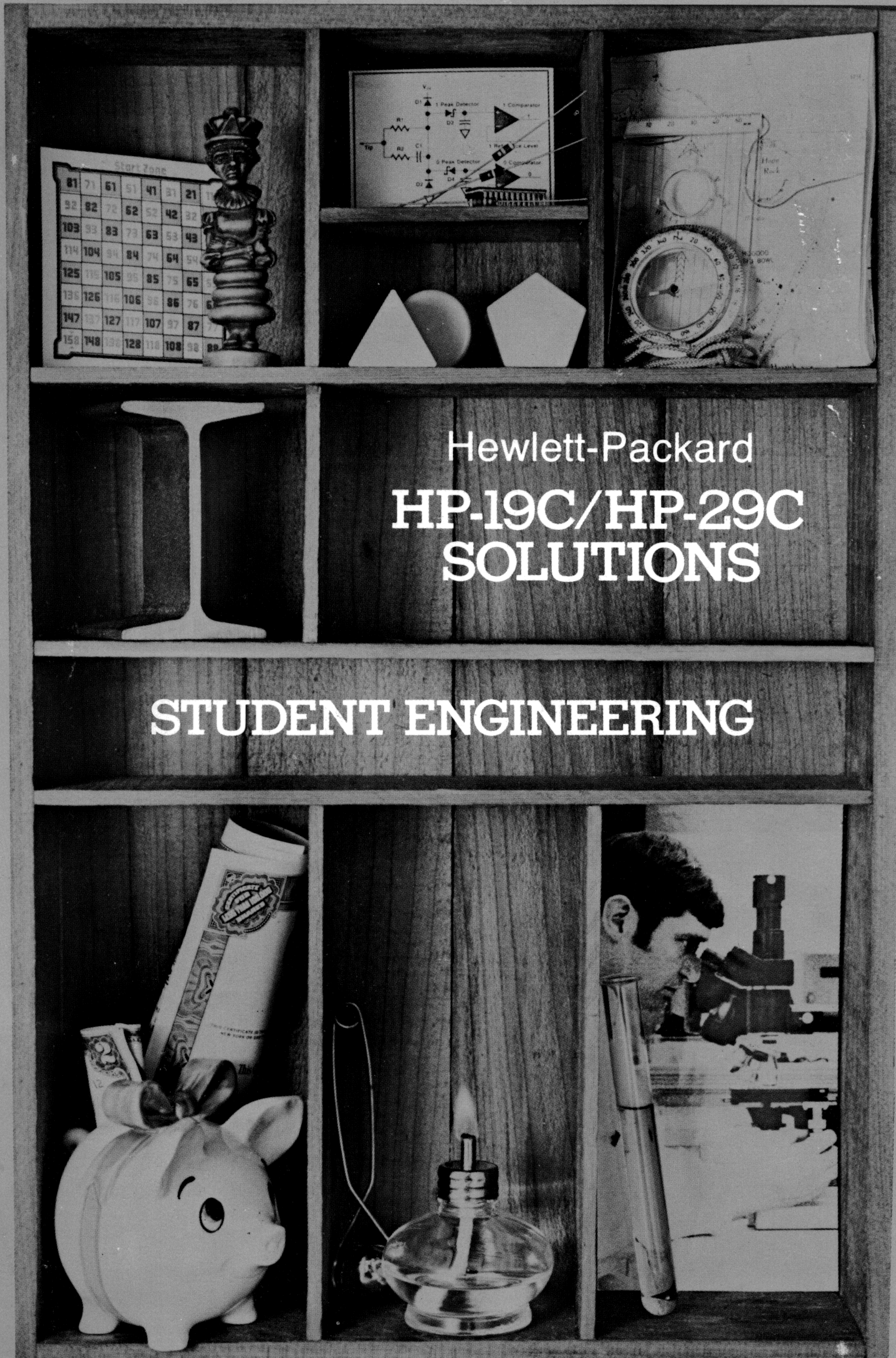
Hewlett-Packard

# HP-19C/HP-29C SOLUTIONS

# STUDENT ENGINEERING



# INTRODUCTION

This HP-19C/HP-29C Solutions book was written to help you get the most from your calculator. The programs were chosen to provide useful calculations for many of the common problems encountered.

They will provide you with immediate capabilities in your everyday calculations and you will find them useful as guides to programming techniques for writing your own customized software. The comments on each program listing describe the approach used to reach the solution and help you follow the programmer's logic as you become an expert on your HP calculator.

You will find general information on how to key in and run programs under "A Word about Program Usage" in the Applications book you received with your calculator.

We hope that this Solutions book will be a valuable tool in your work and would appreciate your comments about it.

# TABLE OF CONTENTS

# RESISTIVE/REACTIVE CIRCUIT CALCULATIONS

This program performs resonance calculations for R-L-C circuits, calculates the reactance of inductive and capacitive branches, the equivalent value of series capacitors or parallel resistors and inductors,and performs power calculations for resistive branches using straightforward manipulations of the following equations:

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

$$X_C = \frac{1}{2\pi fC}$$

$$X_L = 2\pi fL$$

$$P = I^2R = E^2/R$$

$$\frac{A_1A_2}{A_1+A_2} = A_3$$

where

$f_r$ = resonant frequency in hertz

L = inductance in henrys

C = capacitance in farads

$X_C$ = capacitive reactance in Ω

$X_L$ = inductive reactance in Ω

P = power in watts

I = current in amps

R = resistance in Ω

E = voltage in volts

$A_1, A_2$ = the values of two parallel resistors in ohms, two parallel inductors in henrys, or two series capacitors in farads

$A_3$ = the resultant, equivalent resistance in ohms, inductance in henrys, or capacitance in farads

NOTE: Given a resistance or capacitance, $A_1$, the value of the circuit element required to produce a desired resultant resistance or capacitance may be calculated by entering $A_1$ as a negative value.

EXAMPLES:

1. C = .01μF, L = 160μh.
   Calculate $f_r$

2. L = 2.5h, $f_r$ = 60Hz
   Calculate C and $X_L$ at $f_r$

3. E = 345v, R = 1.25MΩ
   Calculate P and I

4. $R_1$= 120Ω, $R_2$ = 240Ω
   a. Find the equivalent resistance of these two resistors in parallel,$R_3$.
   b. Parallel $R_3$ with 50Ω.
   c. Find the resistance required for a resultant resistance of 25Ω.

SOLUTION:

```
              ENG4
  160.-06 ENT↑
  0.01-06 GSB1
125.82+03  ***   f_r

  60.0000 ENT↑
   2.5000 GSB2
2.8145-06  ***   C

  60.0000 ENT↑
   2.5000 GSB4
942.48+00  ***   X_L

 345.0000 ENT↑
  1.25+06 GSB5
95.220-03  ***   P

  1.25+06 GSB7
276.00-06  ***   I

 120.0000 ENT↑
 240.0000 GSB9
80.000+00  ***   R_3

  50.0000 GSB9   4b
30.769+00  ***
              CHS
  25.0000 GSB9   4c
133.33+00  ***
```

# User Instructions

| STEP | INSTRUCTIONS | INPUT DATA/UNITS | KEYS | | OUTPUT DATA/UNITS |
|---|---|---|---|---|---|
| 1. | Key in the program and choose an appropriate | | | | |
| | display format | | | | |
| 2. | Calculate $f_r$ | L | ENT | | |
| | | C | GSB | 1 | $f_r$ |
| 3. | Calculate L or C | $f_r$ | ENT | | |
| | | C or L | GSB | 2 | L or C |
| | REACTANCE CALCULATIONS | | | | |
| 4. | Calculate $X_C$ | f | ENT | | |
| | | C | GSB | 3 | $X_C$ |
| 5. | Calculate $X_L$ | f | ENT | | |
| | | L | GSB | 4 | $X_L$ |
| | POWER CALCULATIONS | | | | |
| 6a | Given E: Calculate P | E | ENT | | |
| | | R | GSB | 5 | P |
| 6b | Given I: Calculate P | I | ENT | | |
| | | R | GSB | 6 | P |
| | Given P,R: | | | | |
| 7a | Calculate I | P | ENT | | |
| | | R | GSB | 7 | I |
| 7b | Calculate E | P | ENT | | |
| | | R | GSB | 8 | E |
| | PARALLEL RESISTANCE/SERIES CAPACITANCE | | | | |
| 8. | Given two circuit elements, calculate resultant | $A_1$ | ENT | | |
| | | $A_2$ | GSB | 9 | $A_3$ |
| 9. | Given one circuit element and the desired | $A_1$ | CHS | ENT | |
| | resultant value, calculate the value of the circuit element required. | $A_3$ | GSB | 9 | $A_2$ |

# Program Listings

| Step | Key | Comments |
|---|---|---|
| 01 | *LBL1 | |
| 02 | × | |
| 03 | √X | |
| 04 | GTO0 | |
| 05 | *LBL2 | |
| 06 | X⇄Y | |
| 07 | GSB0 | |
| 08 | X² | |
| 09 | X⇄Y | |
| 10 | ÷ | |
| 11 | R/S | L or C |
| 12 | *LBL3 | |
| 13 | × | |
| 14 | GTO0 | |
| 15 | *LBL4 | |
| 16 | × | |
| 17 | GSB0 | |
| 18 | 1/X | |
| 19 | R/S | $X_L$ |
| 20 | *LBL5 | |
| 21 | 1/X | |
| 22 | *LBL6 | |
| 23 | X⇄Y | |
| 24 | X² | |
| 25 | × | |
| 26 | R/S | P |
| 27 | *LBL7 | |
| 28 | 1/X | |
| 29 | *LBL8 | |
| 30 | × | |
| 31 | √X | I or E |
| 32 | R/S | |
| 33 | *LBL0 | |
| 34 | 2 | |
| 35 | × | |
| 36 | Pi | |
| 37 | × | |
| 38 | 1/X | $f_r$ or $X_C$ |
| 39 | RTN | |
| 40 | *LBL9 | |
| 41 | × | |
| 42 | ENT↑ | |
| 43 | ENT↑ | |
| 44 | LSTX | |
| 45 | ÷ | |
| 46 | LSTX | |
| 47 | + | $A_3$ or $A_2$ |
| 48 | ÷ | |
| 49 | R/S | |

**REGISTERS**

| | | | | | |
|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 |
| 6 | 7 | 8 | 9 | .0 | .1 |
| .2 | .3 | .4 | .5 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 |

# IMPEDANCE OF A LADDER NETWORK

This program computes the input impedance of an arbitrary ladder network. Elements are added one at a time starting from the right. The first element must be in parallel.

