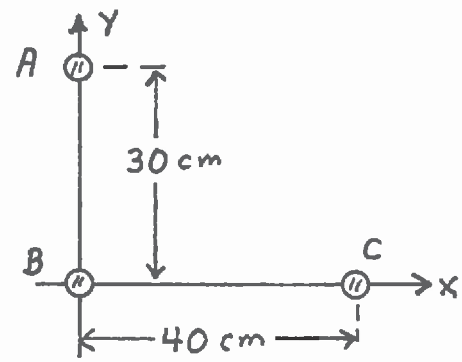


7. [0.7] A 0.500 kg mass, attached to the end of a string, moves in a *vertical* circle of radius 2.00 m. When the string is horizontal, the speed of the mass is 8.00 m/s. Determine the magnitude of the force on the mass due to the string at this position. (16 N)

8. [0.4] A 0.300 kg mass, attached to the end of a string of radius 1.6 meters, moves in a vertical circle as shown. At the instant when $\theta = 50°$, the tension in the string is 8.0 N. Find the magnitude of the *resultant force* that acts on the mass at this instant. (6.5 N)



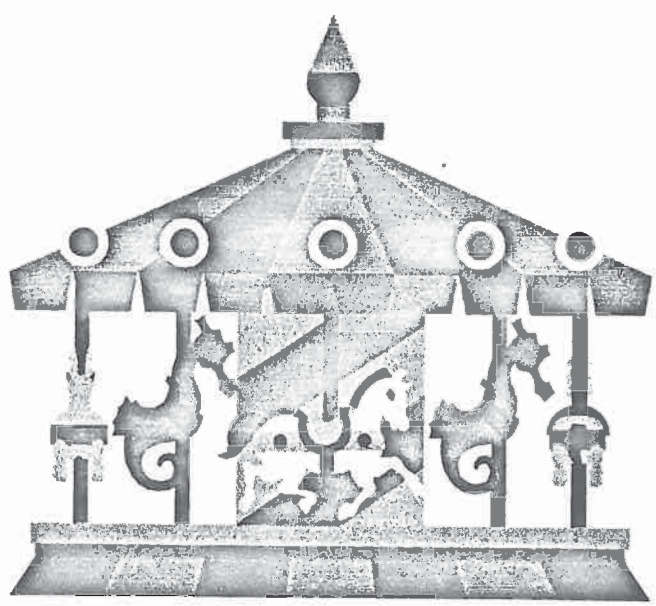
9. [0.8] Three 5.00 kg masses are located at points in the xy plane as shown. What is the magnitude of the resultant force on mass C? (1.60×10^{-8} N)



10. [0.8] The period of a satellite circling planet Nutron is observed to be 84 seconds when it is in a circular orbit of radius 8.00×10^{6} meters. Determine the mass of planet Nutron. (4.30×10^{28} kg)

11. [0.4] A satellite circles planet Roton every 2.8 hours (10,800 s) in an orbit of radius 1.20×10^{7} meters. If the radius of Roton is 5.00×10^{6} meters, determine the magnitude of the acceleration due to gravity on Roton. (27 m/s^2)

12. [0.5] Two stars of masses M and 6M are separated by distance D. Determine the distance, as measured from the star of mass M, to the point where the net gravitational force on a third mass would be *zero*. (0.290 D)



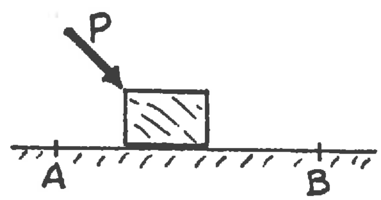
WORK, KINETIC ENERGY AND POWER

1. [0.9] A constant force of +12 **i** N acts on a 4.0 kg object as the object moves from the origin to the position 6 **i** - 8 **j** m. Determine the work done on the object by the force during this displacement. (+72 J)

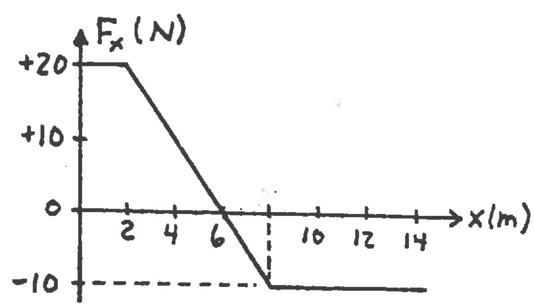
2. [0.7] A 2.0 kg particle has an initial velocity of 5 **i** -4 **j** m/s. Some time later its velocity is 7 **i** + 3 **j** m/s. How much work was done on the particle during this time? (+17 J)

3. [0.8] A projectile of mass 2.0 kg moves from its initial position to a position that is 20 m to the right and 15 meters above its initial position. How much work was done on the mass by the force of gravity during this motion? (-290 J)

4. [0.5] A block is pushed 0.50 meters across a *rough* horizontal surface from point A to point B by force **P** as shown in the figure at the right. The magnitude of force **P** is 5.4 N and the magnitude of the force of friction is 1.2 N. If the kinetic energy of the block is 4.0 J at position A and 5.6 J at position B, determine the work done on the block by force **P**. (2.2 J)



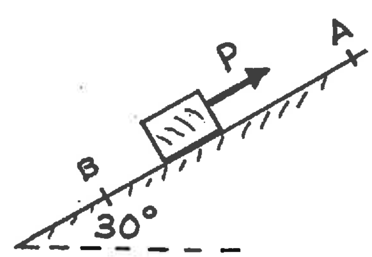
5. [0.8} The magnitude/position plot for a variable force is shown at the right. Determine the work done on an object by this force as the object moves from x = 2 to x = 8 m. (+30 J)



6. [0.9] The force acting on an object moving along the x-axis is given by $F_x = 3x^2 - 16x$ N where x is in meters. What work on the object is done by this force as the object moves from x = -2 to x = 1 m? (+ 33 J)

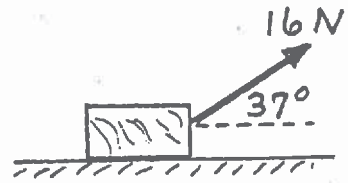
7. [0.7] A constant force of 4 **i** - 3 **j** N acts on a 2.0 kg object as the object moves from 2 **i** + 5 **j** to 6 **i** - 2 **j** m. If the *speed* of the object at its initial position is 4.0 m/s, determine the kinetic energy of the object at its final position. (53 J)

8. [0.7] A 2.0 kg block slides 2.0 meters down a frictionless incline from point A to point B as shown at the right. A force **P** of magnitude 3.0 N, acts on the block as shown during this motion. If the kinetic energy of the block is 10 J at point A, determine its kinetic energy at point B. (24 J)

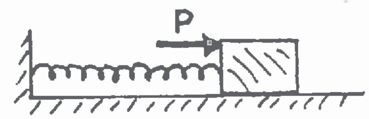


Georgia Tech Problems

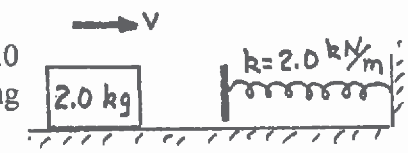
9. [0.7] A constant force of 16 N acting at an angle of 37° above the horizontal pulls a 3.0 kg block through a distance of 5.0 meters over a *rough* surface as shown at the right. If the speed of the block increases from 4.0 to 6.0 m/s, determine the work done on the block by the force of friction. (−34 J)



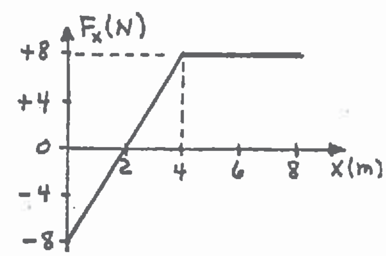
10. [0.6] A 10 kg block is connected to a spring of constant 1200 N/m and sits at rest on a frictionless surface at the equilibrium position of the spring. A force **P** is applied to the block as shown in the figure at the right. If the speed of the block is 0.80 m/s when its position is 0.08 meters from the equilibrium position of the spring, determine the work done on the block by force **P** during this displacement. (7.0 J)



11. [0.6] A 2.0 kg block, sliding to the right over a frictionless surface at 6.0 m/s, hits a spring as shown at the right. How fast is the block moving when the spring has been compressed 0.15 m? (3.7 m/s)



12. [0.7] The magnitude/position plot for a variable force that acts on a 1.60 kg object is shown at the right. If the speed of the object at x = 2.0 m is 5.0 m/s, what is the kinetic energy of the object at x = 5.0 m? (36 J)



13. [0.5] A 10 kg block sitting on a *rough* surface is connected to a spring of constant 1400 N/m. The block is pulled 0.08 m to the right from the equilibrium position of the spring and released from rest. If the force of friction between the block and surface has a magnitude of 30 N, determine the kinetic energy of the block as it passes back through the equilibrium position. (2.1 J)

14. [0.8] The resultant force acting on a 2.0 kg object is given by the expression $F_x = 3x^2 + 2x$ N where x is in meters. Determine the change in kinetic energy of the object as it moves from x = 1.0 to x = 3.0 m. (34 J)

15. [0.9] The resultant force acting on a 2.0 kg object is given by the expression $F_x = 4x$ N where x is in meters. If the kinetic energy of the object is 20 J at x = 2.0 m, what is its kinetic energy at x = 3.0 m? (30 J)

16. A 6.0 kg block slides along a *rough* horizontal surface where the coefficient of kinetic friction is 0.20. Determine the rate the *force of friction* does work on the block (i.e. the power dissipated) at the instant the speed of the bock is 4.0 m/s. (−47 W)

17. [0.7] A 2.0 kg block is pushed up a *rough* inclined surface at a *constant* speed of 1.1 m/s by an applied force of magnitude 12 N acting parallel to the inclined surface. If the surface is inclined at 20° above the horizontal, determine the rate the *force of friction* is doing work on the block. (−5.8 W)

CONSERVATION OF MECHANICAL ENERGY

1. [0.7] A 1.50 kg mass is pulled along the x-axis by a single conservative force given by the expression $F(x) = 6\ x^2$ N where x is in meters. At x = 0 its speed is 4.0 m/s and the potential energy associated with the force is +30 J. Find the potential energy at x = 2.0 meters. (14 J)

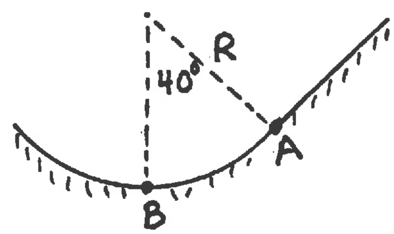
2. [0.5] A single conservative force, F(x) = (6 x − 12) N, pushes a particle along the x-axis. The potential energy associated with this force at x = 0 is +20 J. Find the potential energy at the position x = 3.0 m. (+29 J)

3. [0.9] A 0.60 kg object is suspended from the ceiling at the end of a 2.0 meters long string. When the object is placed in motion, swinging back and forth, its speed at the lowest point in its motion is 4.0 m/s. Determine the *maximum* angle the string makes with the vertical during its swing. (54°)

4. [0.8] A simple pendulum consists of a 1.5 kg mass swinging at the end of a string of length 2.0 m. At the lowest point in its swing, the tension in the string is equal to 20 N. To what maximum height (measured vertically) above this lowest point does the mass rise? (0.36 m)

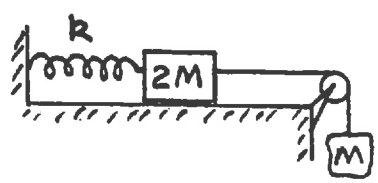
5. [0.8] A 2.0 kg mass is projected from the top of a 20 meter tall building with an initial speed of 24 m/s at an unknown angle above the horizontal. What kinetic energy does the mass have just before it strikes the ground? (970 J)

6. [0.8] A skier of weight 800 N comes down a frictionless ski run that has a circular path of radius R = 30 m at the bottom as shown at the right. If the speed of the skier is 12 m/s at point A, what is her speed at point B, the bottom of the hill? (17 m/s)



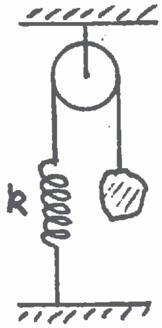
7. [0.8] A spring with spring constant k = 200 N/m is suspended from its upper end. A 2.0 kg object is attached to the lower end of the spring and the object is released from rest. Find the speed of the object after it has fallen 0.04 meters. (0.79 m/s)

8. [0.6] The blocks shown at the right are released from rest with the spring *unstretched*. The horizontal surface is frictionless. If k = 400 N/m and M = 4.5 kg, determine the maximum extension of the spring. (0.22 m)



9. [0.7] A spring of constant k = 1600 M/m is at the bottom of the frictionless plane that makes an angle of 30 ° with the horizontal. A 4.0 kg block is placed against the upper end of the spring, the spring is compressed 0.12 m, and the mass released from rest. How far along the incline will the mass slide before coming momentarily to rest? (0.59 m)

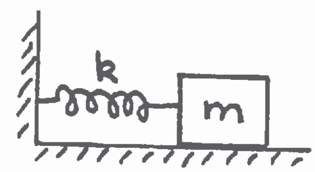
10. [0.6] A 20 kg mass is attached over a frictionless pulley to a light spring of constant 380 N/m as shown at the right. The mass is released from rest when the spring is *unstretched*. What is the speed of the mass after it has fallen 0.40 meters? (2.2 m/s)



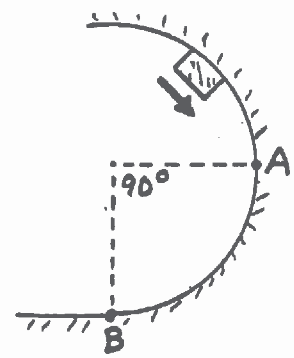
11. [0.9] A 0.75 kg object, released from rest, falls in a *viscous* medium and is moving at 5.0 m/s after falling 2.0 meters. How much work was done on the object during this fall? (−5.3 J)

12. [0.8] During a given displacement of a particle, its kinetic energy increases by 25 J while its potential energy decreases by 10 J. Determine the work done by *non-conservative* forces acting on the particle during this displacement. (+15 J)

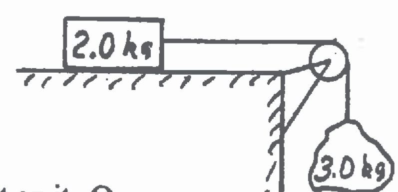
13. [0.7] A block of mass 0.50 kg, connected to a spring of constant 50 N/m, is pulled 0.10 m from the equilibrium position of the spring and released from rest. If the coefficient of kinetic friction between the block and the surface is 0.25, find the speed of the block when it next passes through the equilibrium position of the spring. (0.71 m/s)



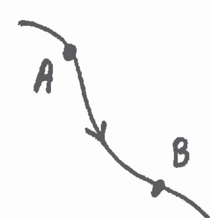
14. [0.8] A 1.2 kg mass is projected down a *rough* circular track of radius 2.0 meters as shown at the right. The speed of the mass is 3.2 m/s at point A and is 6.0 m/s at point B. Determine the work done by the force of friction between points A and B. (−8.1 J)



15. [0.8] The two masses shown at the right are released from rest. After the 3.0 kg mass has fallen 1.5 meters, it is moving with a speed of 3.8 m/s. Determine the work done by the force of fiction on the 2.0 kg block during this motion. (−8.0 J)



16. [0.5] As an object moves from point A to point B, only two forces act on it. One force is *conservative* and does −70 J of work on the object and the other force is *non-conservative* and does +50 J of work on the object. Which statement best describes the energy transfers as the object moves from A to B?
a) The KE of the object decreases and its total mechanical energy increases.
b) The KE of the object increases and its total mechanical energy increases.
c) The KE of the object decreases and its total mechanical energy decreases.
d) The KE of the object increases and its total mechanical energy decreases.
(a)

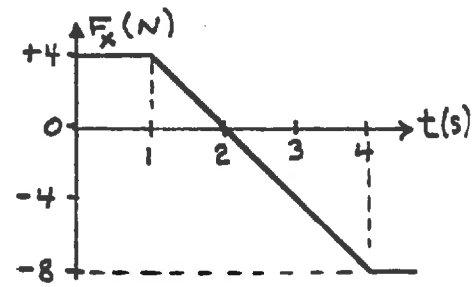


LINEAR MOMENTUM AND IMPULSE

1. [0.9] A 1.2 kg object, moving at 8.0 m/s, collides with a wall and rebounds backwards with a speed of 6.0 m/s. If the object is in contact with the wall for 0.002 seconds, determine the *magnitude* of the average force applied on the object due to the wall. (8400 N)

2. [0.7] A 1.5 kg ball is moving with a velocity of 3.0 m/s directed 30° below the horizontal just before it strikes a horizontal surface. The ball is in contact with the surface for 0.50 seconds and then leaves the surface with a velocity of 2.0 m/s directed 60° above the horizontal. Find the *magnitude* of the average force that acted on the ball due to the surface. (11 N)

3. [0.5] The only force that acts on a 2.0 kg object is shown at the right. If the velocity of the object is $v_x = -2.0$ m/s at $t = 0$, what is its velocity at $t = 4.0$ s? (−3.0 m/s)



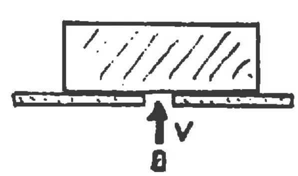
4. [0.6] The only force that acts on a 2 kg mass moving along the x-axis is given by the expression $F(x) = 4\,t$ N where t is in seconds. If the velocity of the mass is $v_x = 3.0$ m/s at $t = 0$ s, at what time is v_x equal to 8.0 m/s? (2.2 s)

5. [0.7] A 2.0 kg ball with an initial velocity $\mathbf{v}_o = 3\,\mathbf{i} - 4\,\mathbf{j}$ m/s collides with the floor and comes away with a velocity $\mathbf{v}_f = 3\,\mathbf{i} + 4\,\mathbf{j}$ m/s. What *impulse* acted on the ball due to the floor? (+16 **j** N·s)

6. [0.5] A 2.4 kg ball falls vertically and hits the floor with a speed of 2.5 m/s. It rebounds upwards with a speed of 1.5 m/s. Determine the *magnitude* of the impulse exerted on the ball due to the floor. (9.6 N·s)

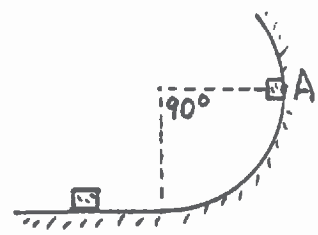
7. [0.8] A 2.0 kg object, moving with a velocity of 5.0 m/s along the positive x-axis, strikes and sticks to a 3.0 kg object moving with a speed of 2.0 m/s in the same direction. Find how much *kinetic energy* was lost in this collision. (5.4 J)

8. [0.7] A 0.010 kg bullet, moving upward at 1000 m/s, strikes and passes through a 2.0 kg block initially at rest as shown at the right. If the bullet emerges from the block with an upward speed of 400 m/s, to what maximum height will the block rise above its original position? (0.46 m)



