

TI-83+ / TI-84+ Calculator Programs

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These calculator programs are written for the Texas Instruments TI-83+ graphing calculator and similar models with the Z80 processor, using the built-in TI-BASIC language. Refer to Chapter 16 of the *TI-83+ Guidebook* for instructions on entering and running a program in the calculator.

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1 Projectile Problem

This program solves the projectile problem: given a target sitting on a hill at coordinates (x_t, y_t) and a cannon with muzzle velocity v_0 , at what angle θ should the cannon be aimed to hit the target? The solution is found numerically using Newton's method.

After running the program, the calculator will be set to degrees mode.

Program Listing

```
PROGRAM:PROJTL
:Radian
:Prompt V,X,Y, $\theta$ 
: $\theta*\pi/180\rightarrow\theta$ 
:For(J,1,15)
: $\theta-(X*\sin(2*\theta)-2*Y*(\cos(\theta))^2-9.8*(X/V)^2)/(2*X*\cos(2*\theta)+2*Y*\sin(2*\theta))\rightarrow\theta$ 
:End
: $\theta*180/\pi\rightarrow\theta$ 
:Disp " $\theta=$ ", $\theta$ 
:Degree
```

Example. Let $v_0 = 30$ m/s, $(x_t, y_t) = (50 \text{ m}, 20 \text{ m})$, and $\theta_0 = 30^\circ$. Enter the above program, press PRGM and execute program PROJTL. At the prompt $V=?$ enter 30 ENTER; at the prompt $X=?$ enter 50 ENTER; at the prompt $Y=?$ enter 20 ENTER; and at the prompt $\theta=?$ enter 30 ENTER. The program returns $\theta = 41.53570793^\circ$.

2 Kepler's Equation

Given the mean anomaly M (in degrees) and the orbit eccentricity e , this program solves Kepler's equation

$$M = E - e \sin E$$

to find the eccentric anomaly E . This is a very simple implementation—it includes no convergence test, and simply solves Kepler's equation by performing 15 iterations of Newton's method.

To run the program, execute program KEPLER. At the prompt M=? enter the mean anomaly M in degrees followed by ENTER. At the prompt E=? enter the eccentricity e followed by ENTER. The program returns the eccentric anomaly E in degrees.

After running the program, the calculator will be set to degrees mode.

Program Listing

```
PROGRAM:KEPLER
:Radian
:Prompt M,E
:M*π/180→M
:M→A
:For(J,1,15)
:A-(M-A+E*sin(A))/(E*cos(A)-1)→A
:End
:A*180/π→A
:Disp "EA=",A
:Degree
```

Example. Let $M = 60^\circ$, $e = 0.15$. Enter the above program, press PRGM and execute program KEPLER. At the prompt M=? enter 60 ENTER; at the prompt E=? enter .15 ENTER. The program returns $E = 67.9666849^\circ$.

3 Hyperbolic Kepler's Equation

Given the mean anomaly M (in degrees) and the orbit eccentricity e , this program solves the hyperbolic Kepler equation

$$M = e \sinh F - F$$

to find the variable F . This is a very simple implementation—it includes no convergence test, and simply solves the hyperbolic Kepler equation by performing 15 iterations of Newton's method.

To run the program, execute program HKEPLER. At the prompt M=? enter the mean anomaly M in degrees followed by ENTER. At the prompt E=? enter the eccentricity e followed by ENTER. The program returns the variable F .

Program Listing

```
PROGRAM:HKEPLER
:Prompt M,E
:M*π/180→M
:M→A
:For(J,1,15)
:A-(M-E*sinh(A)+A)/(1-E*cosh(A))→A
:End
:Disp "F=",A
```

Example. Let $M = 60^\circ$, $e = 1.15$. Enter the above program, press PRGM and execute program HKEPLER. At the prompt M=? enter 60 ENTER; at the prompt E=? enter 1.15 ENTER. The program returns $F = 1.555518594$.

4 Barker's Equation

Given the constant $K = \sqrt{GM/(2q^3)}(t - T_p)$, this program solves Barker's equation

$$\tan\left(\frac{f}{2}\right) + \frac{1}{3}\tan^3\left(\frac{f}{2}\right) = \sqrt{\frac{GM}{2q^3}}(t - T_p)$$

to find the true anomaly f .

To run the program, execute program BARKER. At the prompt K=? enter the dimensionless number

$$K = \sqrt{\frac{GM}{2q^3}}(t - T_p)$$

followed by ENTER. The program returns the true anomaly f in degrees.

The program will work in either Degrees or Radians mode.

Program Listing

```
PROGRAM: BARKER
: Prompt K
: 1.5*abs(K) → A
: √(1+A*A) + A → B
: B^(1/3) → C
: (C*C-1) / (2*C) → D
: 2*D → E
: If K < 0
: Then
: -E → E
: End
: 2*tan-1(E) → F
: Disp "F=", F
```

Example. Let $K = 19.38$, and put the calculator in Degrees mode. Enter the above program, press PRGM and execute program BARKER. At the prompt K=? enter 19.38 ENTER. The program returns the true anomaly $f = 149.0847249^\circ$.