Suppose we have a network whose input admittance is $Y_{in}$. Adding a shunt R, L, or C, the input admittance becomes

$$Y_{new} = \begin{cases} Y_{in} + \left(\frac{1}{R} + j0\right) \\ Y_{in} + \left(0 - j\,\frac{1}{\omega L_p}\right) \\ Y_{in} + (0 + j\,\omega\, C_p) \end{cases}$$

Adding a series R, L, or C, we have

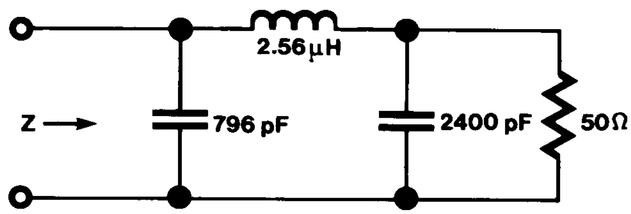
$$Y_{new} = \begin{cases} \left(\frac{1}{Y_{in}} + (R_s + j0)\right)^{-1} \\ \left(\frac{1}{Y_{in}} + (0 + j\,\omega\, L_s)\right)^{-1} \\ \left(\frac{1}{Y_{in}} + \left(0 - j\,\frac{1}{\omega C_s}\right)\right)^{-1} \end{cases}$$

The program converts this admittance to an impedance for display.

NOTE: An erroneous entry may be corrected by entering the negative of the incorrect value.

EXAMPLE:

f = 4 MHz




SOLUTION:

```
            FIX2
   4.+06    GSB1
   50.00    GSB3    |Zin|
   50.00    ***
            X⇄Y
    0.00    ***     ∠Zin
2400.-12    GSB5
   15.74    ***     |Zin|
            X⇄Y
  -71.66    ***     ∠Zin
 2.56-06    GSB2
            GSB5
   49.65    ***     |Zin|
            X⇄Y
   84.28    ***     ∠Zin
 796.-12    GSB5
  497.69    ***     |Zin|
            X⇄Y
    0.98    ***     ∠Zin
```

# User Instructions

| STEP | INSTRUCTIONS | INPUT DATA/UNITS | KEYS | | OUTPUT DATA/UNITS |
|---|---|---|---|---|---|
| 1. | Key in the program and choose an appropriate display format. | | | | |
| 2. | Initialize | f | GSB | 1 | W |
| 3. | Input a parallel element: | | | | |
| | | $R_p$ | GSB | 3 | $\|Z_{in}\|$ |
| | | | x↔y | | $\angle Z_{in}$ |
| | | $C_p$ | GSB | 5 | $\|Z_{in}\|$ |
| | | | x↔y | | $\angle Z_{in}$ |
| | | $L_p$ | GSB | 4 | $\|Z_{in}\|$ |
| | | | x↔y | | $\angle Z_{in}$ |
| 4a | For a series element: | | | | |
| | | $R_s$ | GSB | 2 | |
| | | | GSB | 3 | $\|Z_{in}\|$ |
| | | | x↔y | | $\angle Z_{in}$ |
| | | $C_s$ | GSB | 2 | |
| | | | GSB | 4 | $\|Z_{in}\|$ |
| | | | x↔y | | $\angle Z_{in}$ |
| | | $L_s$ | GSB | 2 | |
| | | | GSB | 5 | $\|Z_{in}\|$ |
| | | | x↔y | | $\angle Z_{in}$ |
| 4b | For a parallel element: Go to step 3 | | | | |
| 5. | Repeat step 4 until all elements are entered. | | | | |

# Program Listings

| Step | Key | Comment |
|---|---|---|
| 01 | *LBL1 | f |
| 02 | 2 | |
| 03 | × | |
| 04 | Pi | |
| 05 | × | Clear flag |
| 06 | CLRG | W |
| 07 | STO3 | |
| 08 | R/S | |
| 09 | *LBL0 | Z↔Y |
| 10 | R↓ | |
| 11 | →P | |
| 12 | 1/X | |
| 13 | X⇄Y | |
| 14 | CHS | |
| 15 | X⇄Y | |
| 16 | →R | |
| 17 | 0 | |
| 18 | RTN | R,C,L |
| 19 | *LBL2 | Set flag (series) |
| 20 | STO0 | |
| 21 | R/S | |
| 22 | *LBL3 | |
| 23 | 1/X | |
| 24 | RCL0 | |
| 25 | X=0? | |
| 26 | GTO8 | O,Y (parallel) |
| 27 | 0 | |
| 28 | GTO8 | |
| 29 | *LBL4 | O,Z (series) |
| 30 | RCL3 | |
| 31 | × | |
| 32 | 1/X | $X_C$ or $B_L$ |
| 33 | CHS | |
| 34 | 0 | |
| 35 | X⇄Y | |
| 36 | GTO8 | |
| 37 | *LBL5 | |
| 38 | RCL3 | |
| 39 | × | $X_L$ or $B_C$ |
| 40 | 0 | |
| 41 | X⇄Y | |
| 42 | *LBL8 | |
| 43 | STO7 | |
| 44 | X⇄Y | |
| 45 | STO6 | |
| 46 | RCL2 | |
| 47 | RCL1 | |
| 48 | RCL0 | |
| 49 | X≠0? | |
| 50 | GSB0 | Convert $Y_{in} \to Z_{in}$ |
| 51 | R↓ | |
| 52 | RCL6 | } Add admittances |
| 53 | + | } or impedances |
| 54 | X⇄Y | } |
| 55 | RCL7 | } |
| 56 | + | } |
| 57 | X⇄Y | |
| 58 | RCL0 | |
| 59 | X≠0? | |
| 60 | GSB0 | |
| 61 | R↓ | Convert Z→Y |
| 62 | STO1 | |
| 63 | X⇄Y | |
| 64 | STO2 | |
| 65 | X⇄Y | |
| 66 | 0 | |
| 67 | GSB0 | Convert Y→Z |
| 68 | STO0 | Clear flag |
| 69 | R↓ | |
| 70 | →P | |
| 71 | R/S | *** $\|Z_{in}\|$ $\angle Z_{in}$ |

*** "Printx" may be inserted.

**REGISTERS**

| | | | | | |
|---|---|---|---|---|---|
| 0 flag | 1 $Re[Y_{in}]$ | 2 $Im[Y_{in}]$ | 3 $\omega = 2\pi f$ | 4 | 5 |
| 6 used | 7 used | 8 | 9 | .0 | .1 |
| .2 | .3 | .4 | .5 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 |

# STANDARD RESISTANCE VALUES*

For a given tolerance, a "step size" is computed which is used to determine two values, one below and one above the non-standard resistance. These are converted by a subroutine to standard values, and the geometric mean of the latter is calculated. If the given non-standard value is below the mean then the lower standard value is selected; otherwise the larger value is selected.

NOTE: Incorrect results will be obtained for tolerances other than 5%, 10%, or 20%.

REFERENCE: International Telephone and Telegraph Corp. Reference Data for Radio Engineers, fourth edition, p. 78.

EXAMPLES: Find the closest standard values for the following:

$R_1 = 432\Omega$

$R_2 = 114\ K\Omega$

$R_3 = 3.5\ M\Omega$

SOLUTION:

```
                 ENG4
     5.0000 GSB1        5%
   432.0000 GSB2
  430.00+00  ***        R'1

    114.+03 GSB2
  110.00+03  ***        R'2

    3.5+06 GSB2
 3.6000+06  ***         R'3

    10.0000 GSB1        10%
   432.0000 GSB2
  470.00+00  ***        R'1

    114.+03 GSB2
  120.00+03  ***        R'2

    3.5+06 GSB2
 3.3000+06  ***         R'3

    20.0000 GSB1        20%
   432.0000 GSB2        R'1
  470.00+00  ***

    114.+03 GSB2
  100.00+03  ***        R'2

    3.5+06 GSB2
 3.3000+06  ***         R'3
```

* Adapted from HP-65 Users' Library program #00915A by Jacob Jacobs.