Georgia Tech Problems

9. [0.7] A 3.0 kg mass is released from rest at point A on a circular track of radius 0.40 meters as shown at the right. The mass slides down the track and collides with a 1.4 kg mass that is initially at rest on a horizontal frictionless surface. If the masses stick together, what is their speed just after the collision? (1.9 m/s)



10. [0.7] A 2.0 kg object, moving at 5.0 m/s along the positive x-axis, collides *elastically* with a 4.0 kg object moving 1.0 m/s in the same direction. What is the change of the *kinetic energy* of the 4.0 kg object? (+25 J)

11. [0.8] A 3.0 kg object, moving along the positive x-axis, collides *elastically* with a 5.0 kg object initially at rest. After the collision, the 5.0 kg object has a velocity of 6.0 m/s along the positive x-axis. Find the initial speed of the 3.0 kg object. (8.0 m/s)

12. [0.8] A 6.0 kg object, moving 2.0 m/s along the positive x-axis, collides *elastically* with a 4.0 kg object moving 3.0 m/s in the opposite direction. Determine the total *kinetic energy* of the two mass system after the collision. (30 J)

13. [0.7] A 0.080 kg particle, moving with an initial speed of 50 m/s along the positive x-axis, strikes and sticks to a 0.060 kg particle moving 50 m/s along the positive y-axis. Find how much *kinetic energy* was lost in this collision. (86 J)

14. [0.7] A 2.0 kg object moving at 3.0 m/s strikes a 1.0 kg object initially at rest. Immediately after the collision, the 2.0 kg object is moving at 1.5 m/s directed 30° from its original direction. Determine the *speed* of the 1.0 kg object just after the collision. (3.7 m/s)

15. [0.5] A 5.0 kg mass with an initial velocity of 4.0 m/s directed *east* collides with a 4.0 kg mass with an initial velocity of 3.0 m/s directed *west*. After the collision, the 5.0 kg mass has a velocity of 1.2 m/s *south*. Determine the *magnitude* of the velocity of the 4.0 kg mass after the collision. (2.5 m/s)

16. [0.7] A 4.0 kg mass has a velocity of 4.0 m/s *east* when it explodes into two 2.0 kg masses. After the explosion, one of the masses is moving at 3.0 m/s at 60° *N of E*. Determine the *magnitude* of the velocity of the other mass after the explosion? (7.0 m/s)

17. [0.4] A 4.0 kg mass, initially at rest on a horizontal frictionless surface, is struck by a 2,0 kg mass moving at 8.0 m/s along the positive x-axis. After the collision, the 2.0 kg mass has a speed of 4.0 m/s directed 37° with respect the positive x-axis. What is the speed of the 4.0 kg mass after the collision? (2.7 m/s)

ROTATIONAL KINEMATICS

1. [0.8] A rotating wheel has a constant angular acceleration. At $t = 0$, its angular velocity is 2.0 rad/s. If two seconds later it has turned through 5.0 complete revolutions, find its angular acceleration. (14 rad/s^2)

2. [0.95] A rotating wheel is slowing down at the constant rate of −0.40 rad/s^2. If, at $t = 0$, its angular velocity is 1.5 rad/s and its angular position is 2.3 radians, find its angular position at $t = 2.0$ seconds. (4.5 rad)

3. [0.9] A record player turntable is rotating at 8.0 rad/s when it is turned off. If the turntable comes to rest 2.5 seconds later, through what angular displacement did it travel as it came to rest? (10 rad)

4. [0.7] A wheel, starting from rest, accelerates uniformly about a fixed axis. If it completes the first revolution in 6.0 seconds, how long does it take to complete the second revolution? (2.5 s)

5. [0.7] A wheel, starting from rest, accelerates uniformly through 8 revolutions in 17 seconds. What is its angular speed at the end of this time? (5.9 rad/s)

6. [0.9] A wheel of *diameter* 0.20 m ($r = 0.10$ m), starting from rest, accelerates uniformly at 2.0 rad/s^2. Determine the *translational* acceleration of a point on the outer edge of the wheel. (0.20 m/s^2)

7. [0.8] A wheel of *diameter* 0.30 m ($r = 0.15$ m), starting from rest, accelerates uniformly at 2.0 rad/s^2. Determine at what time the *centripetal* acceleration of a point on the outer edge of the wheel will have the magnitude 0.50 m/s^2. (0.91 s)

8. [0.7] A disk of *radius* 0.08 meters starts from rest and accelerates uniformly up to an angular speed of 4.0 rad/s in 2.0 seconds. Determine the magnitude of the *total* acceleration of a point on the rim of the disk at the instant the angular velocity of the disk is 1.5 rad/s^2. (0.24 m/s^2)

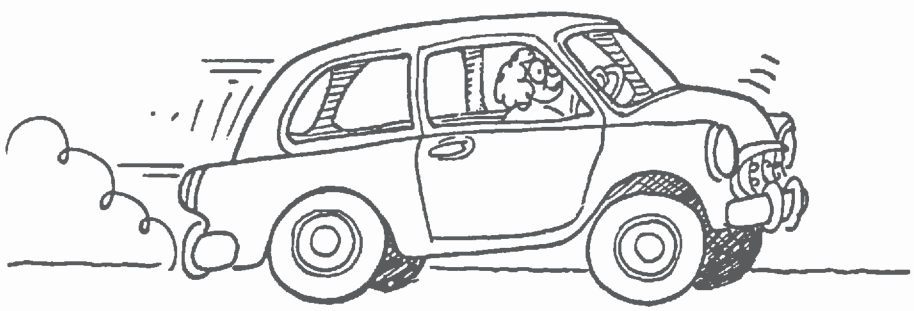
9. [0.7] A wheel of *diameter* 0.40 m ($r = 0.20$ m), starting from rest, accelerates uniformly at 2.0 rad/s^2. Determine the magnitude of the *centripetal* acceleration of a point on the outer edge of the wheel at $t = 2$ seconds. (3.2 m/s^2)

10. [0.9] A wheel of *diameter* 0.40 m ($r = 0.20$ m), starting from rest, accelerates uniformly at 2.0 rad/s^2. Determine the magnitude of the *translational* acceleration of a point on the outer edge of the wheel at $t = 2$ seconds. (0.40 m/s^2)

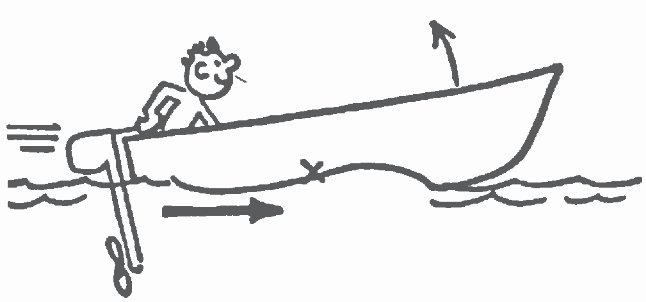
NOSING CAR

When a car accelerates forward, it tends to rotate about its center of mass. The car will nose upward

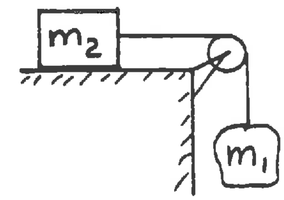
a) when the driving force is imposed by the rear wheels (for front-wheel drive the car would nose downward).
b) whether the driving force is imposed by the rear or the front wheels



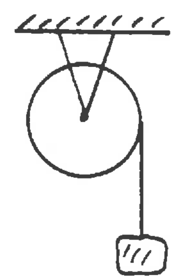
The car noses up only while it accelerates. The car goes back to level when it has achieved a constant speed. However, a motor boat stays nosed up even when its speed is constant. How come?



ROTATIONAL DYNAMICS



1. [0.4] A mass $m_1 = 5.0$ kg is connected via a light cord to mass $m_2 = 4.0$ kg which is moving on a frictionless surface as shown at the right. The pulley has a radius of 0.20 meters and rotates about a frictionless axle. If the acceleration of m_2 is 3.5 m/s^2, determine the *moment of inertia* of the pulley. (0.20 kg·m^2)



2. [0.4] A light cord wrapped around a wheel of radius 0.20 meters supports a 0.50 kg object as shown at the right. When released, the object falls with a downward acceleration of 5.0 m/s^2. Find the *moment of inertia* of the wheel. (0.019 kg·m^2)

3. [0.6] Two particles of mass $m_1 = 0.20$ kg and $m_2 = 0.30$ kg are positioned at the ends of a 2.0 meter long rod of negligible mass. What is the *moment of inertia* of this body about an axis perpendicular to the rod and through its center of mass? (0.48 kg·m^2)

4. [0.5] Two uniform solid spheres, each of mass 2.0 kg and radius 0.20 m, are used to make a "dumbbell" by connecting them to the opposite ends of a 0.30 meter long rod of negligible mass. Determine the *moment of inertia* of the body about an axis that passes through the center of mass of *one of the spheres*, perpendicular to the rod. (0.55 kg·m^2)

5. [0.8] Four identical particles, each of mass 0.40 kg, are placed at the vertices of a rectangle of size 2.5 x 4.0 m and are held in place by four light rods. Determine the *moment of inertia* of this body about an axis that passes through the mid-points of the shorter sides and is parallel to the longer sides. (2.5 kg·m^2)

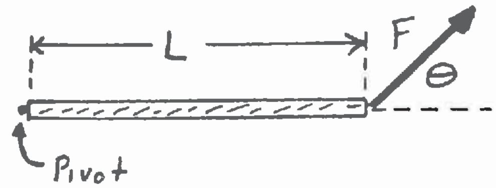
6. [0.5] A uniform rod of mass 2.0 kg and length 0.60 m is free to rotate about a frictionless axis at one end. If the rod is released from rest in the horizontal position, what is the magnitude of the angular acceleration of the rod at the instant it is 60° *below* the horizontal? (12 rad/s^2)

7. [0.6] A uniform rod of mass 1.5 kg and length 2.0 m is pivoted about a frictionless axis at one end. If the rod is released from rest at an angle of 30° *below* the horizontal, determine the angular acceleration of the rod at the instant it is released.. (6.4 rad/s^2)

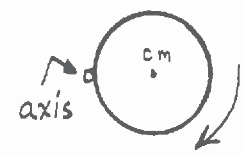
8. [0.4] A uniform rod of length 2.0 m is mounted so that it can freely rotate about a horizontal axis perpendicular to the rod that passes through a point 0.50 m from one end of the rod. If the rod is released form rest in a horizontal position, find the angular speed of the rod as it rotates through its lowest position. (4.1 rad/s)

9. [0.6] The object at the right shows two particles connected to a light rod of length L = 0.80 meters. If M = 2.0 kg, determine the kinetic energy of the object when its angular speed about is center of mass is 5.0 rad/s. (12 J)

10. [0.6] A uniform rod of mass m = 1.2 kg and length 0.80 m is free to rotate about one end. If force **F** = 5.0 N, acting at 40° above the horizontal as shown at the right, is applied to the right end of the rod, find the initial angular acceleration of the rod. (10 rad/s²)



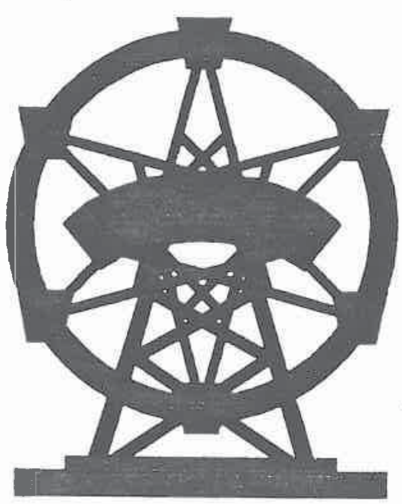
11. [0.4] A uniform sphere of radius 0.20 m is mounted so it can rotate freely about a horizontal axis tangent to the sphere. If the sphere is released from rest with its center of mass at the same height as the axis, determine its angular speed about this axis as the sphere moves through its lowest position. (8.4 rad/s)



12. [0.95] Three particles are placed in the xy plane. A 4 kg particle is placed at (3, 4) m and a 5 kg particle is placed at (−2, −6) m. Where must you place a 2 kg particle so that the center of mass of the system is located at the origin? (−1, 7)

13. [0.6] At an instant when a particle of mass 8 kg has a velocity of 25 m/s along the positive y-axis, a 7.5 kg particle has a velocity of 20 m/s along the positive x-axis. Determine the *speed* of the center of mass of the two-particle system at this instant. (16 m/s)

14. [0.9] At an instant when a particle of mass3 kg has a velocity of 6 m/s along the negative y-axis, a 4.0 kg particle has a velocity of 7 m/s along the positive x-axis. Determine the *speed* of the center of mass of the two-particle system at this instant. (4.8 m/s)

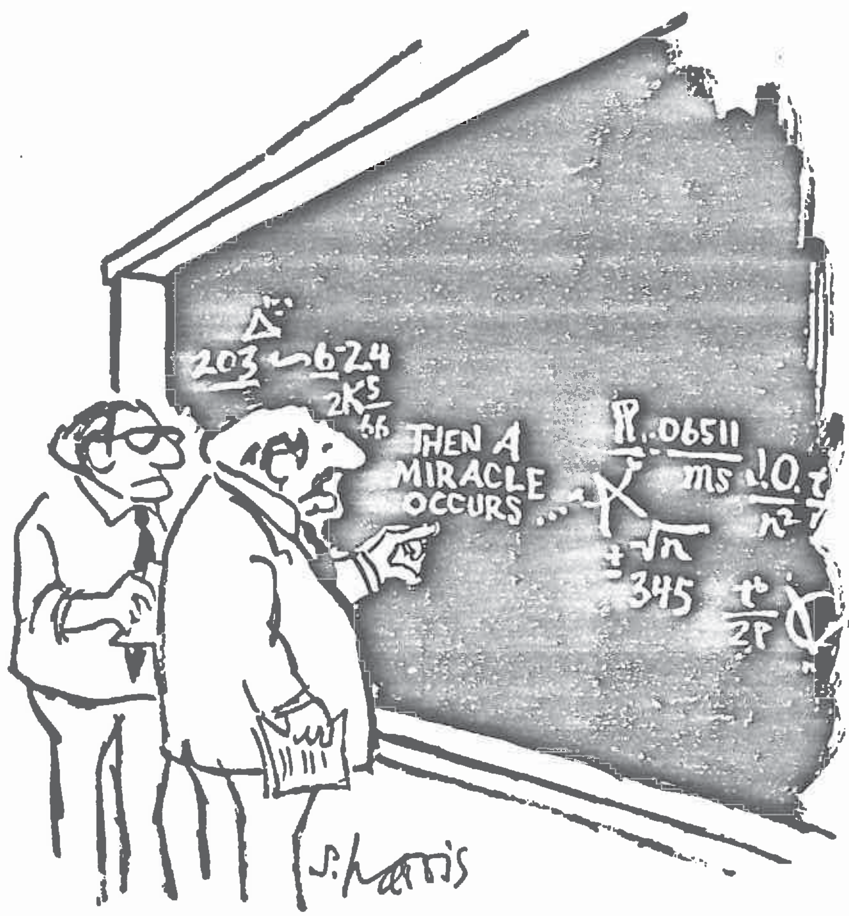


A WORKBOOK IN MECHANICS

FOR PHYSICS 103

PART II - SAMPLE EXAMS

This section of your workbook contains sample exams for Physics 103. There are two samples for each of three semester exams. These sample exams are copies of exams that were given in previous semesters. Although your exam will probably be very different from these sample exams, these exams show you the types of definitions, questions, and problems that can occur on exams. Not all topics studied in class will be on an exam and your exam will probably have problems on topics not shown on the sample exams. Use these sample exams as practice exams. Give yourself two hours to work through an exam and try to do as much as possible. Work with other students and compare answers. Use the exam to test your understanding of the material. If you have problems or questions, see your instructor immediately. Do not assume or hope that a topic that you do not understand will not be on the exam.



"I think you should be more explicit here in step two."

SAMPLE 1
PHYSICS 103 **EXAM 1** **NAME**________________

Write your name above. This exam has two parts. **Part 1** has 5 questions and **Part 2** has 4 problems. The last page of the exam is the formula page. You may remove it for use during the exam and keep it for future use. Note that some problems are worth more points than others.

Part 1. Questions. Answer each question in the space provided.

1. (9 pts) Define or describe the following quantities:

   a) *distance* ____

   ____

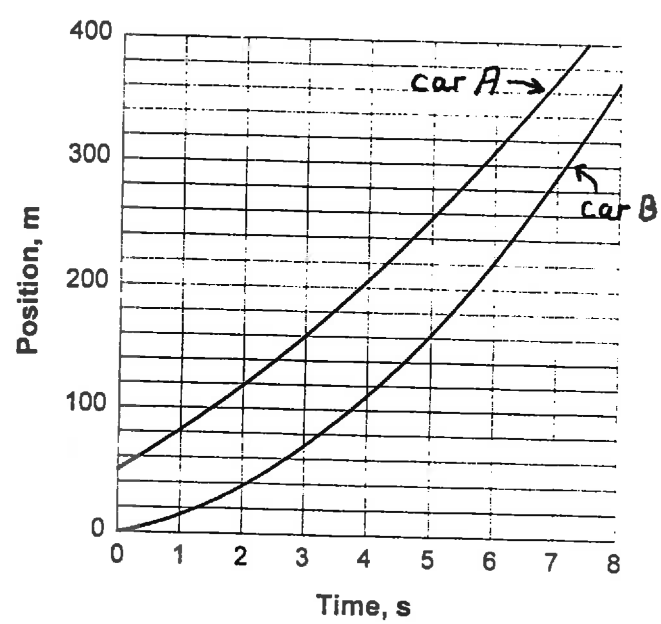
   b) *average speed* ____

   ____

   c) *position vector* ____

   ____

2. (9 pts) The **position vs time** plots for two cars, car **A** and car **B** are shown at the right.

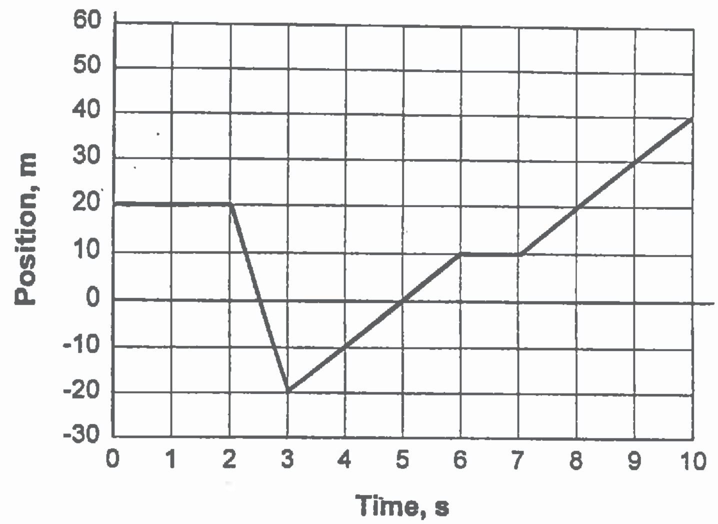


   a) Which car has the greater *initial velocity*? **Explain** how you know.

   b) Which car is moving *faster* at t=6 s? **Explain** how you know.

   c) Find the *speed* of car **B** at t=5 s.