5 Reduction of an Angle

This program reduces a given angle to the range $[0, 360^\circ)$ in degrees mode, or $[0, 2\pi)$ in radians mode. It will work correctly whether the calculator is set for degrees or radians mode.

To run the program, execute program REDUCE. At the prompt $\theta=?$ enter the angle θ (in either degrees or radians) followed by ENTER. The program will return the equivalent reduced angle.

Program Listing

```
PROGRAM:REDUCE
:Prompt  $\theta$ 
: $2*\cos^{-1}(-1)\rightarrow T$ 
:If  $\theta < 0$ 
:Then
:iPart( $-\theta/T+1$ ) $\rightarrow V$ 
: $\theta+V*T\rightarrow R$ 
:Goto Z
:End
:If  $\theta \geq T$ 
:iPart( $\theta/T$ ) $\rightarrow V$ 
: $\theta-V*T\rightarrow R$ 
:Goto Z
:End
: $\theta \rightarrow R$ 
:Lbl Z
:Disp " $\theta=" , R$ 
```

Example. Let $\theta = 5000^\circ$, and set the calculator for Degrees mode. Enter the above program, press PRGM and execute program REDUCE. At the prompt $\theta=?$ enter 5000 ENTER. The program returns $\theta = 320^\circ$.

6 Helmert's Equation

Given the latitude θ (in degrees) and the elevation H , this program uses Helmert's equation to find the acceleration due to gravity g .

To run the program, execute program HELMERT. At the prompt $\theta=?$ enter the latitude θ in degrees followed by ENTER. At the prompt $H=?$ enter the elevation H followed by ENTER. The program returns the acceleration due to gravity g in m/s^2 .

After running the program, the calculator will be set to degrees mode.

Program Listing

```
PROGRAM:HELMERT
:Degree
:Prompt  $\theta$ ,H
: $9.80616-0.025928*\cos(2*\theta)+6.9E-5*(\cos(2*\theta))^2-3.086E-6*H\rightarrow G$ 
:Disp "G=",G
```

Example. Let $\theta = 38.898^\circ$, $H = 53$ m. Enter the above program, press PRGM and execute program HELMERT. At the prompt $\theta=?$ enter 38.898 ENTER; at the prompt $H=?$ enter 53 ENTER. The program returns $g = 9.800518527 \text{ m/s}^2$.

7 Pendulum Period

Given the length L and amplitude θ of a simple plane pendulum, this program finds the period T , using the arithmetic-geometric mean method.

To run the program, execute program PENDING. At the prompt $L=?$ enter the pendulum length L in meters followed by ENTER. At the prompt $\theta=?$ enter the pendulum amplitude θ in degrees followed by ENTER. The program returns the period T in seconds.

After running the program, the calculator will be set to degrees mode.

Program Listing

```
PROGRAM: PENDING
:Degree
:Prompt L,θ
:.5*(1+cos(.5*θ))→A
:√(cos(.5*θ))→G
:For(N,1,10)
:.5*(A+G)→B
:√(A*G)→G
:B→A
:End
:2*π*√(L/9.8)/A→T
:Disp "T=",T
```

Example. Let $L = 1.2$ m and $\theta = 65^\circ$. Enter the above program, press PRGM and execute program PENDING. At the prompt $L=?$ enter 1.2 ENTER. At the prompt $\theta=?$ enter 65 ENTER. The program returns $T = 2.389769497$ sec.

8 1D Perfectly Elastic Collisions

Given the masses m_1 and m_2 of two bodies and their initial velocities v_{1i} and v_{2i} , this program finds the post-collision velocities v_{1f} and v_{2f} , using

$$v_{1f} = \left(\frac{m_1 - m_2}{m_1 + m_2} \right) v_{1i} + \left(\frac{2m_2}{m_1 + m_2} \right) v_{2i}$$
$$v_{2f} = \left(\frac{2m_1}{m_1 + m_2} \right) v_{1i} + \left(\frac{m_2 - m_1}{m_1 + m_2} \right) v_{2i}$$

To run the program, execute program ELAS1D. At the prompts, enter the masses m_1 (as M) and m_2 (as N), and the initial velocities v_{1i} (as V) and v_{2i} (as W), in consistent units. The program will return the post-collision velocities v_{1f} and v_{2f} in the same units.

Program Listing

```
PROGRAM:ELAS1D
:Prompt M,N,V,W
:(M-N)/(M+N)*V+2*N*W/(M+N)->X
:2*M*V/(M+N)+(N-M)/(M+N)*W->Y
:Disp "V1F=",X
:Disp "V2F=",Y
```

Example. Enter the above program, press PRGM and execute program ELAS1D. At the prompts, enter: $m_1 = M = 2.0$ kg; $m_2 = N = 7.0$ kg; $v_{1i} = V = 4.0$ m/s; and $v_{2i} = W = -5.0$ m/s. The program returns $v_{1f} = -10$ m/s and $v_{2f} = -1$ m/s.