# User Instructions

| STEP | INSTRUCTIONS | INPUT DATA/UNITS | KEYS | | OUTPUT DATA/UNITS |
|---|---|---|---|---|---|
| 1. | Key in the program and choose an appropriate display format | | | | |
| 2. | Enter tolerance (5,10, or 20) | T% | GSB | 1 | |
| 3. | Enter non-standard resistor size and compute nearest standard value | R,Ω | GSB | 2 | R;Ω |
| 4. | Change tolerance at any time by going to step 2 | | | | |

# Program Listings

```
01 *LBL1
02    1
03    2
04    0
05    ÷
06   10^x
07  STO2      10^tol/120
08   R/S
09 *LBL2
10   LOG
11  ENT↑
12   INT
13  STO4
14    -
15    1
16    +
17   10^x
18  STO3
19    1
20  ST-4
21    1
22    0
23  STO5
24 *LBL0
25  RCL3
26  RCL5      This step >
27  X>Y?      Normal R?
28  GTO9
29  RCL2
30    x
31  STO5
32  GTO0
33 *LBL9
34  GSB8
35  STO7      This step
36  RCL5
37  RCL2
38    ÷
39  GSB8
40  STO6      Last step
41  RCL7
42    x
43   √X       √(This step)*(Last step)
44  RCL3
45  X≤Y?
46  GSB7
47  RCL7
48  RCL4
49   10^x
```

```
50    x       10 EXP R7
51   R/S      *** R
52 *LBL8      Finds standard R
53    .       value from multiple
54    5       of step size
55    +
56   INT      Round up
57  STO6
58    2
59    6
60  X>Y?
61  GTO6
62    4
63    7
64  RCL6
65  X>Y?
66  GTO3
67    1       26<R<47 then add 1
68    +
69   RTN
70 *LBL3
71    8
72    3
73  RCL6
74  X≠Y?
75   RTN
76    8
77    2
78   RTN
79 *LBL7
80  RCL6
81  STO7
82   RTN
83 *LBL6
84  RCL6
85   RTN
86   R/S
```

*** "Printx" may be inserted before "R/S".

**REGISTERS**

| | | | | | |
|---|---|---|---|---|---|
| 0 | 1 | 2 Step size | 3 Normal R | 4 Exp of R | 5 This step |
| 6 Temp | 7 Temp | 8 | 9 | .0 | .1 |
| .2 | .3 | .4 | .5 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 |

# EXPONENTIAL GROWTH OR DECAY

Many growth or decay phenomena encountered in science and engineering obey an exponential law of the general form:

$$X_t = X_{ss} - (X_{ss} - X_0)\, e^{\frac{-t}{\tau}}$$

where:

- $X_t$ = Value at any time, t, (i.e., the instantaneous value)
- $X_{ss}$ = Steady state value (i.e., at $t = \infty$)
- $X_0$ = Initial value (i.e., at t = 0)
- t = Elapsed time (time after t = 0)
- $\tau$ = Exponential time-constant for specific phenomena

This program provides interchangeable solutions for any one of the four variables $X_t$, $X_{ss}$, $X_0$ or t provided three variables and $\tau$ are known.

EXAMPLE 1:

Given a 5μF capacitor in series with a 1 megohm resistor. 1.5 seconds after the circuit is completed 125 volts are measured across R. To what voltage was the capacitor originally charged?

Note:

$\tau$ = the RC time-constant, and the voltage at $t = \infty$ is zero

SOLUTION:

```
  5.-06 ENT↑
  1.+06   ×
        STO4   τ = time-constant
125.00  STO1   v
  0.00  STO2   Xss
  1.50  STO3   time
        GSB0
168.73   ***   volts
```

EXAMPLE 2:

A cobalt 60 source (half-life = 5.26 years) had an activity of 3.54 curies when purchased 8.5 years ago. What is its present activity?

Note:

Activity at $t = \infty$ will be zero, $\tau$ = half-life/LN2

SOLUTION:

```
 5.26  ENT↑
 2.00    LN
          ÷
       STO4   τ
 3.54  STO0   X0
 0.00  STO2   Xss
 8.50  STO3   t
       GSB1
 1.15   ***   curies
```

# User Instructions

| STEP | INSTRUCTIONS | INPUT DATA/UNITS | KEYS | | OUTPUT DATA/UNITS |
|---|---|---|---|---|---|
| 1 | Key in the program | | | | |
| 2 | Store time constant | $\tau$ | STO | 4 | $\tau$ |
| 3 | Store variables | | | | |
| | Initial value | $X_0$ | STO | 0 | $X_0$ |
| | Instantaneous value | $X_t$ | STO | 1 | $X_t$ |
| | Steady state value | $X_{ss}$ | STO | 2 | $X_{ss}$ |
| | Elapsed time | t | STO | 3 | t |
| | (Store any 3 of the 4 variables) | | | | |
| 4 | To calculate: | | | | |
| | $X_0$, initial value | | GSB | 0 | $X_0$ |
| | $X_t$, Instantaneous value | | GSB | 1 | $X_t$ |
| | $X_{ss}$, Steady state value | | GSB | 2 | $X_{ss}$ |
| | t, elapsed time | | GSB | 3 | t |
| 5 | For a new case go to step 2 | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

# Program Listings

```
01 *LBL1      Xt
02  RCL0
03  RCL2
04    -
05  GSB5
06    ÷
07  RCL2
08    +
09   R/S      ***
10 *LBL2      Xss
11  GSB5
12  ENT↑
13  ENT↑
14  RCL1
15    x
16  RCL0
17    -
18   X⇄Y
19    1
20    -
21    ÷
22   R/S      ***
23 *LBL0      X0
24  GSB5
25  RCL1
26  RCL2
27    -
28    x
29  RCL2
30    +
31   R/S      ***
32 *LBL3      t
33  RCL0
34  RCL2
35    -
36  RCL1
37  RCL2
38    -
39    ÷
40   LN
41  RCL4
42    x
43   R/S      ***
44 *LBL5      e^(-t/τ)
45  RCL3
46  RCL4
47    ÷
48   e^x
49   RTN
50   R/S
```

*** "Printx" may be inserted before "R/S".

**REGISTERS**

| | | | | | |
|---|---|---|---|---|---|
| 0 $X_0$ | 1 $X_t$ | 2 $X_{ss}$ | 3 t | 4 | 5 |
| 6 τ | 7 | 8 | 9 | .0 | .1 |
| .2 | .3 | .4 | .5 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 |

# EQUATIONS OF MOTION

This program calculates an interchangeable solution among the variables: displacement, acceleration, initial velocity, and time or final velocity for an object that undergoes constant acceleration. The motion must be linear.

## EQUATIONS:

Final velocity $v = \sqrt{v_0^2 + 2ax}$

Initial velocity $v_0 = \sqrt{v^2 - 2ax}$

Displacement $x = \dfrac{v^2 - v_0^2}{2a}$

Acceleration $a = \dfrac{v^2 - v_0^2}{2x}$

Displacement $x = v_0 t + \frac{1}{2} at^2$

Initial velocity $v_0 = \frac{x}{t} - \frac{1}{2} at$

Acceleration $a = \dfrac{x - v_0 t}{\frac{1}{2} t^2}$

Time $t = \dfrac{\sqrt{v_0^2 + 2ax} - v_0}{a}$

## REMARKS:

Any consistent set of units may be used.

Displacement, acceleration, and velocity should be considered signed (vector) quantities. For example, if initial velocity and acceleration are in opposite directions, one should be positive and the other negative.

All equations assume initial displacement, $x_0$, equals zero.

## EXAMPLE 1:

An automobile accelerates for 4 seconds from a speed of 35 mph and covers a distance of 264 feet. Assuming constant acceleration, what is the acceleration in ft/sec$^2$? (7.33 ft/sec$^2$) If the acceleration continues to be constant, what distance is covered in the next second? (84.33 ft)

## SOLUTION:

```
 264.00 STO1   x
  35.00 ENT↑
5280.00   ×
3600.00   ÷
        STO2   v0
   4.00 STO3   t
        GSB4
   7.33  ***   a

   5.00 STO3   t + 1 sec
        GSB1
 348.33  ***   x at t + 1 sec

 264.00   -    x at t
  84.33  ***   x(t+1) - x(t)
```

EXAMPLE 2:

An airplane's take off velocity is 125 mph. Assume a constant acceleration of 15 ft/sec$^2$. How much runway length in feet will be used from start to take-off? (1120.37 ft.) How long will it take for the plane to reach take-off velocity? (12.22 sec)

SOLUTION:

```
   0.00 STO2   v0
  15.00 STO4
 125.00 ENT↑
5280.00    x
3600.00    ÷
        STO5   v
        GSB7
1120.37  ***   x

        GSB3
  12.22  ***   t
```