3. (10 pts) The *position vs time* plot for a moving object is shown at the right.



a) What distance did the object move in the time interval t=0 to t=9 s?

b) What was the displacement of the object during the time interval t=0 to t=9 s?

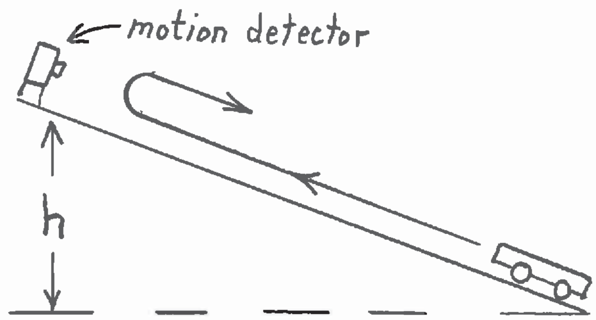
c) Find the average velocity of the object over the time interval t=3 to t=8 s.

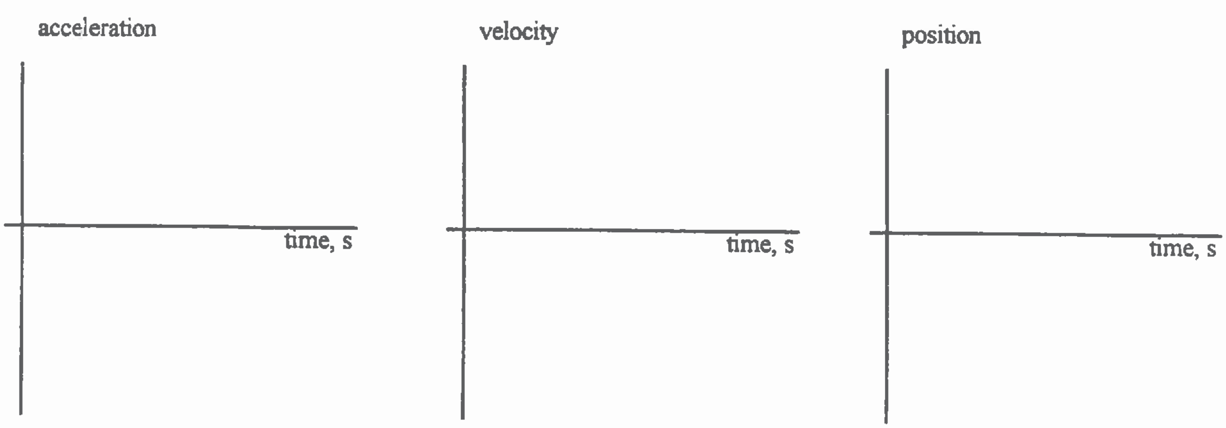
d) During what time intervals, if any, is the object moving to the left?

f) What is the instantaneous velocity at t=5 s?

4. (12 pts) Sketch the graphs as requested.

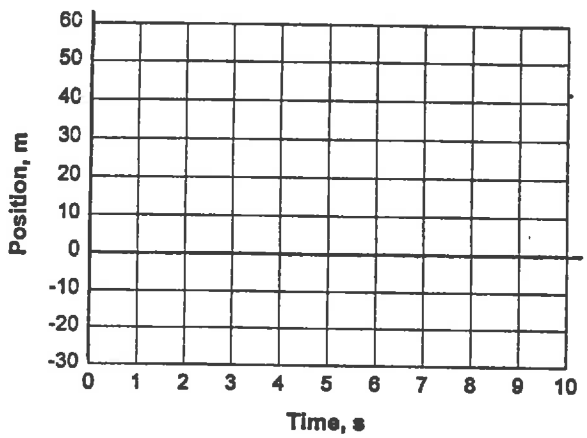
a) The left end of a straight track of length is raised distance h to produce an incline. A cart is placed at the bottom of the incline and given an initial velocity up the track as shown at the right. The cart moves up the track, slows to a stop, and then travels back down the track. Sketch the time-graphs of its motion.

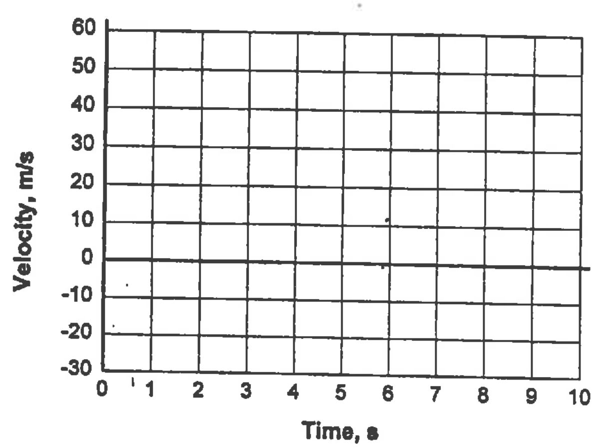




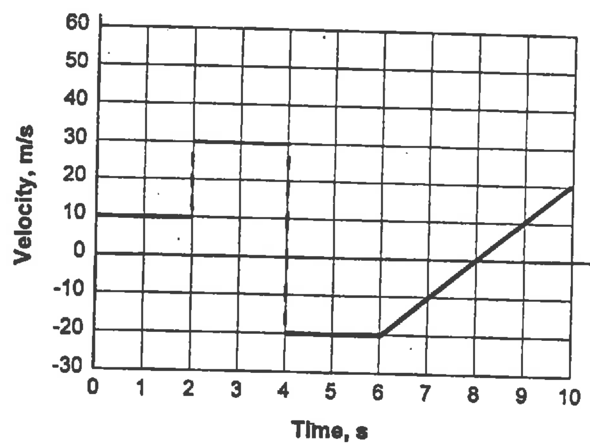
b) Sketch the velocity vs time and position vs time graphs for the motion described below.

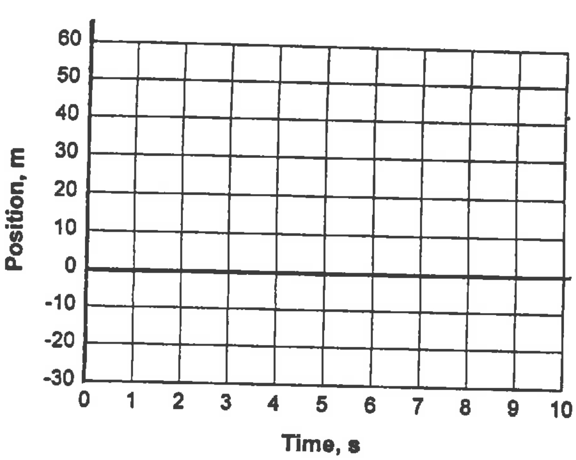
An object, initially at 10 m, moves away from the origin with a steady speed for 3 seconds, then reverses direction and moves back to its original position in 2 seconds, stays at rest for the next 2 seconds, and finally moves away from the origin with constant acceleration for 3 seconds.

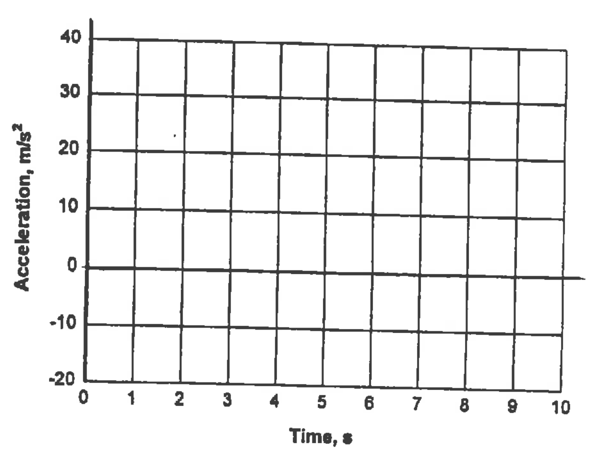




5. (10 pts) The velocity-time graph for a moving object is shown at the right. Sketch below the position-time graph and the acceleration-time graph.







Part 2. Problems. Work each problem in the space provided. To receive full credit for each problem, you must show all work including **relevant diagrams, sketches,** and **starting formulas**.

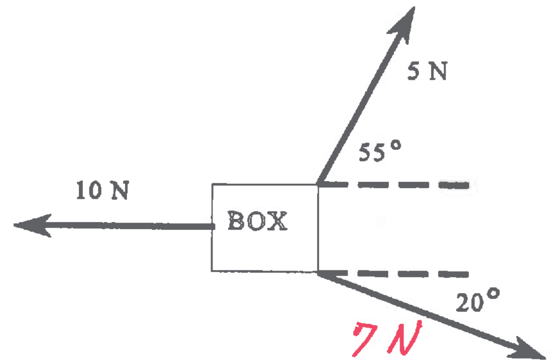
1. (12 pts) A helicopter makes the following journey: it flies due North at 80 m/s for 10 s, West at 120 m/s for 5 s, and then due South at 100 m/s for 5 s.

   a) Find the average *speed* for this journey.

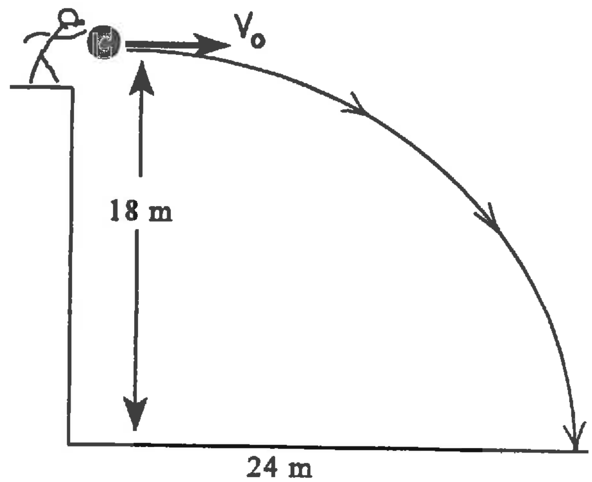
   b) Find the average *velocity* for this journey.

2. (12 pts) A car is traveling along a straight road when a tree falls across the road. The driver immediately slams on the brakes, slowing the car at the uniform rate of 5.60 m/s^2. The car does not stop in time and hits the tree. The police measure the skid marks to be 62.4 meters long and the driver noted that the time between applying the brakes and hitting the tree was 4.2 seconds. Find the *speed* at which the car hit the tree.

3. (12 pts) Three forces act on a box as shown at the right. Find the *magnitude* and *direction* of the resultant force that acts on the box.



4. (12 pts) A student reads in her physics book that you can determine the speed of throwing a ball using only a meter stick. She stands at the top of a building and throws a ball horizontally as shown. When the ball leaves her hand, it is 18 m above the ground. She measures the distance from the base of the building to where the ball hits the ground to be 24 m. How fast did she throw the ball?



FORMULA	FORMULA	FORMULA

$$\sin\theta = \frac{opp.}{hyp.}$$

$$\cos\theta = \frac{adj.}{hyp.}$$

$$\tan\theta = \frac{opp.}{adj.}$$

LAW OF SINES

$$\frac{\sin a}{A} = \frac{\sin b}{B} = \frac{\sin c}{C}$$

LAW OF COSINES

$$c^2 = a^2 + b^2 - 2ab\cos\theta$$

Pythagorean Th^m

$$c^2 = a^2 + b^2$$

Quadratic Formula

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$u_{AV} = \frac{d}{t}$$

$$\vec{V}_{AV} = \frac{\Delta\vec{x}}{\Delta t} = \frac{\vec{x}_2 - \vec{x}_1}{t_2 - t_1}$$

$$\vec{V} = \frac{d\vec{x}}{dt}$$

$$\vec{a}_{AV} = \frac{\Delta\vec{V}}{\Delta t} = \frac{\vec{V}_2 - \vec{V}_1}{t_2 - t_1}$$

$$\vec{a} = \frac{d\vec{v}}{dt}$$

If $a = const$,

$$V = V_0 + at$$

$$x = x_0 + V_0 t + \frac{1}{2}at^2$$

$$V^2 = V_0^2 + 2a(x - x_0)$$

$$\vec{a}_g = -g\,\hat{\jmath}$$

$$g = 9.80\ m/s^2$$

1 in = 2.54 cm

1 ft = 0.3048 m

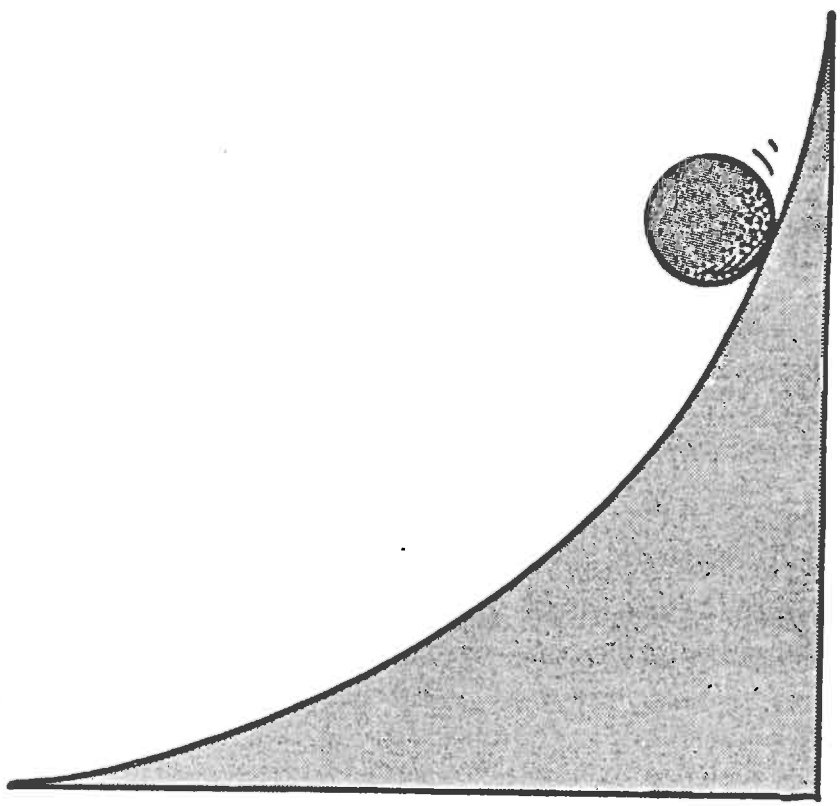
$$1\ \frac{mi}{hr} = 1.61\ \frac{km}{hr}$$

$$1\ \frac{m}{s} = 3.60\ \frac{km}{hr}$$

SPEED AIN'T ACCELERATION

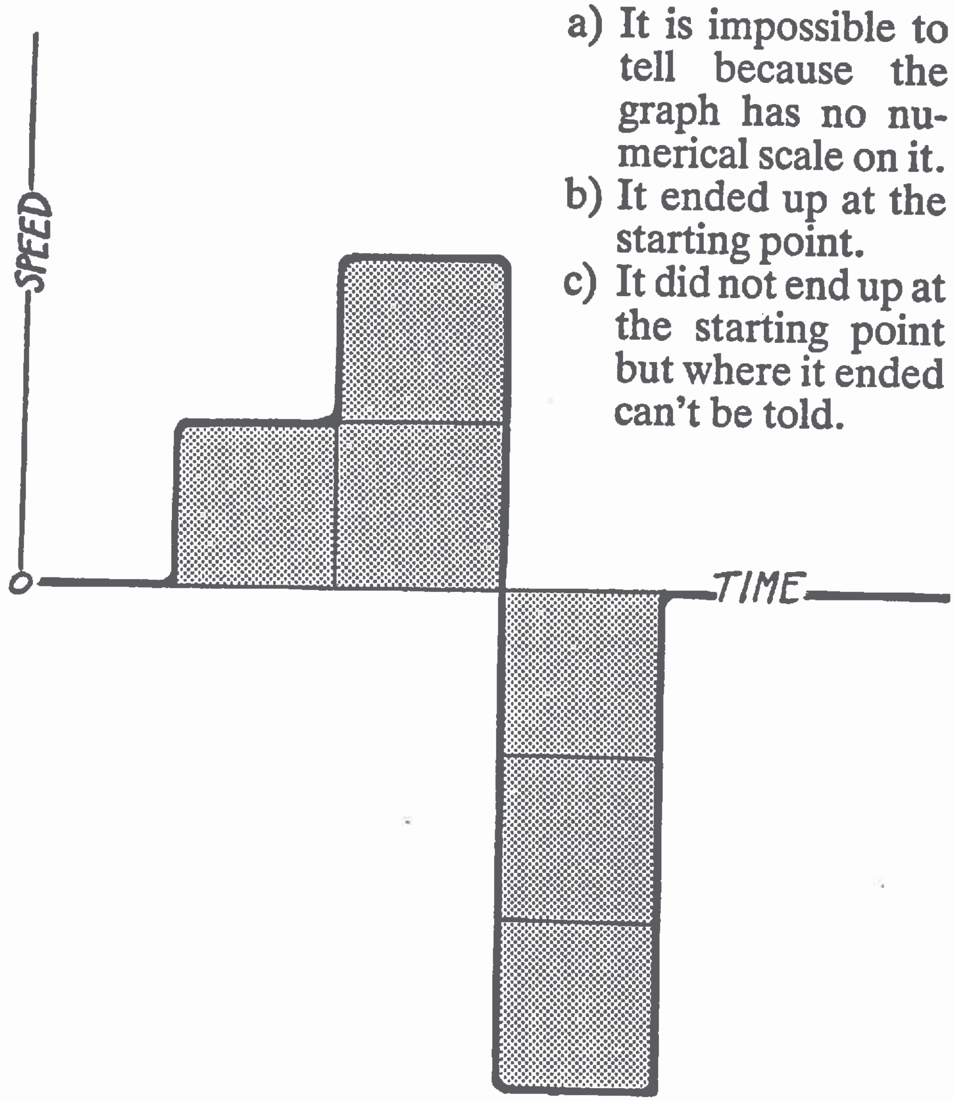
As the ball rolls down this hill

a) its speed increases and acceleration decreases
b) its speed decreases and acceleration increases
c) both increase
d) both remain constant
e) both decrease



NOT FAR

Look at this speed graph and tell how far away from the starting point this thing ended up.



a) It is impossible to tell because the graph has no numerical scale on it.
b) It ended up at the starting point.
c) It did not end up at the starting point but where it ended can't be told.

SAMPLE 2
PHYSICS 103 **EXAM 1** **NAME** ______________
McClure

Write your name above. This exam has *10* questions. To receive full credit for each questions, **show all your work** including relevant diagrams, sketches and starting formulas. Be sure to write complete answers including units. The last page of this exam is the formula page. You may remove it for use during the exam. Note that some questions are worth more points than other questions.

PART I. Questions. (6 pts each) Answer each question in the space provided.

1. Define or describe the following quantities:

   a) acceleration ____

   ____

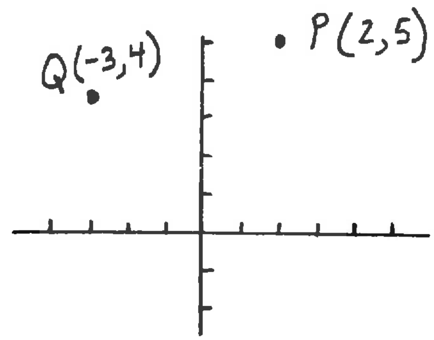
   b) scalar quantity ____

   ____

   c) position vector ____

   ____

2. Point P (2,5) and point Q (-3,4) are shown on the coordinate system at the right.



   a) Write expressions in **unit vector form** for the position vectors for point P and Q.

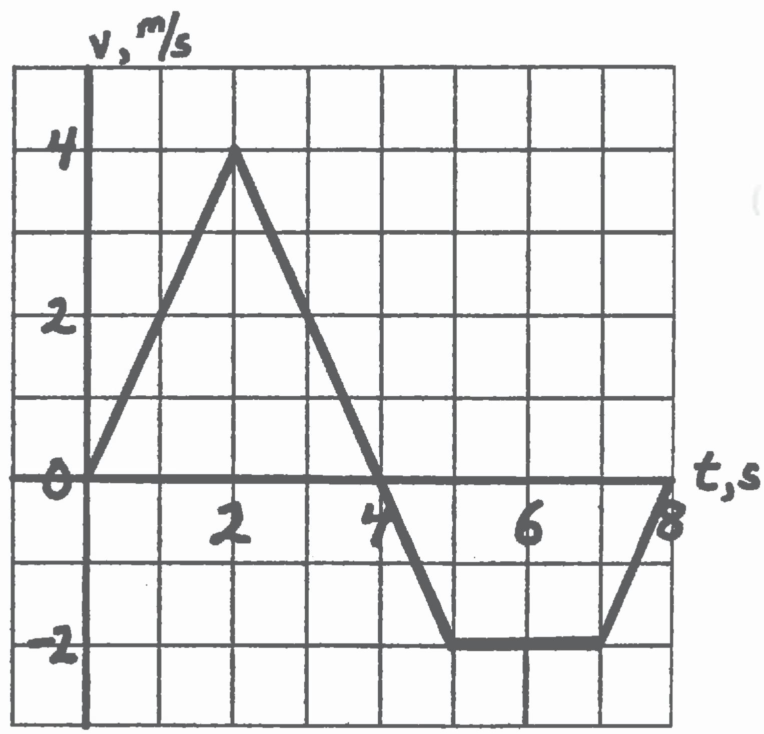
   b) Find the displacement vector in **unit vector form**.

3. Two vectors are given by **A** = 3 **i** - 4 **j** + 5 **k** and **B** = -2 **i** -3 **j** + 7 **k**.

a) Find the magnitude of vector **A**.

b) Find vector **C** such that 2**C** + **A** + **B** = 0.

4. The **velocity vs time** graph of a particle is shown below.



a) For what time intervals, if any, is the **speed** of the particle decreasing?

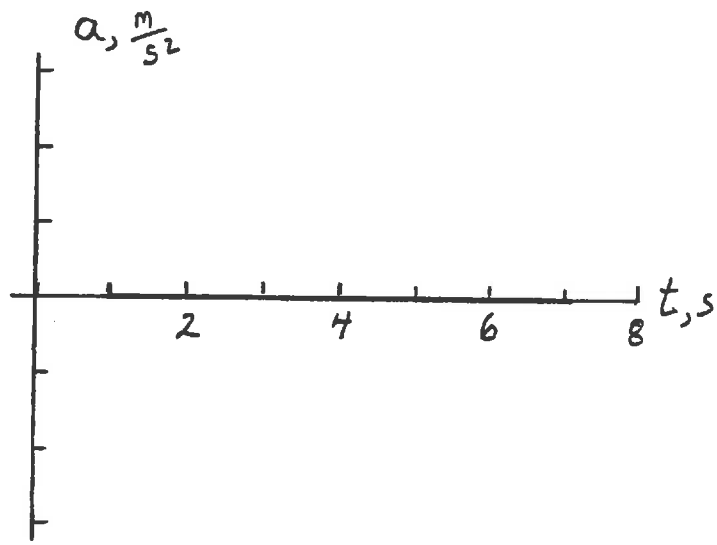
b) For what time intervals, if any, is the particle moving in the **negative** x direction?

c) For what time intervals, if any, is the **acceleration** of the particle negative?

5. The following questions refer to the velocity vs time graph on the previous page.

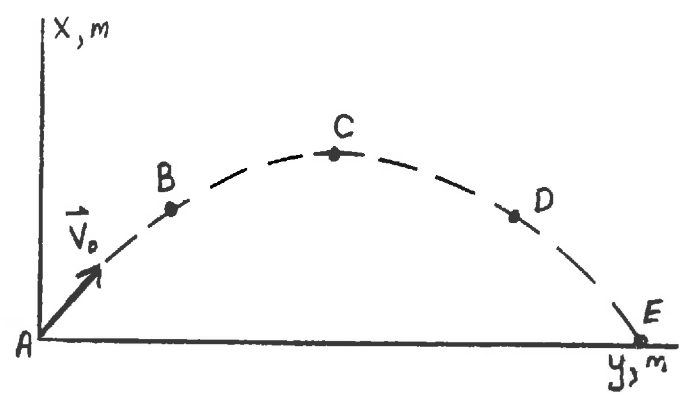
a) What is the **average acceleration** from t = 1 to t = 5 sec?

b) Sketch the **acceleration vs time** curve for the particle on the graph at the right. Label the vertical axis of the graph with the appropriate units and scale.



6. The curve ABCDE below shows the trajectory of a kicked soccer ball. At point A the ball was given an initial velocity of 40 m/s at an angle of 35° above the horizontal.

a) What is the magnitude of the **velocity** of the ball at point C, the highest point of the trajectory?

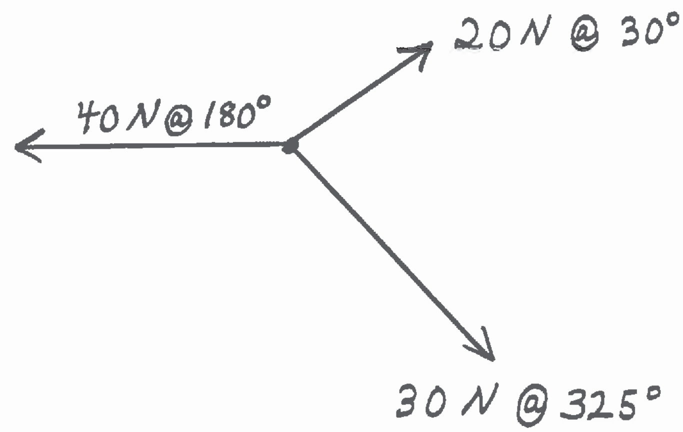


b) What is the vertical component of velocity of the ball at point E, just **before** the ball touches the ground?

c) What is the **acceleration** of the ball at point C?

PART II. Problems. (16 pts each) Answer each problem in the space provided. Show all work.

1. Three forces act at a point as shown. Find the **magnitude** and **direction** of the resultant.



2. A student stands at the top of a 75 m high building and throws a ball straight **down**. The ball hits the ground 3 seconds later.

   a) How fast was the ball thrown?

   b) How fast is the ball moving just **before** it hits the ground?

3. A baseball is hit at a height of 1 meter above the ground. The ball leaves the bat at 42 m/s at an angle of 35° with respect to the horizontal and flies over a fence 18 meters high, located 130 m from the batter.

a) How far above the fence (vertically) did the ball pass over the fence?

b) What was the **magnitude** of the velocity of the ball just as it passed over the fence?

4. A car moving at 30 m/s approaches a hill of constant slope. At the bottom of the hill, the driver puts the car in neutral and allows it to coast up the incline. The car comes to rest 4.0 seconds later.

a) How far up the hill does the car travel?

b) If the driver allows the car to coast freely back down the hill, how fast is it moving 25 m from the bottom?

THE TRIP

Suppose you wish to average 40 mph on a particular trip and find that when you are half way to your destination you have only averaged 20 mph. How fast would you have to travel on the remaining half of your trip to attain the overall average of 40 mph?*

a) 60 mph
b) 80 mph
c) 90 mph
d) 120 mph
e) Faster than the speed of light

EXAM #2 - SAMPLE 1

PHYSICS 103 **EXAM 2** **NAME**________________

McClure

Write your name above. This exam has 8 questions. To receive full credit for each questions, **show all your work** including relevant diagrams, sketches and starting formulas. Be sure to write complete answers including units. The last page of this exam is the formula page. You may remove it for use during the exam. Note that some questions are worth more points than other questions.

1. (10pts) Questions. Answer each question in the space provided.

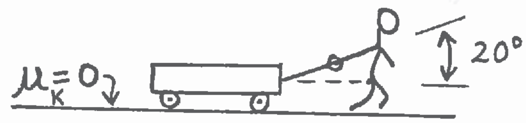
   a) Suppose the gravitational force between a nickel and a dime, seperated by one meter, is 3 μN (micronewtons). A second dime is placed on the first dime and the nickel is moved to 0.25 meter from the dimes. What is the new graviational force?

   b) Newton discovered that there are two masses: inertial mass and gravitational mass. What is the difference between these masses?

   c) A 0.850 hockey puck slides across the ice with a constant speed. What force, if any, is required to keep the puck moving?

2. (10 pts) A child is pulling a 3 kg wagon with a force of 8 N as shown below.

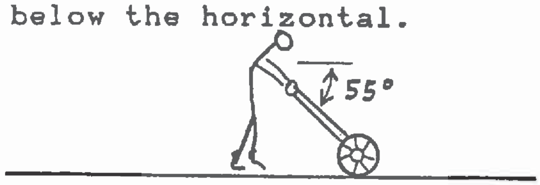
a) Draw the complete force diagram for the wagon.



b) Assume that each force in your force diagram above is an action force. Write below a complete description of the reaction force for each action force.

3. (12 pts) For each situation below, draw and label a complete free body diagram.

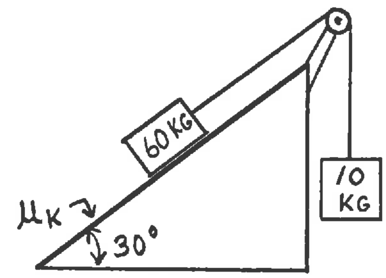
a) A man pushes a lawnmower to the right over rough ground with a force of 50 N directed along the handle, which makes an angle of 55° below the horizontal.



b) An 1800 kg truck pushes a disabled 1200 kg car. Assume all resistive forces of friction are zero.

4. (12 pts) A 60 kg block, connected via a rope and smooth pulley to a hanging 10 kg mass, slides down a rough incline as shown below.

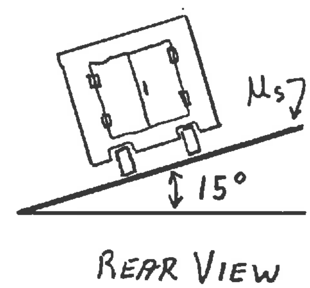
a) Draw the free body diagram for each body.



b) In terms of the forces in your diagrams above, write the complete equations of motion (i.e. the second law equations) for each body. Do NOT solve.

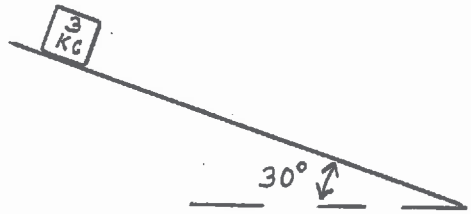
5. (12pts) A 2500 kg truck rounds a banked exit ramp from the beltway as shown below. Assume the truck goes around the corner with a speed faster than the design speed.

a) Draw the free body diagram for the truck.



b) In terms of the forces in your free body diagram, write an expression for the centripetal force on the truck. Do NOT solve.

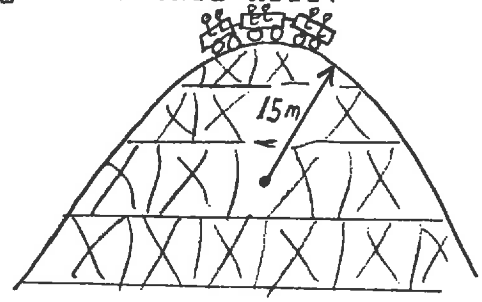
6. (15 pts) A 3 kg block starts from rest at the top of a 30o rough incline and slides a distance of 2 meters down the incline in 1.5 seconds.



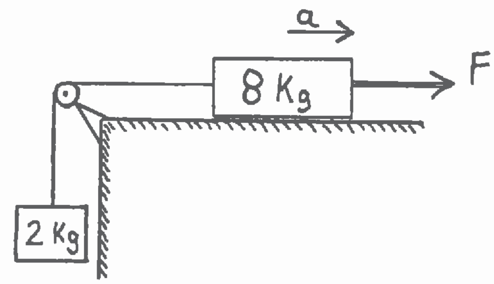
a) Find the acceleration of the block.

b) Find the coefficient of kinetic friction between the block and the incline.

7. (15 pts) A roller coaster is designed so that its cars go over the top of a hill at 8.2 m/s as shown in the sketch below. What apparent weight is felt by a 720 N passenger as the cars go over this hill?



8. (15pts) The system shown below is caused to accelerate to the right at 2.5 m/s^2 by force F attached to the 8 kg mass. Assume the pulley is frictionless and massless and that the coefficient of <u>kinetic</u> friction between the plane and the 8 kg mass is 0.4. Find the magnitude of force F.



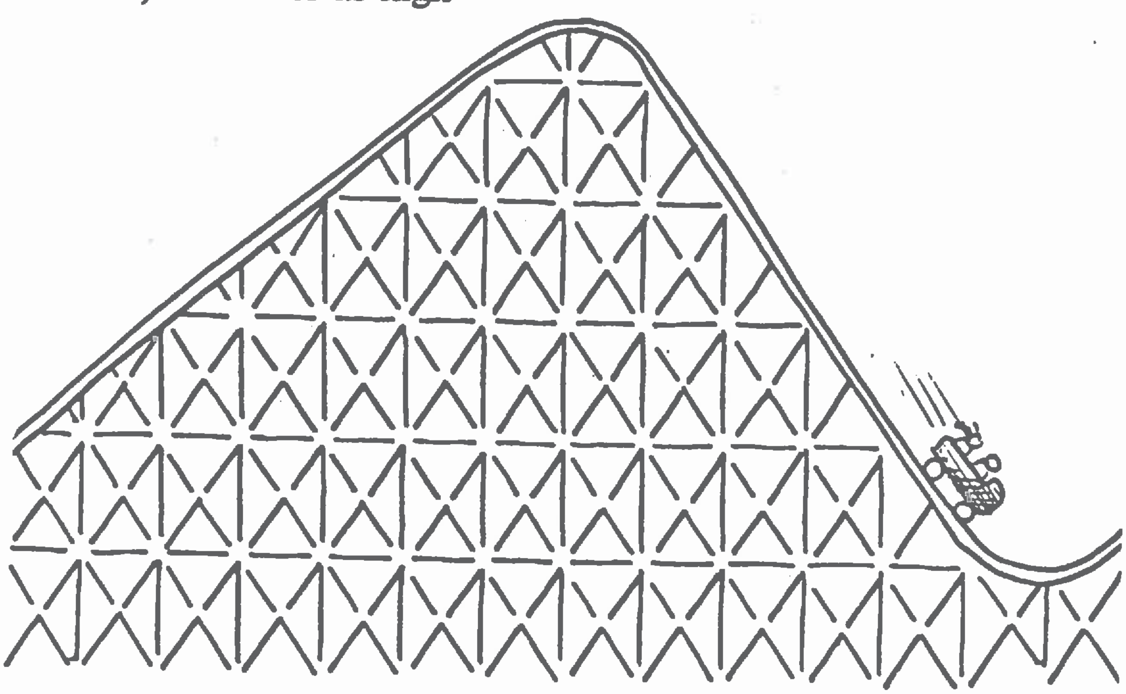
PHYSICS 103 - EXAM 2

FORMULA	FORMULA	FORMULA
$\boxed{\Sigma \vec{F} = m\vec{a}}$	$d = u_{AV} t$	$g = 9.80\ m/s^2$
$F_w = mg$	$v = v_0 + at$	$G = 6.673 \times 10^{-11}\ \frac{N \cdot m^2}{kg^2}$
$f = \mu F_N$	$x = x_0 + v_0 t + \frac{1}{2} a t^2$	$1\ h.p. = 746\ W$
reaction = − action	$v^2 = v_0^2 + 2a\Delta x$	$M_E = 5.98 \times 10^{24}\ kg$
$F_G = \frac{G m_1 m_2}{r^2}$	$a_c = \frac{v^2}{r}$	$R_E = 6.37 \times 10^6\ m$
$W_x = \frac{G M_x m}{R_x^2}$		$M_{moon} = 7.36 \times 10^{22}\ kg$
$g_x = \frac{G M_x}{R_x^2}$	$W = F_{\parallel} \Delta x = \vec{F} \cdot \vec{\Delta x}$	$R_{moon} = 1.74 \times 10^6\ m$
$v^2 = \frac{GM}{r}$	$W = \int_{x_1}^{x_2} \vec{F} \cdot \vec{dx}$	$\vec{a} \cdot \vec{b} = ab\cos\theta$
	$W_s = \frac{1}{2} k x^2$	$\vec{a} \cdot \vec{b} = a_x b_x + a_y b_y$
	$\boxed{W_{NET} = \Delta K = K_f - K_i}$	
	$K = \frac{1}{2} m v^2$	
	$P_{AV} = \frac{W}{t}$	
	$P = \frac{dW}{dt} = \vec{F} \cdot \vec{v}$	

CHUTE THE CHUTE

A roller coaster is pulled to the top of a "chute the chute" and allowed to roll down. For a bigger thrill you might wish the car to be going twice as fast at the bottom of the run. To make your wish come true, the chute should be

a) twice as high
b) three times as high
c) four times as high
d) five times as high
e) six times as high



EXAM #2 - SAMPLE 2

PHYSICS 103 **EXAM 2** **NAME**____________________

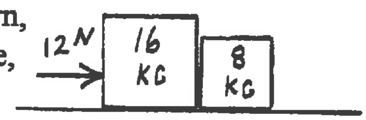
McClure

Write your name above. This exam has 3 parts. The last page of this exam is the formula page. You may remove it for use during the exam. Note that some questions are worth more points than other questions. Answer each question in the space provided.

PART I. Multiple Choice. (2.5 pts each) Circle the letter corresponding to best answer. There are 10 multiple choice questions.

1. A 50 kg student stands on a scale in an elevator. The scale shows a weight of 540 N. The elevator is moving
   a) upward with constant acceleration.
   b) downward with constant acceleration.
   c) upward with constant velocity.
   d) downward with constant velocity.
   e) Both (c) and (d) are correct answers.