# User Instructions

| STEP | INSTRUCTIONS | INPUT DATA/UNITS | KEYS | | OUTPUT DATA/UNITS |
|---|---|---|---|---|---|
| 1. | Key in the program | | | | |
| 2. | Store variables | | | | |
| | displacement | x | STO | 1 | x |
| | initial velocity | $v_0$ | STO | 2 | $v_0$ |
| | time | t | STO | 3 | t |
| | acceleration | a | STO | 4 | a |
| | final velocity | v | STO | 5 | v |
| | (store appropriate unknowns) | | | | |
| 3. | To calculate: | | | | |
| | A. Displacement($a, v_0$ and t or v known) | | | | |
| | if t is known | | GSB | 1 | x |
| | if v is known | | GSB | 7 | x |
| | B. Initial Velocity (a,x, and t or v known) | | | | |
| | if t is known | | GSB | 2 | $v_0$ |
| | if v is known | | GSB | 6 | $v_0$ |
| | C. Acceleration ($v_0$,x and t or v known) | | | | |
| | if t is known | | GSB | 4 | a |
| | if v is known | | GSB | 8 | a |
| | D. Time ($v_0$,x and a known) | | GSB | 3 | t |
| | E. Final Velocity ($v_0$,x and a known) | | GSB | 5 | v |
| 4. | For a new case go to step 2 | | | | |

# Program Listings

```
01 *LBL1     x (t known)
02  RCL2
03  RCL4
04     2
05     ÷
06  RCL3
07     x
08     +
09  RCL3
10     x
11  STO1
12   R/S     ***
13 *LBL2     v0(t known)
14  RCL1
15  RCL3
16     ÷
17  LSTX
18  RCL4
19     x
20     2
21     ÷
22     -
23  STO2
24   R/S     ***
25 *LBL4     a (t known)
26  RCL1
27  RCL2
28  RCL3
29     x
30     -
31  RCL3
32    X²
33     2
34     ÷
35     ÷
36  STO4
37   R/S     ***
38 *LBL3     t
39  GSB5
40  RCL2
41     -
42  RCL4
43     ÷
44  STO3
45   R/S     ***
46 *LBL5     v
47  RCL2
48    X²
49     2
50  GSB9
51  STO5
52   RTN
53 *LBL9
54  RCL4
55  RCL1
56     x
57     x
58     +
59    √X
60   RTN
61 *LBL6     v0(v known)
62  RCL5
63    X²
64     2
65   CHS
66  GSB9
67  STO2
68   R/S     ***
69 *LBL7     x ( v known)
70     4
71  STO0
72  GSB0
73  STO1
74   R/S     ***
75 *LBL0
76  RCL5
77    X²
78  RCL2
79    X²
80     -
81  RCL1
82     2
83     x
84     ÷
85   RTN
86 *LBL8     a (v known)
87     1
88  STO0
89  GSB0
90  STO4
91   R/S     ***
```

*** "Printx" may be inserted before "R/S".

**REGISTERS**

| | | | | | |
|---|---|---|---|---|---|
| 0 Used | 1 x | 2 $v_0$ | 3 t | 4 a | 5 v |
| 6 | 7 | 8 | 9 | .0 | .1 |
| .2 | .3 | .4 | .5 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 |

# KINETIC ENERGY

This program calculates an interchangeable solution among the variables weight (or mass), velocity, and kinetic energy, for an object moving at constant velocity. The program operates in either English or metric units. For metric units, any consistent set of units may be used; the quantity mass must be used. For English units, the energy must be in foot-pounds, the velocity in feet per second, and the quantity weight in pounds.

K.E. = Kinetic energy

W = Weight (lb)

m = Mass (kg, g)

v = Velocity

g = Acceleration due to gravity = 32.17398 ft/sec$^2$

EQUATIONS:

English

$$K.E. = \frac{1W}{2g} v^2$$

Metric

$$K.E. = \frac{1}{2}mv^2$$

1 ft-lb = 1.98 x 10$^6$ hp

EXAMPLE 1:

The slider of a slider-crank mechanism is used to punch holes in a slab of metal. It is found that the work required to punch a hole is 775 ft-lb. If the slider weighs 5 lb. 4 oz., how fast must it be moving when it strikes the metal? (97.46 ft/sec) What is the required work in horsepower? (3.91 x 10$^{-4}$ hp)

SOLUTION:

```
         GSB2
  64.35  ***   English Units

 775.00  STO1
   5.00  ENT↑
   4.00  ENT↑
  16.00  ÷
         +
   5.25  ***   W
         STO2

         GSB5
  97.46  ***   v

         GSB3
 775.00  ***   ft-lb
         R/S
3.91-04  ***   hp
```

EXAMPLE 2:

An object weighing 4.8 kg is moving with constant velocity of 3.5 m/sec. Find its kinetic energy. (29.40 joules)

SOLUTION:

```
         GSB1
   2.00  ***   Metric Units

   4.80  STO2
   3.50  STO3
         GSB3
  29.40  ***   K.E.
```

# User Instructions

| STEP | INSTRUCTIONS | INPUT DATA/UNITS | KEYS | | OUTPUT DATA/UNITS |
|---|---|---|---|---|---|
| 1 | Key in the program | | | | |
| 2 | Choose system of units | | | | |
| | Metric (SI) | | GSB | 1 | 2.00 |
| | or | | | | |
| | English | | GSB | 2 | 64.35 |
| 3 | Input two of the following variables | | | | |
| | Kinetic energy | K.E. | STO | 1 | K.E. |
| | Weight (mass) | W(m) | STO | 2 | W(m) |
| | Velocity | v | STO | 3 | v |
| 4 | Compute the remaining variables: | | | | |
| | Kinetic energy | | GSB | 3 | K.E. |
| | Optional: convert K.E.(ft-lb) to K.E.(hp) | | R/S | | K.E.(hp) |
| | Weight (mass) | | GSB | 4 | W(m) |
| | Velocity | | GSB | 5 | v |
| 5 | To change any input variable go to step 3 | | | | |
| 6 | For a new case, go to step 2 | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

# Program Listings

```
01 *LBL1        Metric
02    2
03  STO4
04   R/S
05 *LBL2        English
06    6
07    4
08    .
09    3
10    4
11    7
12    9
13    6
14  STO4
15   R/S
16 *LBL3        K.E. Calc.
17  RCL2
18  RCL3
19  ENT↑
20    x
21    x
22  RCL4
23    ÷
24  STO1        ***
25   R/S
26  RCL1
27    1
28    9
29    8
30   EEX
31    4
32    ÷         ***
33   R/S
34 *LBL4        W(m) Calc.
35  RCL1
36  RCL4
37    x
38  RCL3
39  ENT↑
40    x
41    ÷
42  STO2        ***
43   R/S
44 *LBL5        v Calc.
45  RCL1
46  RCL4
47    x
48  RCL2
49    ÷
50   √X
51  STO3        ***
52   R/S
```

*** "Printx" may be inserted before "R/S".

**REGISTERS**

| | | | | | |
|---|---|---|---|---|---|
| 0 | 1 K.E. | 2 W(m) | 3 v | 4 2(met) 64.3(Eng) | |
| 6 | 7 | 8 | 9 | .0 | .1 |
| .2 | .3 | .4 | .5 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 |

# RPM/TORQUE/POWER

This program provides an interchangeable solution for RPM, torque, and power in both Systeme International (metric) and English units.

| | SI | English |
|---|---|---|
| RPM | RPM | RPM |
| Torque | nt-m | ft-lb |
| Power | watts | hp |

EQUATIONS:

RPM x Torque ≑ Power

1 hp = 745.7 watts

1 ft-lb = 1.356 joules

1 RPM = $\pi$/30 radians/sec

1 hp = 550 $\frac{\text{ft-lb}}{\text{sec}}$

EXAMPLE 1:

Calculate the torque from an engine developing 11 hp at 6500 RPM. Find the SI equivalent.

EXAMPLE 2:

A generator is turning at 1600 RPM with a torque of 20 nt-m. If it is 90% efficient, what is the power input in both systems?

SOLUTIONS:

(1)

```
        GSB4
6500.00 ENT↑
   0.00 ENT↑
  11.00 GSB5
   8.89  ***   Torque, ft-lb
         R/S
  12.05  ***   Torque, nt-m
```

(2)

```
        GSB3
1600.00 ENT↑
  20.00 ENT↑
   0.90   ÷
   0.00 GSB5
3723.37  ***   Power, watts
         R/S
   4.99  ***   Power, hp
```

# User Instructions

| STEP | INSTRUCTIONS | INPUT DATA/UNITS | KEYS | | OUTPUT DATA/UNITS |
|---|---|---|---|---|---|
| 1. | Key in the program | | | | |
| 2. | Choose sytem of units: | | | | |
| | Metric | | GSB | 3 | 1.36 |
| | or | | | | |
| | English | | GSB | 4 | 5251.41 |
| 3. | Enter variables (the unknown quantity, x, | | | | |
| | must be input as zero) and compute x. | | | | |
| | RPM | RPM | ENT↑ | | |
| | Torque | Torque | ENT↑ | | |
| | Power | Power | GSB | 5 | x |
| | | | | | |
| 4. | (Optional) to convert torque or power to | | | | |
| | other system | | R/S | | x converted |