2. A 12 N force is applied horizontally to a 16 kg block which, in turn, pushes on an 8 kg block. If the blocks are on a frictionless surface, what force does each block exert on the other?
   a) zero b) 2 N c) 4 N d) 8 N e) 16 N



3. A flat (unbanked) curve on a highway has a radius of 300 m. A car rounds the corner at 40 m/s. What is the minimum coefficient of friction needed to prevent sliding?
   a) 0.12 b) 0.54 c) 0.65 d) 0.75 e) 0.81

4. If the acceleration due to gravity on planet X is 4.85 m/s^2, how much would a 720 N person (earth weight) weigh on planet X? a) 720 N b) 356 N c) 254 N d) 148 N e) 73 N

5. A block slides down an incline of angle 35° with respect to the horizontal. If the velocity of the block is constant, what is the coefficient of kinetic friction between the block and the surface?
   a) 0.423 b) 0.466 c) 0.574 d) 0.628 e) 0.700

6. If the weight of a moving car is doubled, its kinetic energy is
   a) doubled. b) quadrupled. c) remains the same. d) halved. e) reduced by 1/4.

7. A satellite of mass m is in orbit at radius h = 2 R_E from the surface of the earth with an orbital speed of v. If a second satellite of mass 2m is placed in the same orbit, its orbital speed must be
   a) 4v. b) 2v. c) v. d) v/2. e) v/4.

8. A 2 kg block is pulled 10 m along a horizontal surface as shown. If its speed increased from 2 m/s to 4 m/s during the motion, what NET work was done on the block?
a)zero b) 2 J c) 12 J d) 20 J e) 32 J

9. If **a** = 2 **i** - 3 **j** and **b** = 4 **i** + 6 **j**, the angle between **a** and **b** is
a) 12.2°. b) 60°. c) 78°. d) 90°. e) 98.8°.

10. Force **F** = 2 **i** - 3 **j** + 4 **k** N acts through displacement **s** = -3 **i** - 2 **j** + 3 **k** m. The work done by the force is
a) 12 J. b) 10 J. c) 4 J. d) -4 J. e) -8 J.

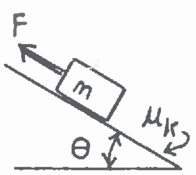
PART II. Questions. Answer each question in the space provided.

1. (5 pts) Write the MKS units for each of the following quantities:

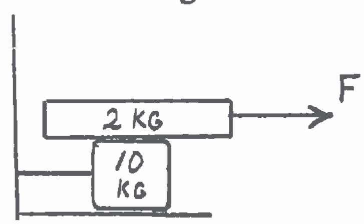
a) inertia____ b) weight____ c) kinetic energy____ d) force____ e) work____

2. (10 pts) Draw a force diagram for the following systems:

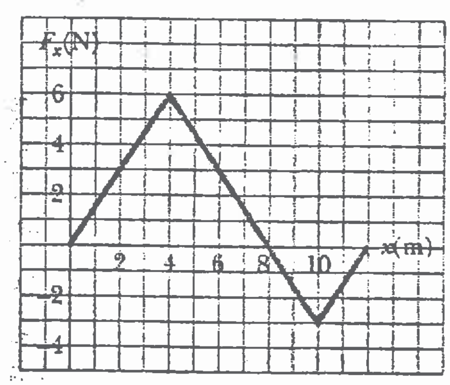
a) A mass pulled up an incline.



b) A 2 kg mass moving on top of a 10 kg mass.



3. (10 pts) The force that acts on a 2 kg block varies as shown in the graph at the right.

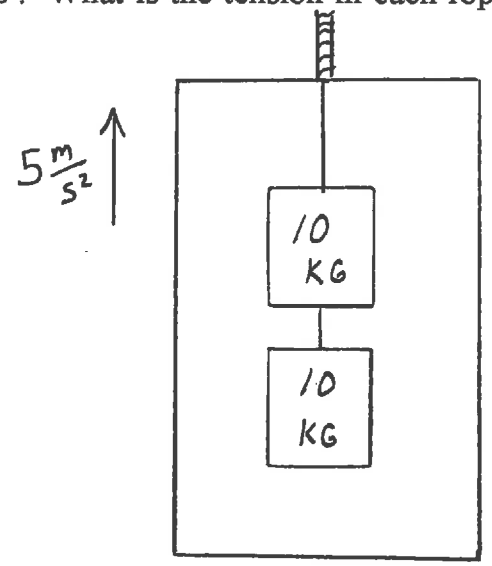


a) Find the work done on the block from x = 4 to x = 10 m.

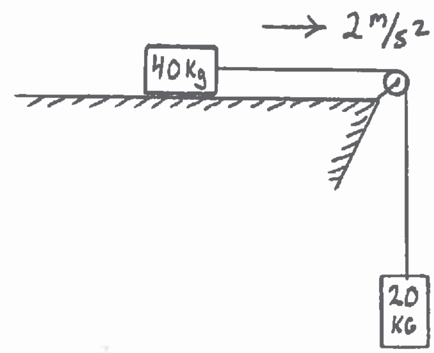
b) If the block starts from rest at x = 0, how fast is it moving at x = 10 m?

PART III. Problems. (10 pts each) To receive full credit for each problem, **show all your work** including relevant diagrams, sketches and starting formulas. Be sure to write complete answers including units. There are 5 problems.

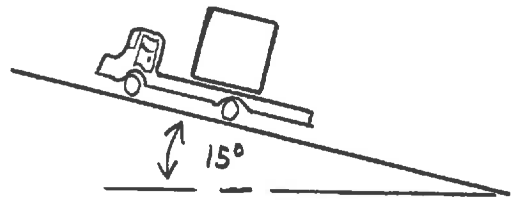
1. Two 10 kg masses, attached to one another by ropes as shown below, are hung in an elevator. The elevator accelerates **upward** at 5 m/s^2. What is the tension in each rope?



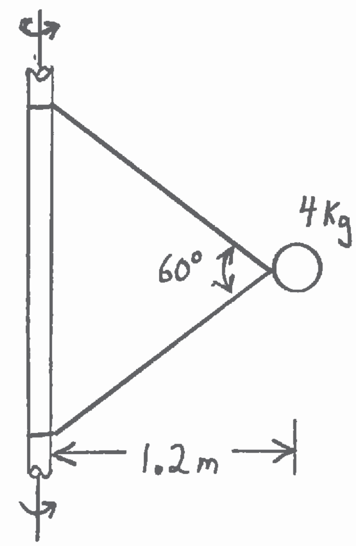
2. The two blocks, shown below connected together by a rope, accelerate at 2 m/s^2. If the surface under the 40 kg block is **rough**, find the coefficient of kinetic friction between the two surfaces.



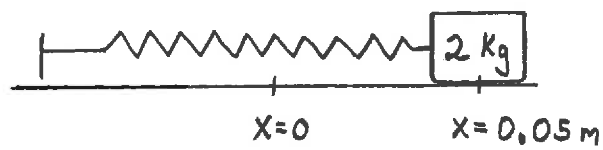
3. A box rests on the back of a flatbed truck. The coefficient of static friction between the box and the bed of the truck is 0.65. The truck begins to accelerate up a hill of constant slope as shown. Find the **maximum** acceleration the truck can have without causing the box to slip.



4. A 4 kg mass is attached 1.2 meters from a vertical rod by two ropes as shown below. The ropes are under tension when the rod is rotated about its axis. If the mass is rotated at a constant 8 m/s, find the tension in each rope.



5. A 2 kg block is attached to a spring of force constant 500 N/m as shown below. The block is pulled 5 cm to the right of equilibrium (x = 0) and released from rest. Use the **Work-Energy Theorem** to find the speed of the block as it passes through equilibrium if the coefficient of friciton between block and surface is 0.35.

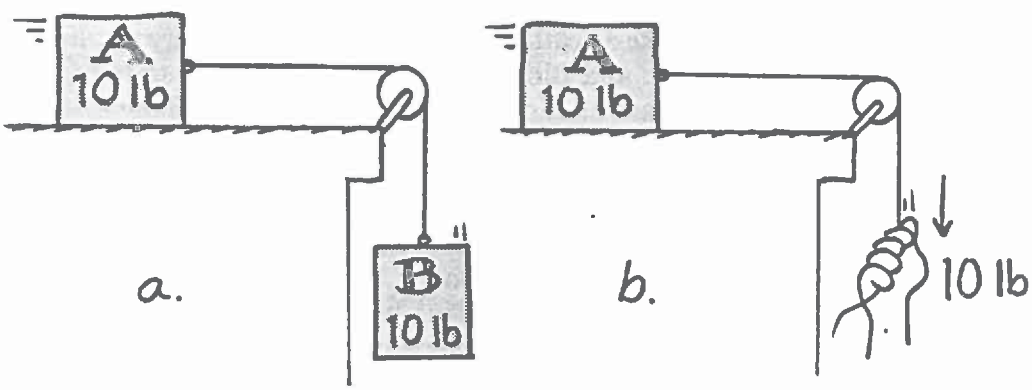


Figuring Physics

PULL

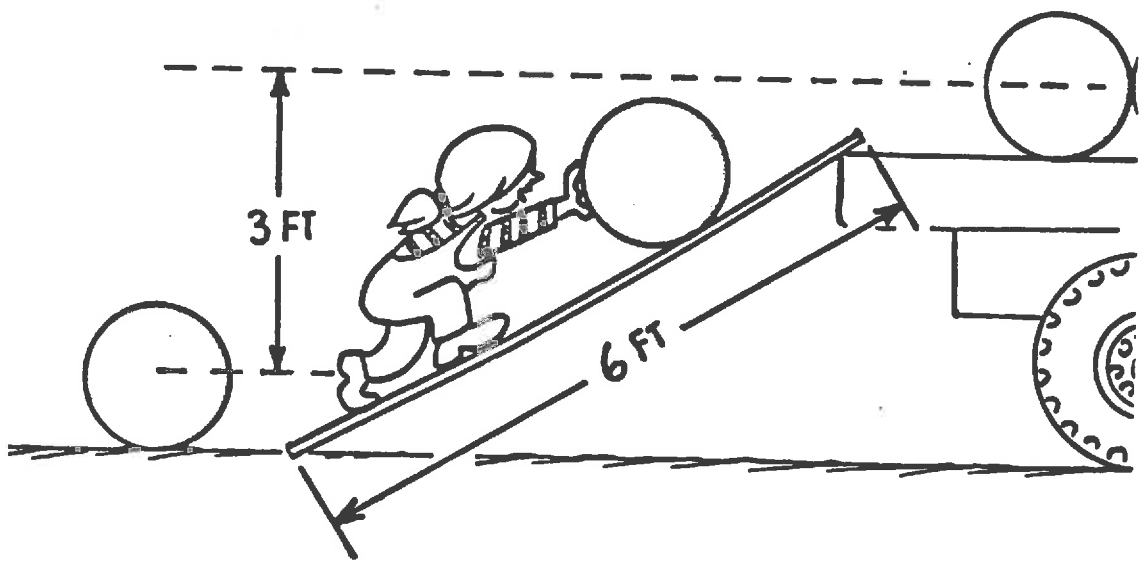
Think carefully about this one: In both Case *a* and Case *b* shown below a net force of 10 lb results in the acceleration of Block A across the table toward the pulley. Disregard friction altogether.* The acceleration of Block A is

a) greater in Case *a*
b) greater in Case *b*
c) the same in both cases



STEVEDORE

The stevedore is loading 100-pound drums on a truck by rolling them up a ramp. The truck bed is 3 feet above the street and the ramp is 6 feet long. How much force must she exert on the drums as she goes up the ramp?

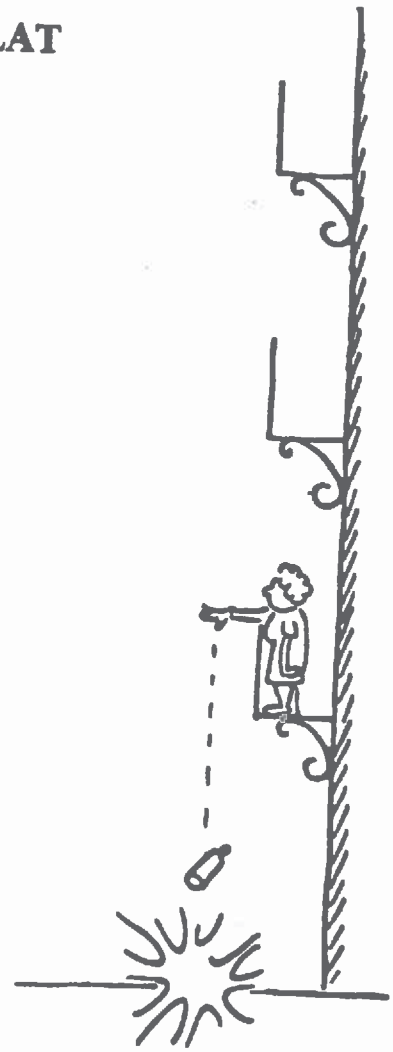


a) 200 lb
b) 100 lb
c) 50 lb
d) 10 lb
e) Can't say

SPLAT

A bottle dropped from a balcony strikes the sidewalk with a particular speed. To double the speed of impact you would have to drop the bottle from a balcony

a) twice as high
b) three times as high
c) four times as high
d) five times as high
e) six times as high



EXAM #3 - SAMPLE 1

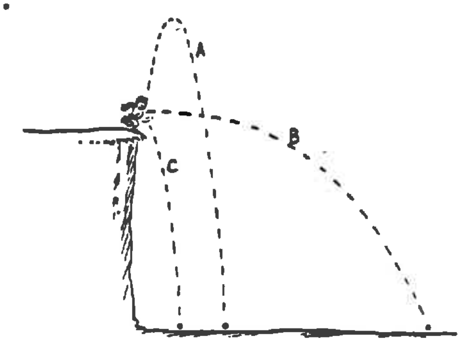
PHYSICS 103 **EXAM 3** **NAME**_______________

McClure

Write your name above. This exam has 8 questions. To receive full credit for each questions, **show all your work** including relevant diagrams, sketches and starting formulas. Be sure to write complete answers including units. The last page of this exam is the formula page. You may remove it for use during the exam. Note that some questions are worth more points than other questions.

1. (10 pts) Answer each question in the space provided

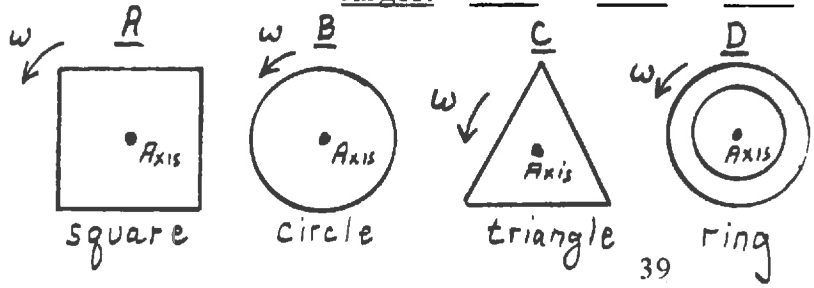
a) Three baseballs are thrown from the top of a cliff along paths A, B and C. If each is thrown with the same initial speed and there is no air resistance, the ball thrown along which path will hit the ground with the greater speed? Explain.



b) A solider fires a rifle. If the forward momentum of the bullet is the same as the backward momentum of the gun, why isn't it as dangerous to be hit by the gun as by the bullet?

c) Four solids, labeled A, B, C, and D, with equal height, equal mass, and equal thickness are shown in cross section below. Arrange the solids in order of their **moment of inertia** from largest to smallest.

largest ____ ____ ____ ____ smallest



2. (10 pts) Write a definition or short description of each term below:

a) energy ____

____

b) momentum ____

____

c) torque ____

____

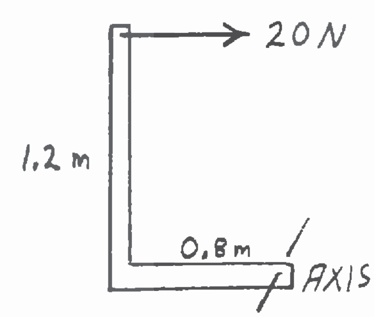
3. (12 pts) Answer each question in the space provided. Show all work.

a) A car has one-half the same mass and twice the speed of a truck. What is the ratio of the KE of the truck to that of the car?

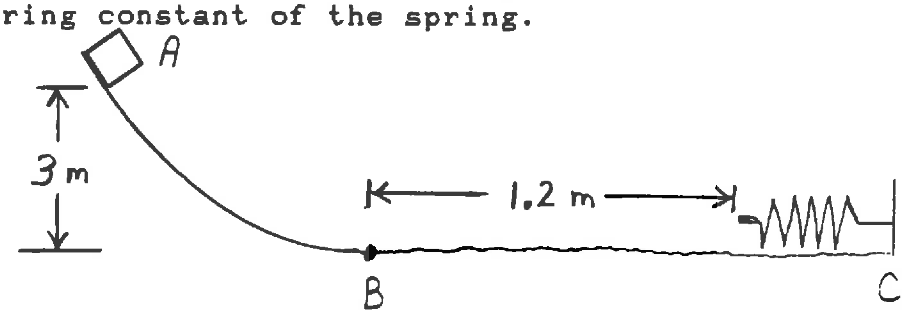
b) A 2 kg mass and a 12 kg mass have the same **kinetic energy**. Which mass, if either, has the larger linear momentum?

c) A red box of mass 2 kg is moving at 10 m/s and a blue box of mass 50 kg is moving at 2 m/s. Both boxes are stopped by the same force. Which box, if either, takes the longer **time** to stop?

d) A 20 N force acts on an "L" shaped arm as shown below. Find the magnitude of the torque on the arm about its axis of rotation.



4. (15 pts) A 10 kg block is released from point A at the top of a curved track as shown below. The track is frictionless except for the part from B to C where the coefficient of kinetic friction is 0.30. The block travels down the track and hits a spring of constant k and compresses it a distance of 0.3 meters before coming to rest momentarily. Find the spring constant of the spring.



5. (12 pts) A small bomb of mass 4 kg is moving along the x-axis with a speed of 8 m/s. When the bomb just reaches the origin of the coordinate system, it explodes into 3 pieces, one piece going straight up along the y-axis.

a) Is linear momentum conserved in this process? Explain.

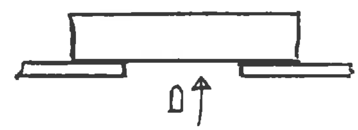
b) Is energy conserved in this process? Explain.

c) What is the x-component of the total momentum just after the collision?

d) Find the x and y cordinates of the center of mass of the pieces 5 sec after the explosion.

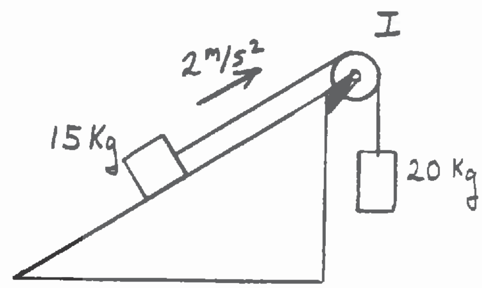
6. (12 pts) A 10 gm (0.010 kg) bullet, moving vertically upward at 1000 m/s, strikes and passes through a 2.0 kg block of wood initially at rest. The bullet emerges from the wood block with a speed of 400 m/s.

a) To what maximum height will the block rise above its initial position?