# Program Listings

```
01 *LBL3        Set up for metric
02    3           units
03    0
04    Pi
05    ÷
06  STO7
07    7
08    4
09    5
10    .
11    7
12  STO5
13    1
14    .
15    3
16    5
17    6
18  STO6
19   RTN
20 *LBL4        Set up for English
21  GSB3          units
22   1/X
23  STO6
24   X⇄Y
25   1/X
26  STO5
27    ÷
28    x
29  STO7
30   RTN
31 *LBL5
32    4
33  STO0
34    R↓
35 *LBL8
36  STOi        Store variables
37    R↓
38   DSZ
39  GTO8
40 *LBL9
41  X=0?        Determine quantity
42  GTOi          to calculate
43   ISZ
44    R↓
45  GTO9
46 *LBL2
47  RCL4
48  RCL3
49    ÷
50  RCL7
51    x
52   R/S        ** RPM
53 *LBL1
54  RCL4
55  RCL2
56    ÷
57  RCL7
58    x
59   R/S        *** Torque
60  RCL6
61    ÷
62   R/S        ** Torque converted
63 *LBL0
64  RCL2
65  RCL3
66    x
67  RCL7
68    ÷
69   R/S        *** Power
70  RCL5
71    ÷
72   R/S        ** Power converted
```

** "Printx" may be inserted before "R/S".

*** "Printx" may replace "R/S".

**REGISTERS**

| | | | | | |
|---|---|---|---|---|---|
| 0 i | 1 Used | 2 RPM | 3 Torque | 4 Power | 5 Used |
| 6 Used | 7 Used | 8 | 9 | .0 | .1 |
| .2 | .3 | .4 | .5 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 |

# BLACK BODY THERMAL RADIATION

Bodies with finite temperatures emit thermal radiation. The higher the absolute temperature, the more thermal radiation emitted. Bodies which emit the maximum possible amount of energy at every wavelength for a specified temperature are said to be black bodies. While black bodies do not actually exist in nature, many surfaces may be assumed to be black for engineering considerations.

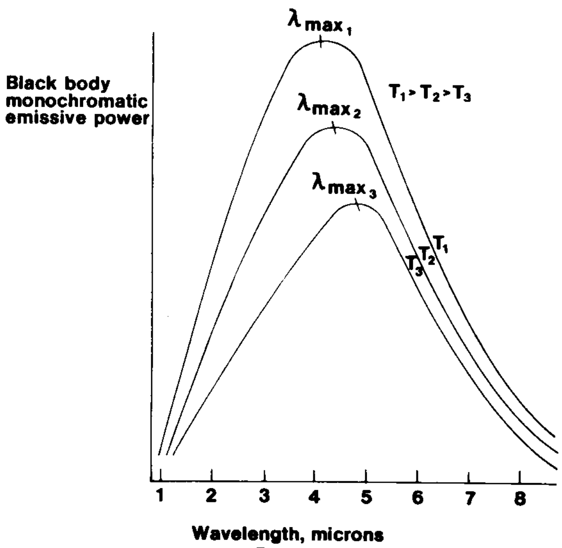


Figure 1.

Figure 1 is a representation of black body thermal emission as a function of wavelength. Note that as temperature increases the area under the curves (total emissive power $E_{b(0-\infty)}$) increases. Also note that the wavelength of maximum emissive power $\lambda_{max}$ shifts to the left as temperature increases.

This program can be used to calculate the wavelength of maximum emissive power for a given temperature, the temperature corresponding to a particular wavelength of maximum emissive power, the total emissive power for all wavelengths and the emissive power at a particular wavelength. It can also be used to calculate the emissive power from zero to an arbitrary wavelength, the emissive power between two wavelengths or the total emissive power.

EQUATIONS:

$$\lambda_{max} \, T_{\lambda_{max}} = c_3$$

$$E_{b(0-\infty)} = \sigma T^4$$

$$E_{b\lambda} = \frac{2\pi c_1}{\lambda^5 (e^{c_2/\lambda T} - 1)}$$

$$E_{b(0-\lambda)} = \int_0^\lambda E_{b\lambda} \, d\lambda$$

$$= 2\pi c_1 \sum_{k=1}^{\infty} -T/kc_2 \; e^{-\frac{kc_2}{T\lambda}} \left[ \left(\frac{1}{\lambda}\right)^3 + \frac{3T}{\lambda^2 kc_2} + \frac{6}{\lambda}\left(\frac{T}{kc_2}\right)^2 + 6\left(\frac{T}{kc_2}\right)^3 \right]$$

$$E_{b(\lambda_1-\lambda_2)} = E_{b(0-\lambda_2)} - E_{b(0-\lambda_1)}$$

where

$\lambda_{max}$ is the wavelength of maximum emissivity in microns;

T is the absolute temperature in °R or K;

$E_{b(0-\infty)}$ is the total emissive power in Btu/hr-ft$^2$ or Watts/cm$^2$;

$E_{b\lambda}$ is the emissive power at $\lambda$ in Btu/hr-ft$^2$-μm or Watts/cm$^2$-μm;

$E_{b(0-\lambda)}$ is the emissive power for wavelengths less than $\lambda$ in Btu/hr-ft$^2$ or Watts/cm$^2$;

$E_{b(\lambda_1-\lambda_2)}$ is the emissive power for wavelengths between $\lambda_1$ and $\lambda_2$ in Btu/hr-ft$^2$ or Watts/cm$^2$.

$c_1 = 1.8887982 \times 10^7$ Btu-μm$^4$/hr-ft$^2$
$= 5.9544 \times 10^3$ Wμm$^4$/cm$^2$

$c_2 = 2.58984 \times 10^4$ μm-°R =
$1.4388 \times 10^4$ μm-K

$c_3 = 5.216 \times 10^3$ μm-°R =
$2.8978 \times 10^3$ μm-K

$\sigma = 1.71312 \times 10^{-9}$ Btu/hr-ft$^2$-°R$^4$=
$5.6693 \times 10^{-12}$ W/cm$^2$-K$^4$

$\sigma_{exp} = 1.731 \times 10^{-9}$ Btu/hr-ft$^2$-°R$^4$
$= 5.729 \times 10^{-12}$ W/cm$^2$-K$^4$

REMARKS:

A minute or more may be required to obtain $E_{b(0-\lambda)}$ or $E_{b(\lambda_1-\lambda_2)}$ since the integration is numerical.

Sources differ on values for constants. This could yield small discrepancies between published tables and outputs.

REFERENCE:

Robert Siegel and John R. Howell, Thermal Radiation Heat Transfer, Vol. 1, National Aeronautics and Space Administration, 1968.

EXAMPLE 1:

What percentage of the radiant output of a lamp is in the visible range (0.4 to 0.7 microns) if the filament of the lamp is assumed to be a black body at 2400 K?

EXAMPLE 2:

If the human eye was designed to work most efficiently in sunlight and the visible spectrum runs from about 0.4 to 0.7 microns, what is the sun's temperature in degrees Rankine? Assume that the sun is a black body. Using the temperature calculated, find the fraction of the sun's total emissive power which falls in the visible range. Find the percentage of the sun's radiation which has a wavelength less than 0.4 microns.

SOLUTIONS:

1.

```
    5954.40 ST01  }
   14388.00 ST02  }  S.I. constants
    2897.80 ST03  }
 5.6693-12 ST04   }
    2400.00 ST05
       0.40 ST06
       0.70 ST07
            GSB4
       4.97  ***
            GSB2   Eb (0 to ∞)
               ÷
     100.00    ×
       2.64  ***   (%)
```

2.

| | | |
|---|---|---|
| 18887982.00 | STO1 | English constants |
| 25898.40 | STO2 | |
| 5216.00 | STO3 | |
| 1.71312-09 | STO4 | |
| 0.40 | ENT↑ | |
| 0.70 | + | |
| 2.00 | ÷ | |
| 0.55 | *** | mean value |
| | RCL3 | |
| | ÷ | |
| | 1/X | |
| 9483.64 | *** | T, (°R) |
| | STO5 | |
| 0.40 | STO6 | |
| 0.70 | STO7 | |
| | GSB4 | |
| 4670556.56 | *** | $E_b$(.4 to .7) |
| | GSB2 | |
| 13857578.83 | *** | $E_b$(0 to ∞) |
| | ÷ | |
| 100.00 | × | |
| 33.70 | *** | (%) |
| 0.40 | STO6 | |
| | GSB1 | |
| 1168606.94 | *** | $E_b$ (0 to .4) |
| | GSB2 | |
| | ÷ | |
| 100.00 | × | |
| 8.43 | *** | (%) |

# User Instructions

| STEP | INSTRUCTIONS | INPUT DATA/UNITS | KEYS | | OUTPUT DATA/UNITS |
|---|---|---|---|---|---|
| 1 | Key in the program | | | | |
| 2 | Store constants: | | | | |
| 2a | English units - | 18887982 | STO | 1 | |
| | (Btu, μm, ft, °R) | 25898.4 | STO | 2 | |
| | | 5216 | STO | 3 | |
| | or | $.171312 \times 10^{-8}$ | STO | 4 | |
| 2b | SI units - | 5954.4 | STO | 1 | |
| | (W, μm, cm, °K) | 14388 | STO | 2 | |
| | | 2897.8 | STO | 3 | |
| | | $5.6693 \times 10^{-12}$ | STO | 4 | |
| 3 | For experimental Stefan-Boltzmann constant | 1.0105 | STO | x | |
| | instead of theoretical constant | | 4 | | |
| 4 | To calculate $\lambda_{max} = f(T)$ | | RCL | 3 | |
| | | T(°R or k) | ÷ | | $\lambda_{max}$(μm) |
| 5 | To calculate $T = f(\lambda)$ for which $\lambda$ is | | RCL | 3 | |
| | maximum | $\lambda$(μm) | ÷ | | T(°R or k) |
| 6 | To calculate total emissive power | T* | STO | 5 | |
| | | | GSB | 2 | $E_b(0 \text{ to } \infty)$ |
| 7 | To calculate emissive power at $\lambda$ | T* | STO | 5 | |
| | | $\lambda$ | STO | 6 | |
| | | | GSB | 3 | $E_b(\lambda)$ |
| 8 | To calculate emissive power from 0 to $\lambda_1$ | T* | STO | 5 | |
| | | $\lambda_1$ | STO | 6 | |
| | | | GSB | 1 | $E_b(0 \text{ to } \lambda_1)$ |
| 9 | To calculate emissive power from $\lambda_1$ to $\lambda_2$ | T* | STO | 5 | |
| | | $\lambda_1$ | STO | 6 | |
| | *any value of T stored previously is still | $\lambda_2$ | STO | 7 | |
| | stored and need not be input again | | GSB | 4 | $E_b(\lambda_1 \text{ to } \lambda_2)$ |