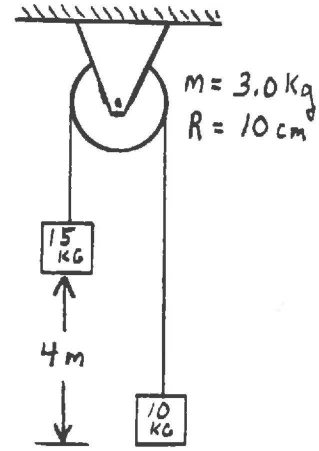


b) Find the impulse that acted on the bullet during the collision.

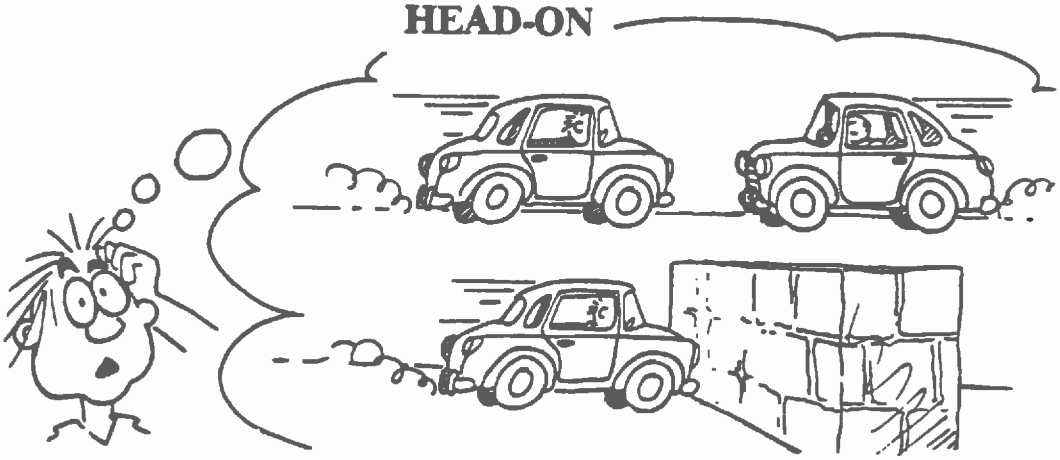
7. (15 pts) A 15 kg block is connected via a cord to a 20 kg block as shown below. The cord passes over a pulley of radius R = 0.250 m and moment of inertia I. When the system is released, the 15 kg block is measured to be accelerating up the incline at 2.00 m/s^2. Assume the inclined surface is frictionless. Find I.



8. (15 pts) A 15 kg mass and a 10 kg mass are suspended by a pulley of radius 10 cm and mass 3.0 kg. The cord has no mass and causes the pulley to rotate without slipping. The masses start 4.0 meters apart as shown. Find the rotational speed of the pulley as the masses pass one another.

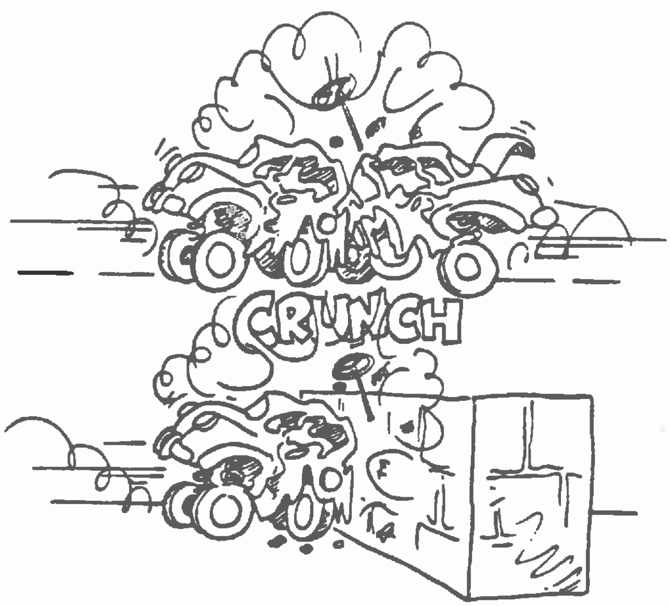


HEAD-ON



Consider the consequences of driving a car into a head-on collision with an identical car travelling toward you at the same speed — as opposed to colliding at the same speed against a massive concrete wall. Which of these two situations would result in the greatest impact force?

a) Colliding with the approaching car
b) Colliding with the massive stationary wall
c) Both would have the same impact



PHYSICS 103 - - EXAM 3

FORMULA

$\vec{v} = \frac{d\vec{x}}{dt}$ $\vec{a} = \frac{d\vec{v}}{dt}$

$v = v_0 + at$

$x = x_0 + v_0 t + \frac{1}{2}at^2$

$v^2 = v_0^2 + 2a\Delta x$

$\boxed{\sum \vec{F} = m\vec{a}}$

$wt = mg$ $f = \mu F_N$

$F_G = \frac{G m_1 m_2}{r^2}$ $F_S = -Kx$

$g_x = \frac{GM_x}{R_x^2}$

$W = \vec{F} \cdot \vec{\Delta x} = \tau \times \Delta\theta$

$K = \frac{1}{2}mv^2$

$U_f = U_i - \int_i^f \vec{F} \cdot d\vec{r}$

$U_g = mgh$ $U_s = \frac{1}{2}Kx^2$

$U_G = -\frac{Gm_1 m_2}{r}$

$\vec{a} \cdot \vec{b} = ab\cos\theta$

$E = U + K$

$\boxed{E_i + W_{NC} = E_f}$

FORMULA

$\omega = \frac{d\theta}{dt}$ $\vec{\alpha} = \frac{d\vec{\omega}}{dt}$

$\omega = \omega_0 + \alpha t$

$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$

$\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$

$\boxed{\sum \vec{\tau} = I\vec{\alpha}}$

$I = \sum m_i r_i^2 = \int r^2 dm$

$I_A = I_{cm} + md^2$

$I(\text{particle}) = mr^2$

$W_{NET} = \Delta K$

$K = \frac{1}{2}I\omega^2$

$\vec{p} = m\vec{v}$

$\boxed{\vec{F}\Delta t = \vec{I} = \vec{\Delta p}}$

$\boxed{\sum \vec{p}_{before} = \sum \vec{p}_{after}}$

$\vec{I} = \int \vec{F}\, dt$

FORMULA

$g = 9.80\ m/s^2$

$\Delta s = r\theta$

$v_T = r\omega$

$a_T = r\alpha$

$a_c = \frac{v^2}{r} = v\omega = r\omega^2$

$\tau = F_\perp r = r_\perp F$

$I_{DISK} = \frac{1}{2}MR^2$

$I_{RING} = MR^2$

$I_{SOLID\ SPHERE} = \frac{2}{5}MR^2$

$I_{HOLLOW\ SPHERE} = \frac{2}{3}MR^2$

$I_{cm\ ROD} = \frac{1}{12}ML^2$

$G = 6.673 \times 10^{-11} \frac{N \cdot m^2}{Kg^2}$

$M_{Earth} = 5.98 \times 10^{24}\ Kg$

$R_{Earth} = 6.37 \times 10^6\ m$

$M_{Mars} = 6.42 \times 10^{23}\ Kg$

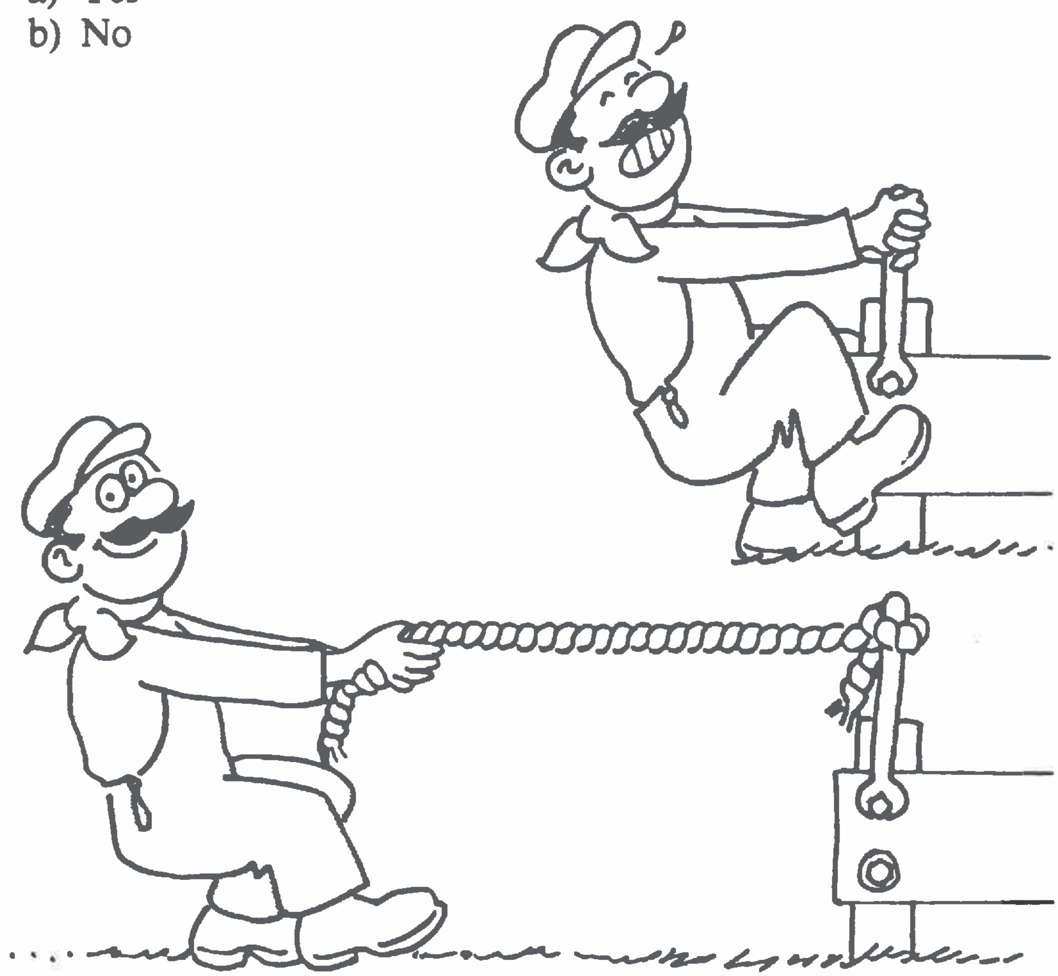
$R_{Mars} = 3.37 \times 10^6\ m$

$P = \frac{W}{t} = \vec{F} \cdot \vec{v}$

TORQUE

Harry is finding it very difficult to muster enough torque to twist the stubborn bolt with a wrench and he wishes he had a length of pipe to place over the wrench handle to increase his leverage. He has no pipe, but he does have some rope. Will torque be increased if he pulls just as hard on a length of rope tied to the wrench handle?

a) Yes
b) No



EXAM #3 - SAMPLE 2

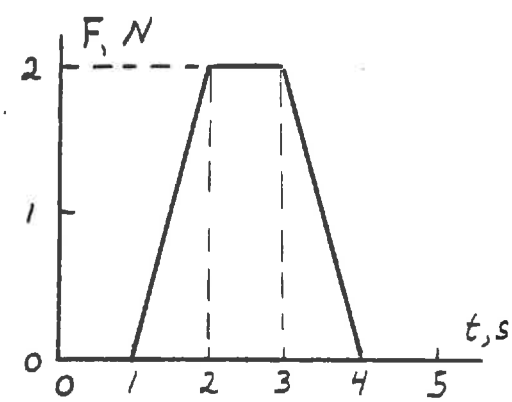
PHYSICS 103 **EXAM 3** **NAME**________________
McClure

Write your name above. This exam has 2 parts. The last page of this exam is the formula page. You may remove it for use during the exam. Note that some questions are worth more points than other questions. Answer each question in the space provided.

PART I. Multiple Choice. (30 pts) Circle the letter corresponding to best answer. There are 10 multiple choice questions.

1. A ball is dropped from a building. If a second ball is dropped from a building twice as high as the first, then the second ball hits the ground with
   a) twice the velocity as the first.
   b) twice the kinetic energy as the first.
   c) four times the velocity as the first.
   d) four times the kinetic energy as the first.
   e) both (b) and (c).

2. The graph at the right shows the time variation of a force acting in the x direction on a 0.5 kg particle initially at rest. Calculate the impulse on the particle.
   a) 0 N·s
   b) 1 N·s
   c) 4 N·s
   d) 6 N·s
   e) 8 N·s

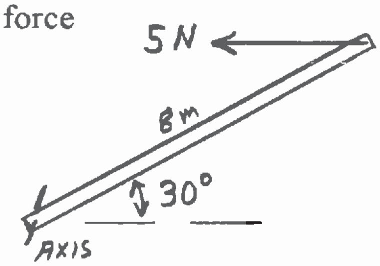


3. A 3 kg steel ball moving at 5 m/s hits a solid wall and rebounds at 5 m/s in the opposite direction. The impulse that acted on the wall was
   a) 30 N·s.
   b) 25 N·s.
   c) 20 N·s.
   d) 15 N·s
   e) 0 N·s.

4. Two lumps of clay are moving toward one another along a straight line with equal speeds of 10 m/s. If the mass of the first lump is twice that of the second, the **magnitude** of the velocity on the final lump is
   a) 10 m/s.
   b) 7.5 m/s.
   c) 6.7 m/s.
   d) 3.3 m/s.
   e) 2.5 m/s.

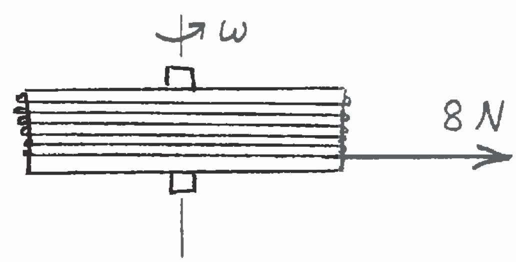
5. An object is moving along the x-axis with a constant velocity. If it receives an impulse which doubles its momentum, its kinetic energy
   a) is doubled.
   b) is quadrupled
   c) increases by 1.7.
   d) remains unchanged.
   e) none of these.

6. A rod of length 8 meters is held at an angle of 30° by a 5 N force as shown. The torque produced by the force about axis A is
   a) 40 N·m.
   b) 34.6 N·m.
   c) 30 N·m.
   d) 20 N·m.
   e) 18.6 N·m.



7. A wheel rotating at 40 rad/s slows down to 10 rad/s in 12 seconds. The angular acceleration is
   a) -1.7 rad/s^2.
   b) -2.5 rad/s^2.
   c) -3.3 rad/s^2.
   d) -7.5 rad/s^2.
   e) -12.5 rad/s^2.

Questions 7 and 8 refer to the flywheel in the form of a disk of radius 0.10 meters and mass 5 kg pictured below. A string is wound about the flywheel as shown. Starting from rest, the string is pulled with a steady force of 8 N for 5 seconds.



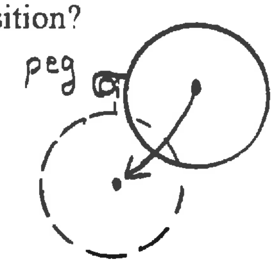
7. The acceleration of the flywheel is
   a) 16 rad/s^2.
   b) 24 rad/s^2.
   c) 32 rad/s^2.
   d) 64 rad/s^2.
   e) 128 rad/s^2.

8. The final kinetic energy of the flywheel is
   a) 180 J.
   b) 320 J.
   c) 450 J.
   d) 640 J.
   e) 840 J.

9. A particle of mass 0.4 kg is attached to one end of a 2 meters long rod of mass 0.6 kg. The other end of the rod is attached to an axis and the rod is rotated in a horizontal plane with constant angular speed 5 rad/s. The moment of inertia of the system (rod + mass) is

a) $0.24\ kg{\cdot}m^2$.
b) $0.48\ kg{\cdot}m^2$.
c) $0.72\ kg{\cdot}m^2$.
d) $0.96\ kg{\cdot}m^2$.
e) $1.24\ kg{\cdot}m^2$.

10. A hook is placed on the surface of a small solid spherical ball of mass M and radius R so that it can attached to a horizontal peg and allowed to rotate about the peg as shown. The sphere is pulled aside until its cm is level with the peg and released. How fast is the sphere rotating (in rad/s) as its cm passes through its lowest position?



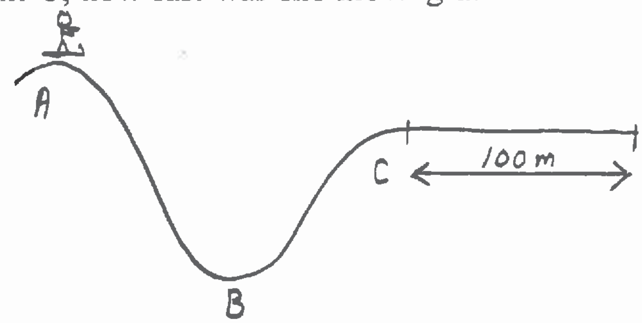
a) $\sqrt{2g/R}$
b) $2\sqrt{g/R}$
c) $\sqrt{g/5R}$
d) $\sqrt{5g/R}$
e) $\sqrt{10g/7R}$

PART II. Problems. To receive full credit for each problem, **show all your work** including relevant diagrams, sketches and starting formulas. Be sure to write complete answers including units. There are 5 problems.

1. (12 pts) A 3 kg ball collides **elastically** head on with a ball of unknown mass that was initially at rest. If the 3 kg ball rebounds from the collision with one-fourth its original speed, what is the unknown mass?

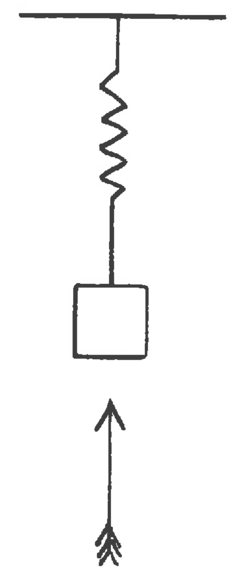
2. (15 pts) A 60 kg skier zooms down Hill A, through valley B, and over the top of hill C. The path from A to C is frictionless.

a) If the skier was moving at 12 m/s at the top of hill C, how fast was she moving at the bottom of valley B?



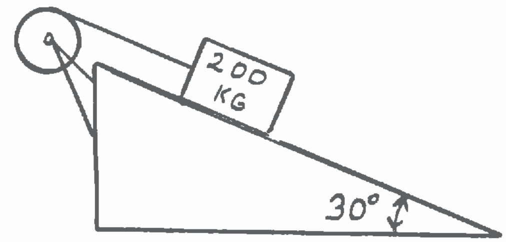
b) Beyond hill C is a horizontal stretch of rough snow. The skier moves 100 meters from point C before coming to rest on this horizontal stretch of snow. Assuming a constant force of friction between skies and snow, find the coefficient of friction between the skies and the snow.