# Program Listings

| Step | Key | Comment |
|---|---|---|
| 01 | *LBL1 | |
| 02 | GSB9 | |
| 03 | R/S | ***$E_{b(0 \text{ to } \lambda_1)}$ |
| 04 | *LBL9 | |
| 05 | 0 | |
| 06 | STO9 | |
| 07 | STO8 | |
| 08 | *LBL0 | |
| 09 | RCL2 | |
| 10 | RCL5 | |
| 11 | ÷ | |
| 12 | ST-8 | $-k\ c_2/T$ |
| 13 | 3 | |
| 14 | RCL8 | |
| 15 | ÷ | |
| 16 | RCL6 | |
| 17 | X² | |
| 18 | ÷ | |
| 19 | LSTX | $\lambda^2$ |
| 20 | RCL6 | |
| 21 | x | |
| 22 | 1/X | |
| 23 | - | |
| 24 | 6 | |
| 25 | RCL6 | |
| 26 | ÷ | |
| 27 | RCL8 | |
| 28 | X² | |
| 29 | ÷ | |
| 30 | - | |
| 31 | 6 | |
| 32 | RCL8 | |
| 33 | 3 | |
| 34 | Yˣ | |
| 35 | ÷ | |
| 36 | + | |
| 37 | RCL8 | |
| 38 | RCL6 | |
| 39 | ÷ | |
| 40 | eˣ | |
| 41 | x | |
| 42 | RCL8 | |
| 43 | ÷ | |
| 44 | ST+9 | $\Delta$ |
| 45 | RCL9 | |
| 46 | ÷ | |
| 47 | EEX | |
| 48 | CHS | |
| 49 | 5 | |
| 50 | X≤Y? | $\Delta \geq .001\%$ |
| 51 | GTO0 | yes, increment k |
| 52 | RCL9 | |
| 53 | 2 | |
| 54 | x | |
| 55 | Pi | |
| 56 | x | |
| 57 | RCL1 | |
| 58 | x | |
| 59 | RTN | $E_{b(0 \text{ to } \lambda)}$ |
| 60 | *LBL2 | |
| 61 | RCL5 | |
| 62 | 4 | |
| 63 | Yˣ | |
| 64 | RCL4 | |
| 65 | x | |
| 66 | R/S | ***$E_{b(0 \text{ to } \infty)}$ |
| 67 | *LBL3 | |
| 68 | RCL1 | |
| 69 | 2 | |
| 70 | x | |
| 71 | Pi | |
| 72 | x | |
| 73 | RCL6 | |
| 74 | 5 | |
| 75 | Yˣ | |
| 76 | ÷ | |
| 77 | RCL2 | |
| 78 | RCL6 | |
| 79 | ÷ | |
| 80 | RCL5 | |
| 81 | ÷ | |
| 82 | eˣ | |
| 83 | 1 | |
| 84 | - | |
| 85 | ÷ | |
| 86 | R/S | ***$E_{b\lambda}$ |
| 87 | *LBL4 | |
| 88 | GSB9 | |
| 89 | ST.0 | $E_{b(0 \text{ to } \lambda_1)}$ |
| 90 | RCL7 | |
| 91 | STO6 | $\lambda_2$ |
| 92 | GSB9 | |
| 93 | RC.0 | |
| 94 | - | |
| 95 | R/S | ***$E_{b(\lambda_1 \text{ to } \lambda_2)}$ |

***"Printx" may be inserted before "R/S"

**REGISTERS**

| | | | | | |
|---|---|---|---|---|---|
| 0 | 1 $c_1$ | 2 $c_2$ | 3 $c_3$ | 4 $\sigma$ | 5 T |
| 6 $\lambda$ | 7 $\lambda_2$ | 8 $-Kc_2/T$ | 9 sum | .0 used | .1 |
| .2 | .3 | .4 | .5 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 |

# CONSERVATION OF ENERGY

This program converts kinetic energy, potential energy, and pressure-volume work to energy. Energy is stored as a running total which may at any time be converted to an equivalent velocity, height, pressure, or energy per unit mass. The program is useful in fluid flow problems where velocity, elevation and pressure change along the path of flow.

EQUATIONS:

$$\frac{v_1^2}{2} + gz_1 + \frac{P_1}{\rho} + \frac{E_1}{\dot{m}} =$$

$$\frac{v_2^2}{2} + gz_2 + \frac{P_2}{\rho} + \frac{E_2}{\dot{m}}$$

where:

v is the fluid velocity;

z is the height above a reference datum;

P is the pressure;

E is an energy term which could represent inputs of work or friction loses (negative value);

g is the acceleration of gravity;

$\rho$ is the fluid density;

$\dot{m}$ is the mass flow rate (assumed to be unity);

subscripts 1 and 2 refer to upstream and downstream values respectively.

NOTES:

Downstream values should be input as negatives. However, when an output is called for, the calculator displays the relative value with no regard to upstream or downstream location.

An error will result when the total energy sum stored in register 8 is negative and an attempt is made to calculate velocity.

EXAMPLE 1:

A water tower is 100 feet high. What is the zero flow rate pressure at the base? The density of water is 62.4 $lb/ft^3$.

If water is flowing out of the tower at a velocity of 10 ft/sec, what is the static pressure?

What is the maximum frictionless flow velocity which could be achieved with the 100 foot tower?

If 10000 pounds of water are pumped to the top of the tower every hour, at a velocity of 20 ft/sec, with a frictional pressure drop of 2 psi, how much power is needed at the pump?

EXAMPLE 2:

An incompressible fluid ($\rho$ = 735 kg/m ) flows through the converging passage of Figure 1. At point 1 the velocity is 3 m/s and at point 2 the velocity is 15 m/s. The elevation difference between points 1 and 2 is 3.7 meters. Assuming frictionless flow, what is the static pressure difference between points 1 and 2?

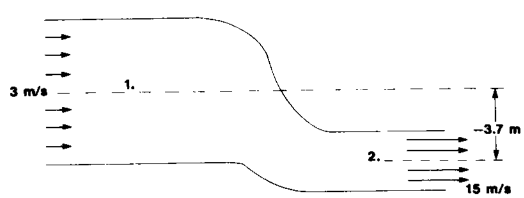



Figure 1.

EXAMPLE 3:

A reservoir's level is 25 meters above the discharge pond. Assuming 85% power generation efficiency, how much power can be generated with a flow rate of 20 $m^3/s$?

$\rho = 1000\ kg/m^3$

SOLUTIONS:

(1)

```
25033.407 ST05
    32.17 ST06
  4632.48 ST07
    62.40 GSB1
   100.00 GSB3
          GSB8
    43.33  ***  (psig)
   -10.00 GSB2
          GSB8
    42.66  ***  (psig)
    62.40 GSB1
   100.00 GSB3
          GSB6
    80.21  ***  (ft/sec)
    62.40 GSB1
    20.00 GSB2
     2.00 GSB4
   100.00 GSB3
          GSB9
     0.14  ***  (BTU/lb)
 10000.00   x
  1424.29  ***  (BTU/hr)
```

(2)

```
     1.00 ST05
          ST07
  9.80665 ST06
   735.00 GSB1
     3.00 GSB2
     3.70 GSB3
   -15.00 GSB2
          GSB8
-52710.82  ***  (Nt/m²)
```

(3)

```
   1000.00 GSB1
     25.00 GSB3
           GSB9
    245.17  ***  (joule/kg)
      0.85   x
    208.39  ***  (joule/kg)
     20.00 ENT↑
   1000.00   x  (kg/s)
             x
4167826.25  *** (watts)
```

# User Instructions

| STEP | INSTRUCTIONS | INPUT DATA/UNITS | KEYS | | OUTPUT DATA/UNITS |
|---|---|---|---|---|---|
| 1. | Key in the program | | | | |
| 2. | For English units: | 25033.407 | STO | 5 | |
| | | 32.17 | STO | 6 | |
| | | 4632.48 | STO | 7 | 1.00 |
| | For S.I. units: | 9.80665 | STO | 6 | |
| 3. | Enter fluid density | ρ | GSB | 1 | 0.00 |
| 4. | Enter the following (negative values are | | | | |
| | downstream values): | | | | |
| | Fluid velocity | v | GSB | 2 | |
| | Height from reference datum | z | GSB | 3 | |
| | Pressure | P | GSB | 4 | |
| | Energy input | E | GSB | 5 | |
| 5. | Repeat step 4 for all input values | | | | |
| 6. | Calculate the unknown: | | | | |
| | Fluid velocity | | GSB | 6 | v |
| | Height from reference datum | | GSB | 7 | z |
| | Pressure | | GSB | 8 | P |
| | Energy | | GSB | 9 | E |
| 7. | For another case, go to step 3, or clear | | | | |
| | register 8 and go to step 4 | 0 | STO | 8 | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