3. (15 pts) Robin Hood shoots an arrow of mass 0.6 kg straight upward into a 1.2 kg block of wood. The block is attached to a spring of constant 90 N/m. The arrows sticks in the block and the resulting motion compresses the spring 2 meters. Find the speed of the arrow just before it hit the block.



4. (15 pts) A 200 kg mass is allowed to slide from rest down a frictionless incline as shown. The mass is attached to a large disk of moment of inertia 288 kg·m^2 and radius 1.2 m via a rope which is wrapped around the disk. Find

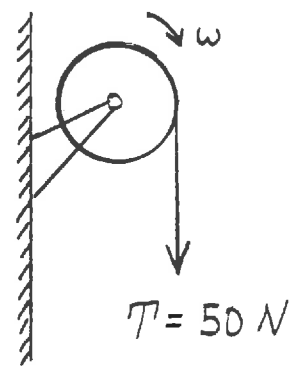
a) The acceleration of the 200 kg mass.



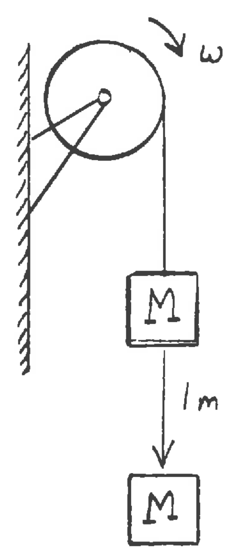
b) The tension in the rope.

5. (15 pts) A cord is wrapped around the rim of a flywheel of radius 0.5 meters and moment of inertia 4 kg·m^2. Assume the bearings of the flywheel are nearly frictionless.

a) A steady pull of 50 N is applied to the cord. Find the kinetic energy of the wheel after it has rotated through 5 complete revolutions.



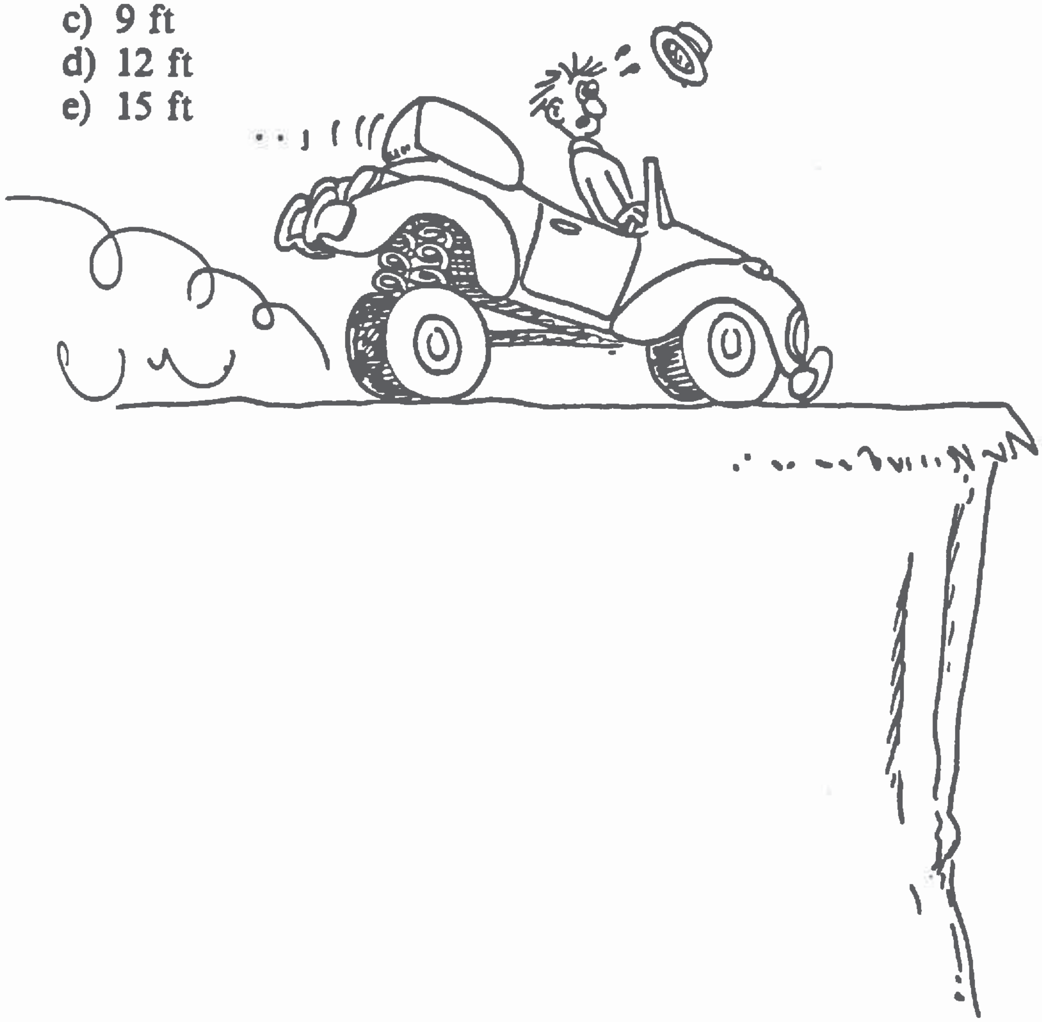
b) A mass M is attached to the cord. What value of M will cause the wheel to start from rest and reach a speed of 10 rad/s after the mass has fallen only one meter?



STOPPING

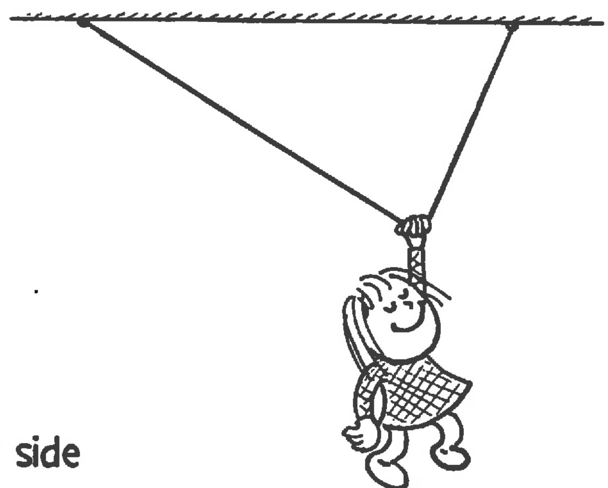
A car is going 10 mph. The driver hits the brakes. The car travels 3 feet after the brakes are applied. A while later the same car is going 20 mph. The driver hits the brakes. About how far does the car go after the brakes are applied?

a) 3 ft
b) 6 ft
c) 9 ft
d) 12 ft
e) 15 ft



FIGURING PHYSICS

Nellie Newton hangs by one hand motionless from a clothesline as shown — which is on the verge of breaking. Which side of the line is most likely to break?



a) Left side
b) Right side
c) 50/50 chance of either side breaking

FIGURING PHYSICS

Whenever an interaction occurs in a system, forces occur in equal and opposite pairs. Which of the following do *not* always occur in equal and opposite pairs?

a) Impulses.
b) Accelerations.
c) Momentum changes.
d) But all of these occur in equal and opposite pairs.
e) None.

Hewitt Drew it!

FINAL EXAM REVIEW

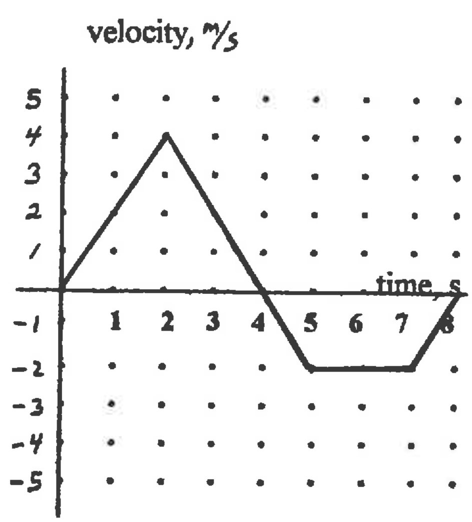
PRACTICE QUESTIONS **PHYSICS 103**

The following practice questions are questions in multiple choice format from all the areas of physics that you studied during the semester. These questions are a mix of knowledge based quires and simple problems designed to test your knowledge of the vocabulary, concepts and the fundamental principles of mechanics and to test your skill in working simple problems based on these concepts and principles. You will need several scratch sheets of paper for working the problems. Read each question carefully, draw a sketch or diagram if needed and determine the *best* answer to each question or problem.

1. The *MKS units* of acceleration are a) meters. b) meters/second. c) $meters^2/second$. d) $meters/second^2$. e) meters/second/meter.

2. Which of the following are *vectors*? a) displacement b) velocity c) distance d) both (a) and (b) e) All are vectors.

3. An object travels from point A to point B. The magnitude of its *displacement* is
   a) greater than or equal to the distance traveled.
   b) less than or equal to the distance traveled.
   c) always equal to the distance traveled.
   d) always smaller than the distance traveled.



Questions 4 through 6 refer to the graph at the right which shows the velocity vs time graph of object.

4. During what *time interval* is the object slowing down? a) 0 to 2 s b) 2 to 5 s c) 2 to 4 s d) 4 to 5 s e) 5 to 7 s

5. What is the *average acceleration* during the time interval t=1 to t=5 seconds? a) 4 m/s^2 b) 2 m/s^2 c) zero d) −1 m/s^2 e) −2 m/s^2

6. What is the *displacement* of the object during the time interval t = 2 s to t = 5 s? a) 5 m b) 3 m c) 1 m d) zero e) −2 m

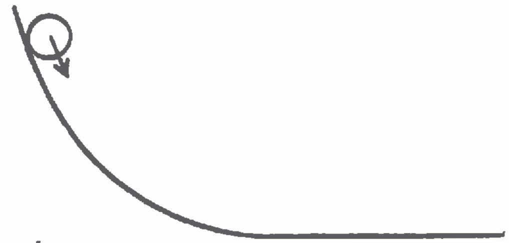
7. Point **P** is (2, 5) and point **Q** is (−3, 4). The *position vector* for point **P** is a) 2 **i** + 5 **j**. b) 3 **i** + 4 **j**. c) −3 **i** + 5 **j**. d) −5 **i** − **j**. e) 4 **i** − 3 **j**.

8. Point **P** is (2, 5) and point **Q** is (−3, 4). The *displacement vector*, **QP**, is a) 2 **i** + 5 **j**. b) 3 **i** + 4 **j**. c) −3 **i** + 5 **j**. d) −5 **i** − **j**. e) 4 **i** − 3 **j**.

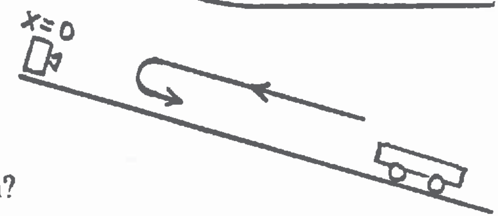
9. If you drop an object, its acceleration is −9.80 m/s^2. If you throw the object straight up with an initial velocity of 5 m/s, its acceleration just after leaving your hand is a) −14.80 m/s^2. b) −9.80 m/s^2. c) −4.80 m/s^2. d) zero. e) +4.80 m/s^2.

10. If you drop an object, its acceleration is $-9.80\ m/s^2$. If you throw the object straight up with a velocity of 5 m/s, its acceleration at the very top of its path is a) $-14.80\ m/s^2$. b) $-9.80\ m/s^2$. c) $-4.80\ m/s^2$. d) zero. e) $+4.80\ m/s^2$.

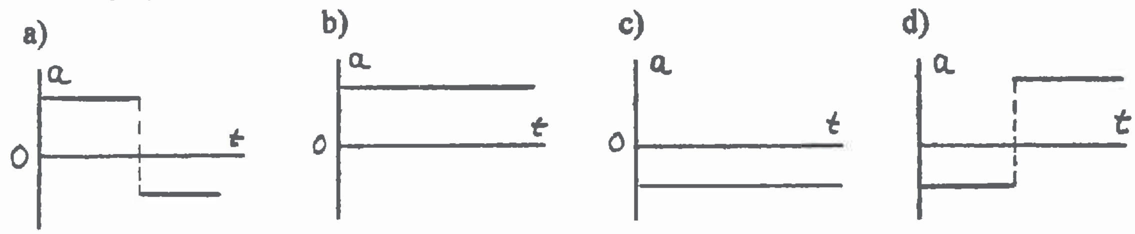
11. A ball rolls down a hill as shown. As it rolls down,
a) its velocity increases and its acceleration increases.
b) its velocity increases and its acceleration decreases.
c) its velocity decreases and its acceleration increases.
d) its velocity decreases and its acceleration decreases.
e) Cannot be determined from the information given.



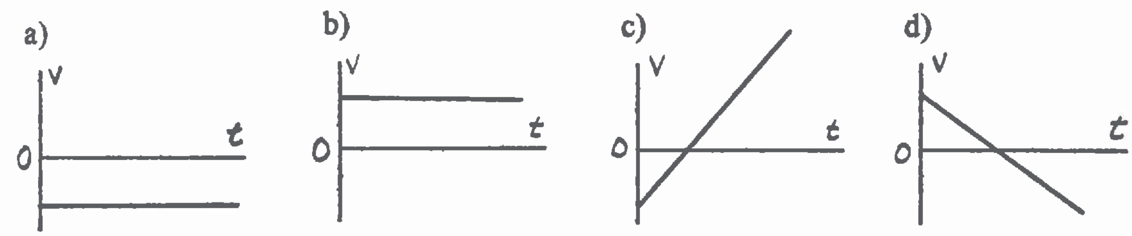
Questions 12 through 14 refer to a cart which is launched up an inclined plane as shown. A motion detector, placed at the top of the plane, records the motion of cart.



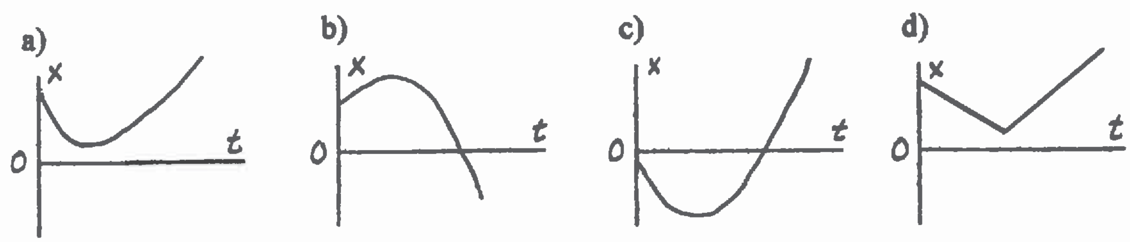
12. Which graph best describes its *acceleration vs time* motion?



13. Which graph best describes its *velocity vs time* motion?



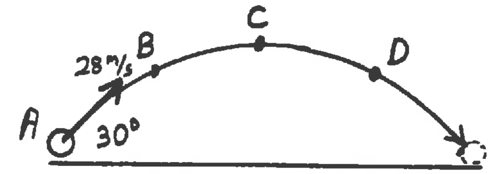
14. Which graph best describes its *position vs time* motion?



15. A truck travels 1000 meters east, then 1000 meters south. The trip takes 500 seconds. The magnitude of the *average velocity* of the truck is a) 4 m/s. b) 2 m/s. c) 2.8 m/s. d) 3.2 m/s. e) 4.4 m/s.

16. Two balls, a **red** ball and a **blue** ball start from rest at the same time and accelerate at the same rate, but the **blue** ball accelerates for twice the time as the **red** ball. The *displacement* of the **blue** ball is how much longer than that of the **red** ball? a) The same. b) 1.5 times longer. c) Twice as long. d) Four times as long.

Questions 17 through 19 refer to a ball thrown with an initial velocity of 28 m/s at an angle of 30° above the horizontal as shown. Points A through D are positions along the trajectory of the ball.



17. What is the *vertical component* of the *velocity* of the ball at point A?
a) 24.2 m/s b) 14 m/s c) 9.8 m/s d) zero e) −9.8 m/s

18. What is the *acceleration* of the ball at position D? a) +24.2 m/s² b) +14 m/s² c) +9.8 m/s² d) zero e) −9.8 m/s²

19. What is the *velocity* of the ball at point C? a) +24.2 m/s b) +14 m/s c) +9.8 m/s d) zero e) −9.8 m/s

20. The *MKS units* for inertia are a) kilograms. b) Newtons. c) Joules. d) grams. e) m/s².

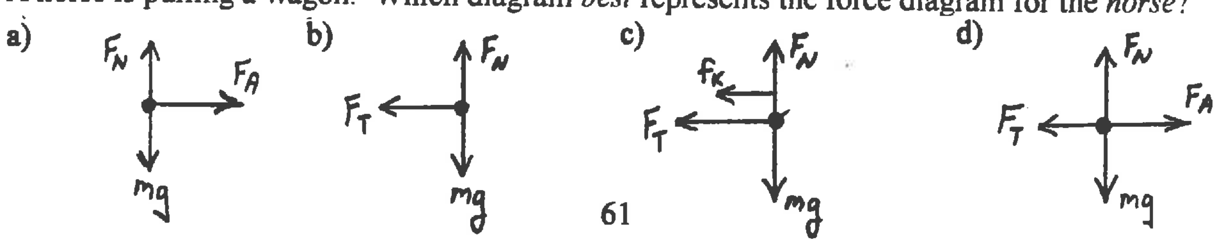
21. Which of the following quantities are *scalars*? a) mass b) energy c) momentum d) Only (a) and (b) are scalars. e) All are scalars.

22. Consider a person of mass M standing in an elevator that is *accelerating* upward. The normal for acting on the person is a) Mg. b) larger than Mg. c) smaller than Mg. d) Cannot be determined from the given information.

23. A horse is pulling a wagon. What force is the *reaction force* to the pull of the horse on the wagon?
a) The pull of the wagon back on the horse.
b) The push of the ground up on the horse.
c) The pull upward on the earth due to horse.
d) The push down on the ground due to the horse.
e) The pull of the ground forward on the feet of the horse.

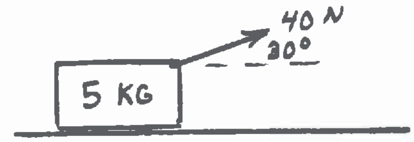
24. A horse is pulling a wagon. What force is the *reaction force* to the weight of the horse?
a) The pull of the wagon back on the horse.
b) The push of the ground up on the horse.
c) The pull upward on the earth due to horse.
d) The push down on the ground due to the horse.
e) The pull of the ground forward on the feet of the horse.