# Program Listings



| Step | Key | Comments |
|---|---|---|
| 01 | *LBL1 | |
| 02 | STO4 | ρ |
| 03 | 0 | |
| 04 | STO8 | Clear Σ E |
| 05 | R/S | |
| 06 | *LBL2 | |
| 07 | ENT↑ | |
| 08 | ABS | |
| 09 | x | |
| 10 | 2 | |
| 11 | ÷ | $\pm v^2/_2$ |
| 12 | GTO5 | |
| 13 | *LBL3 | |
| 14 | RCL6 | |
| 15 | x | |
| 16 | GTO5 | gz |
| 17 | *LBL4 | |
| 18 | RCL7 | |
| 19 | x | |
| 20 | RCL4 | |
| 21 | ÷ | $^{\rho}/\rho$ |
| 22 | *LBL5 | E |
| 23 | ST+8 | |
| 24 | R/S | |
| 25 | *LBL6 | |
| 26 | RCL8 | |
| 27 | 2 | |
| 28 | x | |
| 29 | √X | |
| 30 | R/S | *** v |
| 31 | *LBL7 | |
| 32 | RCL8 | |
| 33 | RCL6 | |
| 34 | ÷ | |
| 35 | R/S | *** z |
| 36 | *LBL8 | |
| 37 | RCL8 | |
| 38 | RCL7 | |
| 39 | ÷ | |
| 40 | RCL4 | |
| 41 | x | |
| 42 | R/S | *** P |
| 43 | *LBL9 | |
| 44 | RCL8 | |
| 45 | RCL5 | |
| 46 | ÷ | |
| 47 | R/S | *** E |

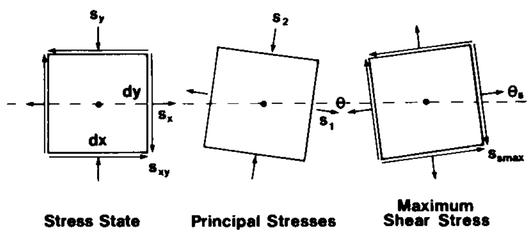
*** "Printx" may be inserted before "R/S".

**REGISTERS**

| | | | | | |
|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 ρ | 5 Used |
| 6 g | 7 Used | 8 Σ E | 9 | .0 | .1 |
| .2 | .3 | .4 | .5 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 |

# MOHR CIRCLE FOR STRESS

Given the state of stress on an element, the principal stresses and their orientation can be found. The maximum shear stress and its orientation can also be found.




EQUATIONS:

$$s_{smax} = \sqrt{\left(\frac{s_x - s_y}{2}\right)^2 + s_{xy}^2}$$

$$s_1 = \frac{s_x + s_y}{2} + s_{smax}$$

$$s_2 = \frac{s_x + s_y}{2} - s_{smax}$$

$$\theta = 1/2 \tan^{-1}\left(\frac{2s_{xy}}{s_x - s_y}\right)$$

$$\theta_s = 1/2 \tan^{-1} - \left(\frac{s_x - s_y}{2s_{xy}}\right)$$

where:

$s_{smax}$ is the maximum shear stress;

$s_1$ and $s_2$ are the principal normal stresses;

$\theta$ is the angle of rotation from the principal axis to the original axis;

$\theta_s$ is the angle of rotation from the axis of maximum shear stress to the original axis;

$s_x$ is the stress in the x direction;

$s_y$ is the stress in the y direction;

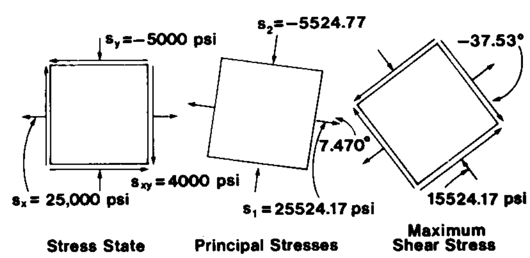
$s_{xy}$ is the shear stress on the element.

REFERENCE:

Spotts, M.F., Design of Machine Elements, Prentice-Hall, 1971.

EXAMPLE:

If $s_x$ = 25000 psi, $s_y$ = -5000 psi, and $s_{xy}$ = 4000 psi, compute the principal stresses and the maximum shear stress.



SOLUTION:

```
25000.00 ENT↑
-5000.00 ENT↑
 4000.00 GSB1
25524.17  ***
          R/S   s1 (psi)
-5524.17  ***   s2 (psi)
          R/S
    7.47  ***   θ (degrees)
          R/S
  -37.53  ***   θs (degrees)
          R/S
15524.17  ***   ssmax (psi)
```

# User Instructions

| STEP | INSTRUCTIONS | INPUT DATA/UNITS | KEYS | | OUTPUT DATA/UNITS |
|---|---|---|---|---|---|
| 1. | Key in the program | | | | |
| 2. | Enter the following: | | | | |
| | Stress in the x direction (negative for compression) | $S_x$ | ENT↑ | | |
| | Stress in the y direction (negative for compression) | $S_y$ | ENT↑ | | |
| | Shear stress | $S_{xy}$ | | | |
| 3. | Compute the following: | | | | |
| | First principal stress | | GSB | 1 | $S_1$ |
| | Second principal stress | | R/S | | $S_2$ |
| | Angle of rotation (principal) | | R/S | | $\theta$ |
| | Angle of rotation (shear) | | R/S | | $\theta_s$ |
| | Maximum shear stress | | R/S | | $s_{smax}$ |
| | NOTE: Do not disturb the stack during step 3 | | | | |
| 4. | For a new case, go to step 2. | | | | |

# Program Listings

| | | | |
|---|---|---|---|
| 01 | *LBL1 | | |
| 02 | ENT↑ | | |
| 03 | R↓ | $s_{xy}$ $s_y$ $s_x$ $s_{xy}$ | |
| 04 | STO3 | | |
| 05 | R↓ | | |
| 06 | X⇄Y | | |
| 07 | STO1 | $s_x$ | |
| 08 | X⇄Y | $s_y$ | |
| 09 | ST+1 | | |
| 10 | - | $s_x - s_y$ | |
| 11 | 2 | | |
| 12 | ST÷1 | | |
| 13 | ÷ | | |
| 14 | STO4 | $(s_x - s_y)/2$ | |
| 15 | →P | | |
| 16 | STO2 | $s_{smax}$ | |
| 17 | RCL1 | | |
| 18 | + | | |
| 19 | R/S | ** $s_1$ | |
| 20 | X⇄Y | $2 \cdot \theta$ | |
| 21 | RCL1 | | |
| 22 | RCL2 | | |
| 23 | - | | |
| 24 | R/S | ** $s_2$ | |
| 25 | X⇄Y | | |
| 26 | 2 | | |
| 27 | ÷ | | |
| 28 | R/S | ** $\theta$ | |
| 29 | RCL4 | | |
| 30 | RCL3 | | |
| 31 | ÷ | | |
| 32 | CHS | | |
| 33 | TAN⁻¹ | | |
| 34 | 2 | | |
| 35 | ÷ | | |
| 36 | R/S | ** $\theta_s$ | ** "Printx" may replace "R/S". |
| 37 | RCL2 | | |
| 38 | R/S | *** $s_{smax}$ | *** "Printx" may be inserted before "R/S". |

**REGISTERS**

| | | | | | |
|---|---|---|---|---|---|
| 0 | 1 $(s_x+s_y)/2$ | 2 $s_{smax}$ | 3 $s_{xy}$ | 4 $(s_x-s_y)/2$ | 5 |
| 6 | 7 | 8 | 9 | .0 | .1 |
| .2 | .3 | .4 | .5 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 |

# POLYNOMIAL EVALUATION--REAL OR COMPLEX

This program evaluates polynomials of the form:

$f(x_0) = a_0+a_1x+...+a_nx^n$

where the coefficients

$a_k$, $k=0,...n (n \leq 28)$ and $x_0$ are real or the coefficients and $x_0$ are complex of the form

$a_k = Re(a_k) + i\ Im(a_k)$

$z_0 = Re(z_0) + i\ Im(z_0)$

$k = 0, 1, ... n$

Example 1:

$f(x) = 11-7x - 3x^2 + 5x^4 + x^5$

for $x_0 = 2.5$

for $x_0 = -5$

Solution:

```
        CLRG
 11.00 GSB1
 -7.00  R/S
 -3.00  R/S
  0.00  R/S
  5.00  R/S
  1.00  R/S
  2.50 GSB2
267.72  ***    f (2.5)
  6.00 STO0
 -5.00 GSB2
-29.00  ***    f (-5)
```

Example 2:

$f(x) = (5-7i) - 10x + (-2+i)x^2 + 18x^3 + (3+4i)x^4$

for $x_0 = 2 + i$

Solution:

```
   1.00 ENT↑
   2.00 GSB3
   4.00 ENT↑
   3.00 GSB4
   0.00 ENT↑
  18.00 GSB4
   1.00 ENT↑
  -2.00 GSB4
   0.00 ENT↑
 -10.00 GSB4
  -7.00 ENT↑
   5.00 GSB5
-106.00  ***   Re f(x0)
          R/S
 220.00  ***   Im f(x0)
```

# User Instructions

| STEP | INSTRUCTIONS | INPUT DATA/UNITS | KEYS | | OUTPUT DATA/UNITS |
|---|---|---|---|---|---|
| 1. | Key in the program | | | | |
| | For real polynomials: | | | | |
| | | | | | |
| 2. | Initialize | | f | REG | |
| | | | | | |
| 3. | Store coefficients | $a_0$ | GSB | 1 | |
| | | | | | |
| 4. | Continue for i = 1 to n, n≤28 | $a_i$ | R/S | | |
| | | | | | |
| 5. | Compute $f(x_0)$ | $x_0$ | GSB | 2 | $f(x_0)$ |
| | | | | | |
| 6. | For a different $x_0$ go to step 5 | n+1 | STO | 0 | |
| | | | | | |
| | For complex polynomials: | | | | |
| 7. | Enter $x_0$ | Im $x_0$ | ENT↑ | | |
| | | Re $x_0$ | GSB | 3 | 0 |
| | | | | | |
| 8. | Enter $a_k$,k=n,n-1,...1 | Im $a_k$ | ENT↑ | | |
| | | Re $a_k$ | GSB | 4 | |
| | | | | | |
| 9. | Enter $a_0$ and run | Im $a_0$ | ENT↑ | | |
| | | Re $a_0$ | GSB | 5 | Re $f(x_0)$ |
| | | | R/S | | Im $f(x_0)$ |
| | | | | | |
| 10. | For a new case, go to step 7 | | | | |

```
01 *LBL1
02   ISZ
03  STOi
04   R/S
05  GTO1
06 *LBL2
07  ENT↑
08  ENT↑
09  ENT↑
10  RCLi
11    x        Multiply by x0
12   DSZ
13 *LBL0
14  RCLi
15    +
16    x        Multiply by x0
17   DSZ
18  GTO0
19   X⇄Y
20    ÷        Divide by x0
21   R/S       *** f(x0)
22 *LBL3       Routines for complex polynomials
23    →P
24  STO1       r
25   X⇄Y
26  STO2       θ
27    0
28  ENT↑       Prepare for LBL 9
29  ENT↑
30  ENT↑
31   RTN
32 *LBL4
33  GSB9
34  GTO8
35 *LBL5
36  GSB9
37   R/S       *** Re f(x0)
38   X⇄Y
39   R/S       *** Im f(x0)
40 *LBL8       Multiply in polar form
41    →P
42  RCL1
43    x
44   X⇄Y
45  RCL2
46    +
47   X⇄Y
48    →R
49   RTN
50 *LBL9       Add real parts and imaginary parts
51   X⇄Y
52    R↓
53    +
54    R↓
55    +
56   X⇄Y
57    R↓
58   X⇄Y
59   RTN
60   R/S
```

**REGISTERS**

| | | | | | |
|---|---|---|---|---|---|
| 0 i | 1 r or $a_0$ | 2 θ or $a_1$ | 3 $a_2$ | 4 . . . $a_n$ | 5 |
| 6 | 7 | 8 | 9 | .0 | .1 |
| .2 | .3 | .4 | .5 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 $a_{28}$ |

*** "Printx" may be inserted or used to replace "R/S".

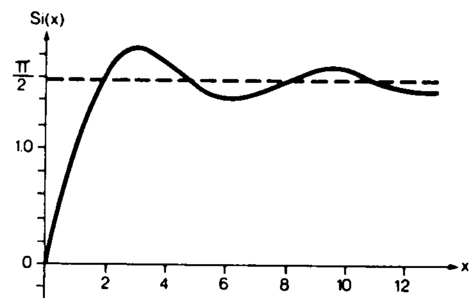
# SINE, COSINE, AND EXPONENTIAL INTEGRALS

Sine integral:

$$Si(x) = \int_0^x \frac{\sin t}{t}\, dt = \sum_{n=0}^{\infty} \frac{(-1)^n x^{2n+1}}{(2n+1)(2n+1)!}$$

where x is real.

This routine computes successive partial sums of the series, stops when two consecutive partial sums are equal, and displays the last partial sum as the answer.




<u>Notes</u>: When x is too large, computing a new term of the series might cause an overflow. In that case, display shows all 9's and the program stops.

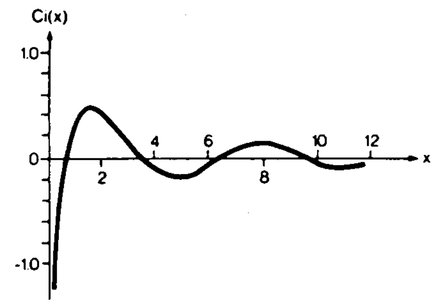
$Si(-x) = -Si(x)$

Cosine integral:

$$Ci(x) = \gamma + \ln x + \int_0^x \frac{\cos t - 1}{t}\, dt = \gamma + \ln x + \sum_{n=1}^{\infty} \frac{(-1)^n x^{2n}}{2n(2n)!}$$

where $x>0$, and $\gamma = 0.577215665$ is the Euler's constant.

This program computes successive partial sums of the series. When two consecutive partial sums are equal, the value is used as the sum of the series.




<u>Notes</u>: When x is too large, computing a new term of the series might cause an overflow. In that case, display shows all 9's and the program stops.

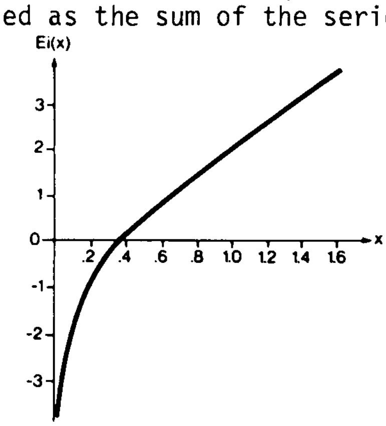
$Ci(-x) = Ci(x) - i\pi$ for $x>0$.

Exponential integral:

$$Ei(x) = \int_{-\infty}^{x} \frac{e^t}{t}\, dt = \gamma + \ln x + \sum_{n=1}^{\infty} \frac{x^n}{n n!}$$

where $x>0$ and $\gamma = 0.577215665$ is Euler's constant.

This program computes successive partial sums of the series. When two consecutive partial sums are equal, the value is used as the sum of the series.



Note: When x is too large, computing a new term of the series might cause an overflow. In that case, display shows all 9's and the program stops.

References: Handbook of Mathematical Functions, Abramowitz and Stegun, National Bureau of Standards, 1968.

Examples:

1. Si (.69)
2. Si (.98)
3. Ci (1.38)
4. Ci (5)
5. Ei (1.59)
6. Ei (.61)

Solutions:

```
0.577215665 ST.0
       0.69 GSB1
       0.67  ***
       0.98 GSB1
       0.93  ***
       1.38 GSB2
       0.46  ***
       5.00 GSB2
      -0.19  ***
       1.59 GSB3
       3.57  ***
       0.61 GSB3
       0.80  ***
```

# User Instructions

| STEP | INSTRUCTIONS | INPUT DATA/UNITS | KEYS | | OUTPUT DATA/UNITS |
|---|---|---|---|---|---|
| 1. | Key in the program | | | | |
| | | | | | |
| 2. | Store α | .577215665 | STO | • | |
| | | | 0 | | α |
| | | | | | |
| 3. | For Sine Integral | x | GSB | 1 | Si(x) |
| | For Cosine Integral | x | GSB | 2 | Ci(x) |
| | For Exponential Integral | x | GSB | 3 | Ei(x) |
| | | | | | |

```
01 *LBL1      Sine Integral
02  STO3      routine
03   X²
04  CHS
05  STO1
06    1
07  STO2
08  RCL3
09 *LBL0
10  RCL1
11  RCL2
12    1
13    +
14    ÷
15  LSTX
16    1
17    +
18  STO2
19    ÷
20  RCL3
21    x
22  STO3
23  RCL2
24    ÷
25    +
26  X≠Y?
27  GTO0
28   R/S      *** Si(x)/Ci(x)
29 *LBL2      Cosine Integral
30   X²       routine
31  CHS
32  STO1
33    1
34  STO3
35    0
36  STO2
37  LSTX
38   LN
39  RC.0
40    +
41  GTO0
42 *LBL3
43  STO1      Exponential In-
44    1       tegral routine
45  STO3
46    0
47  STO2
48  RCL1
49   LN
50  RC.0
51    +
52 *LBL9
53  RCL1
54  RCL2
55    1
56    +
57  STO2
58    ÷
59  RCL3
60    x
61  STO3
62  RCL2
63    ÷
64    +
65  X≠Y?
66  GTO9
67   R/S      *** Ei(x)
```

**REGISTERS**

| | | | | | |
|---|---|---|---|---|---|
| 0 | 1 used | 2 used | 3 used | 4 | 5 |
| 6 | 7 | 8 | 9 | .0 used | .1 |
| .2 | .3 | .4 | .5 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 |

*** "Print X" may be used to replace "R/S".

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