25. A horse is pulling a wagon. Which diagram *best* represents the force diagram for the *horse*?

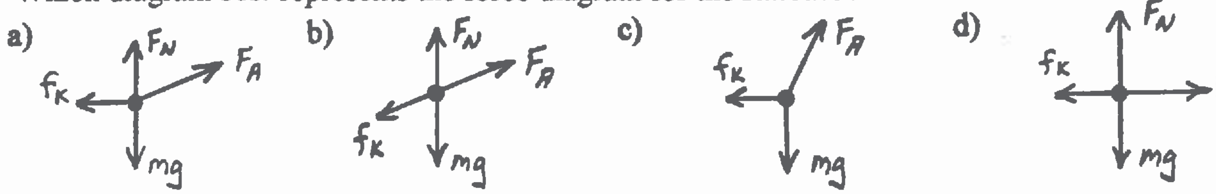


26. An 800 kg horse is pulling a wagon of mass 1200 kg. If the acceleration of the wagon is 2 m/s^2, with what force is the horse pushing backward on the ground? Ignore friction acting on the wagon.
a) 4000 N b) 6000 N c) 8000 N d) 2000 N e) 19,600 N

Questions 27 through 30 refer to a 5 kg suitcase that is pulled 12 meters over a *rough* surface by a force of 40 N directed 30° above the horizontal as shown in the diagram.



27. Which diagram *best* represents the force diagram for the *suitcase*?



28. If the suitcase accelerates at 3 m/s^2, what is the *magnitude* of the *force of friction*? a) 5.8 N b) 8.4 N c) 12.7 N d) 19.6 N e) 34.6 N

29. The *magnitude* of the *normal force* that acts on the suitcase is a) 29 N. b) 35 N. c) 49 N. d) 56 N. e) 68 N.

30. The *work* done on the suitcase by the pulling force is a) 480 J. b) 240 J. c) 416 J. d) 588 N.

31. The MKS units for *work* are a) Joules. b) Newton·second. c) kg·m/s. d) Watt. e) Watt·meters.

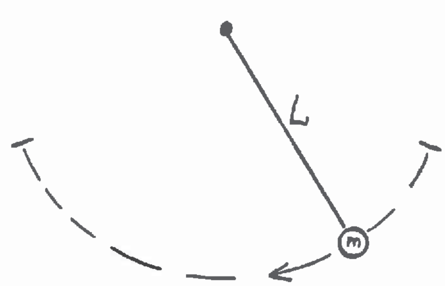
32. A dart is shot straight up into the air by a spring-loaded toy gun and the dart reaches a height of 24 meters. If the same dart is now shot a second time from the same gun, but the spring is compressed only *one-half* as much, how high does the dart rise? a) 6 m b) 8 m c) 12 m d) 48 m e) 96 m

33. A 10 N object is thrown straight upward. If air resistance acts on the object, what diagram *best* represents the force diagram of the object just after it was released?

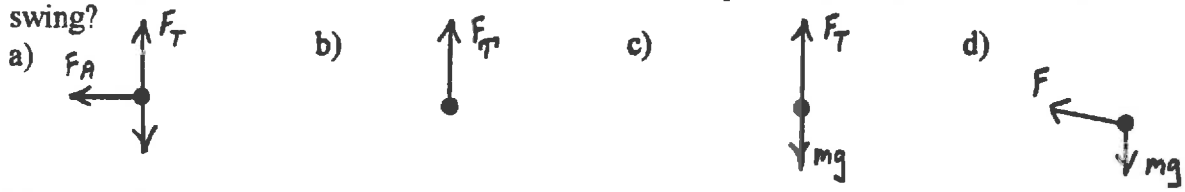
34. A 10 N object, thrown straight upward, is given an initial kinetic energy of 200 J. If it rises to a maximum height of 12 meters, the magnitude of the air resistance is a) 6.6 N. b) 5.2 N. c) 3.6 N d) 1.8 N.

Questions 35 through 36 refer to a pendulum of mass 0.25 kg and length 0.80 m swinging back and forth over the same path as shown at the right.

35. At what point in its swing is the tension in the string the greatest?
a) At the bottom of its path.
b) At either end of its path.
c) Somewhere between the end and the bottom.
d) The tension is the same at all points of its path.



36. Which diagram *best* represents the force diagram of the pendulum bob when it is at the bottom of its swing?

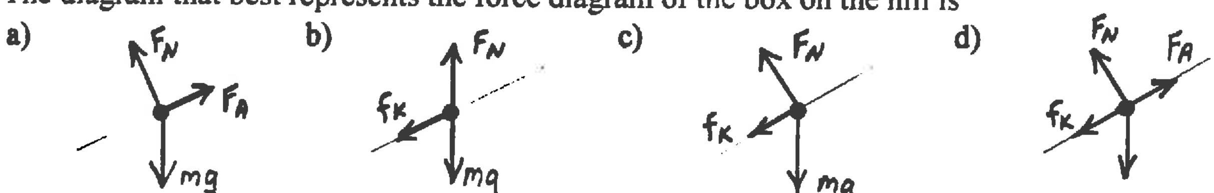


37. If the tension in the string at the bottom of the swing is 6 N, what is the *speed* of the pendulum?
a) 5.80 m/s b) 4.52 m/s c) 3.37 m/s d) 2.89 m/s e) 1.25 m/s

38. If the mass of the earth doubled and its radius decreased to one-half its present value, then your *weight* would change by a factor of a) ½. b) 1. c) 2. d) 4. e) 8.

Questions 39 through 41 refer to a 3 kg box originally sliding along a level surface at 10 m/s toward a hill. The surface of the hill is *rough.*

39. The diagram that best represents the force diagram of the box on the hill is



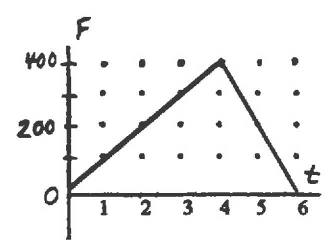
40. If the box slides 6 meters up along the hill to a height of 2 meters, what average *force of friction* acted on the box? a) 15.2 N b) 12.6 N c) 10.6 N d) 18.4 N e) 29.4 N

41. How high would the box slide if the hill were *frictionless*? a) 1.5 m b) 2.0 m c) 3.8 m d) 4.5 m e) 5.1 m

42. The **red** box of mass 2 kg is moving at 10 m/s and the **blue** box of mass 8 kg is moving at 5 m/s. Both boxes are stopped by the same force. Which force must act for the *longer time*? a) The force on the **red** box. b) The force on the **blue** box. c) The time is the same for both forces.

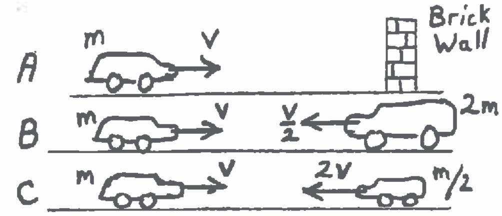
43. The **red** box of mass 2 kg is moving at 10 m/s and the **blue** box of mass 8 kg is moving at 5 m/s. Both boxes are stopped by the same force. Which force must act over the *longer distance*? a) The force on the **red box.** b) The force on the **blue** box.
c) The distance is the same for both forces.

44. The time variation of a force is shown in the graph at the right. The *impulse* delivered by this force is a) 400 N·s. b) 800 N·s. c) 1000 N·s.
d) 1200 N·s. e) 1400 N·s.



45. A 2 kg ball, traveling at 10 m/s, hits a brick wall and rebounds at 8 m/s. The *impulse* delivered to the wall by the ball is a) 12 N·s. b) 16 N·s. c) 20 N·s.
d) 36 N·s. e) Cannot be determined from the given information.

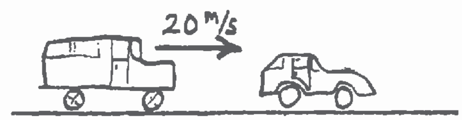
46. A 2 kg ball, traveling at 10 m/s, hits a brick wall and rebounds at 8 m/s. The *average force* exerted on the wall by the ball is a) 12 N. b) 16 N. c) 20 N. d) 32 N. e) Cannot be determined from the given information.



47. All three collisions are shown in the figure at the right are perfectly inelastic. Which collision brings the car on the left to a halt? a) Collision A b) Collision B c) Collisions A and B d) All three collisions. e) Collision C.

48. Two lumps of clay are moving toward one another along the x-axis with equal speeds of 10 m/s. If the mass of the first lump is twice that of the second lump and the two lumps stick together during the collision, what is the *speed* of the final lump after their collision? a) 10 m/s b) 7.5 m/s c) 6.7 m/s d) 3.3 m/s e) 2.5 m/s.

Questions 49 through 51 refer to the 3000 kg truck, moving to the right at 20 m/s, which collides into the rear of a 1000 kg car at rest. The car leaves the collision with an initial velocity of 10 m/s to the right.



49. Which vehicle experiences the larger collision force? a) The truck. b) The car. c) The collision force is the same on both. d) Cannot be determined from the information given.

50. What *impulse* acted on the car during the collision? a) 10,000 N·s b) 20,000 N·s c) 30,000 N·s d) 40,000 N·s e) 50,000 N·s

51. The *velocity* of the truck after the collision is a) −4.7 m/s. b) zero. c) 8.7 m/s. d) 12.3 m/s e) 16.7 m/s.

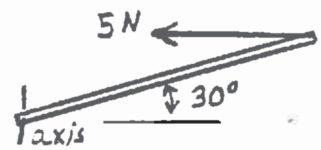
52. An object, moving along the x-axis, receives an impulse that doubles its momentum. It *kinetic energy* is a) doubled. b) halved. c) increased by $\sqrt{2}$. d) increased by 2. e) increased by 4.

53. Which quantity, if any, is <u>not</u> a *vector*? a) impulse b) torque c) angular displacement d) angular acceleration e) All are vectors.

54. The *MKS units* of <u>moment of inertia</u> are a) kg. b) $kg{\cdot}s^2$. c) $kg{\cdot}m^2$. d) N·m. e) $kg{\cdot}m^2/s$.

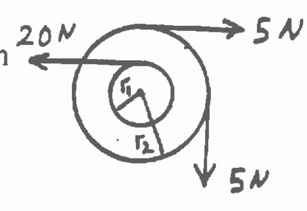
55. An auto with tires of radius 20 cm is moving at 15 m/s. Each tire is rotating at a) 25 rad/s. b) 50 rad/s. c) 75 rad/s. d) 100 rad/s. e) 30 rad/s.

56. A meter stick, fixed to rotate about one end, has a 5 N force applied to its other end as shown. The *torque* due to this force is a) 4 N·m. b) 3.5 N·m. c) 3.0 N·m. d) 2.5 N·m. e) 1.9 N·m.



57. What is the *net torque* exerted on the wheel shown at the right? a) 10 N·m b) 5 N·m c) 2.5 N·m d) zero e) −2.5 N·m

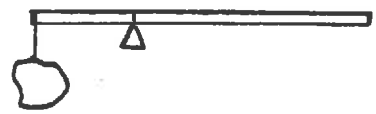
$r_1 = 25$ cm
$r_2 = 50$ cm



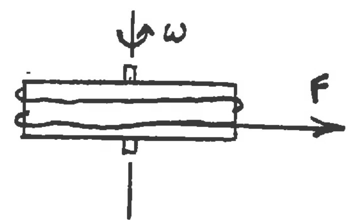
58. A bus makes a right turn. The *direction* of its angular velocity is a) to the front of the bus. b) to the read of the bus. c) up toward the sky. d) down toward the ground.

59. After placing a key in your door lock, you turn the key counterclockwise to unlock the door. The *direction* of the torque applied to the key is a) in toward the door. b) out from the door. c) to the left. d) to the right. e) up to the top of the door.

60. A 10 N rock is tied to one end of a meter stick as shown at the right. The meter stick is then balanced at its 25 cm mark. What is the *weight* of the meter stick? a) 2.5 n b) 5 N c) 10 N d) 15 N e) 20 N



Questions 61 through 63 refer to the flywheel at the right which has a cord wound around it. The cord is pulled with a steady force of 80 N for a distance of 5 meters. The radius of the flywheel is 0.10 meters and it starts from rest.



61. If the angular acceleration of the flywheel is 2 rad/s^2, what is the *moment of inertia* of the wheel? a) 4 kg·m^2 b) 2 kg·m^2 c) 1 kg·m^2 d) 0.5 kg·m^2 e) 0.25 kg·m^2

62. The final *kinetic energy* of the flywheel is a) 200 J. b) 380 J. c) 400 J. d) 500 J. e) 800 J.

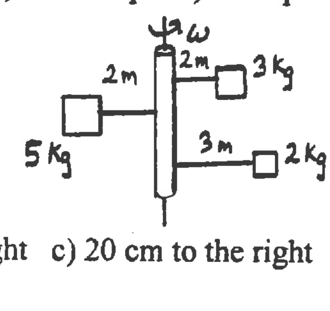
63. What was the *angular displacement* of the wheel during its acceleration? a) 10 rad b) 25 rad c) 50 rad d) 75 rad e) 100 rad

64. A hoop and a sphere of the same mass and radius are released simultaneously from the top of an incline. Which, if either, has the larger *total KE* at the bottom? a) The hoop. b) The sphere. c) They both have the same KE.

65. A hoop and a sphere of the same mass and radius are released simultaneously from the top of an incline. Which, if either, *reaches the bottom* of the incline first? a) The hoop. b) The sphere. c) They both reach the bottom at the same time.

66. A hoop and a sphere of the same mass and radius are released simultaneously from the top of an incline. Which, if either, has the larger *rotational KE* at the bottom? a) The hoop. b) The sphere. c) They both have the same rotational KE.

Questions 67 and 68 refer to the three mass system shown at the right. Each mass is attached to a vertical rod and the rod rotates about an axis through its center.

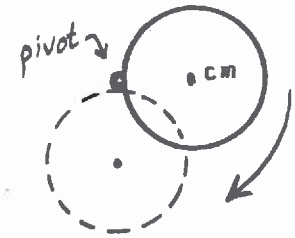


67. At the instant shown in the figure, where is its *center of mass* with respect to the axis of rotation? a) 25 cm to the left b) 15 cm to the right c) 20 cm to the right d) 25 cm to the right

68. The *moment of inertia* of the system about its axis of rotation is a) 25 kg·m^2. b) 50 kg·m^2. c) 65 kg·m^2. d) 75 kg·m^2. e) 80 kg·m^2.

69. The *MKS units* for <u>angular momentum</u> are a) kg·m². b) kg·m/s². c) kg·m²/s. d) N·m/s.

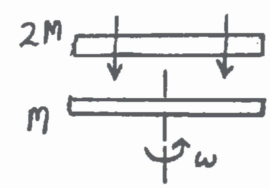
70. A disk of mass M and radius R is free to rotate about an axis through its rim as shown. If it is released from rest when its c.m. is level with the axis, what expression gives its angular speed as it rotates through its lowest position? a) $\sqrt{2g/R}$ b) $2\sqrt{gR}$ c) $\sqrt{g/R}$ d) $\sqrt{5g/R}$ e) $\sqrt{10g/5R}$



71. Which quantity is a *vector*? a) angular momentum b) moment of inertia c) rotational KE d) only (a) and (b) e) All three are vectors.

72. A person stands on a platform that is free to rotate about a vertical axis. The person holds a weight in each hand at arm's length and it given a small rotational velocity. The person then pulls the masses in close to her body. As the masses are pulled in, a) her angular momentum increases. b) her angular momentum decreases. c) her angular speed decreases. d) her rotational kinetic energy decreases. e) None of the above.

73. A disk of mass M and radius R is rotating about its center with angular speed ω as shown when a second disk of mass 2M and radius R is dropped onto it. When the two disks finally acquire the same angular speed, their *speed* is a) 2ω. b) 3ω. c) ω. d) ω/2. e) ω/3.

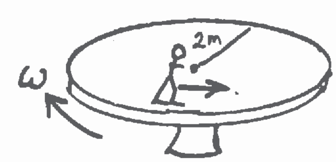


74. A 20 kg disk of radius 0.5 m is rotating at 4 rad/s and a 50 kg solid sphere of radius 0.5 m is rotating at 2 rad/s. If both objects are stopped by the same torque, which object, if either, will be stopped in the *shortest* time? a) The disk. b) The sphere. c) The times are equal.

75. A 20 kg disk of radius 0.5 m is rotating at 4 rad/s and a 50 kg solid sphere of radius 0.5 m is rotating at 2 rad/s. If both objects are stopped by the same torque, which object, if either, will be stopped with the *shortest* angular displacement? a) The disk. b) The sphere. c) The times are equal.

76. A 200 N mass is attached to the end of a rope that is wrapped around a flywheel. If the mass is released from rest 2 meters above the floor, the final rotational kinetic energy of the flywheel is a) 400 J. b) Less than 400 J. c) Greater than 400 J.

Questions 77 through 79 refer to the diagram at the right which shows an 80 kg person initially *standing* at the rim of a large playground disk of radius 2 meters. The person begins to walk around its rim at a steady speed of 6 m/s with respect to us.



77. We observe that the large disk is rotating with an angular speed of 4 rad/s. What is the *angular speed* of the person? a) 3 rad/s b) 4 rad/s c) 6 rad/s d) 8 rad/s e) Cannot determine from the information given.

78. As the person walks on the rim of the disk, we observe its angular speed to be 4 rad/s. Determine the *moment of inertia* of the disk. a) 80 kg·m² b) 120 kg·m² c) 180 kg·m² d) 240 kg·m² e) 360 kg·m²

79. What angular impulse was applied to the disk by the person to get the disk spinning? a) 120 N·m·s b) 240 N·m·s c) 380 N·m·s d) 960 N·m·s e) 1260 N·m·s

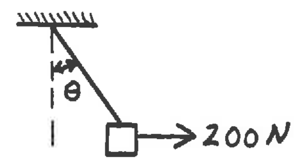
80. As you drive your car forward, what is the *direction* of the angular momentum of the right front tire? a) To the front of the car. b) To the rear of the car. c) To your left. d) To your right. e) Up toward the sky.

81. The sum of *forces* on an object is zero. Is the object in equilibrium? a) Definitely yes. b) Definitely no. c) Cannot tell from the information given.

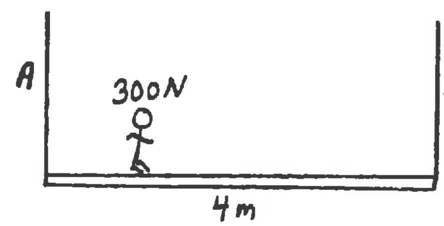
82. The sum of *torques* on an object is zero. Is the object in equilibrium? a) Definitely yes. b) Definitely no. c) Cannot tell from the information given.

83. You determine that the net torque and the net force acting on an object are both zero. Can the object still be rotating and translating with respect to you? a) Yes. b) No. c) Cannot tell from the information given.

84. A 100 N box, hanging from the ceiling via a rope, is pushed to one side by a 200 N force as shown at the right. The angle θ the rope makes with the vertical is a) 30°. b) 54.2°. c) 58.4°. d) 63.4°.



Questions 85 and 86 refer to the diagram at the right which shows a 300 N person standing on a horizontal plank of length 4 meters and weight 600 N. The plank is held up by two ropes attached to each end of the plank.



85. If the tension in rope B is 400 N, what is the tension in rope A? a) 200 N b) 300 N c) 400 N d) 500 N e) 600 N

86. How far is the person standing from the left end of the plank? a) 0.94 m b) 1.33 m c) 1.35 m d) 1.84 m e) 2.00 m

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