03250D

Program Description I

Program Title DOPPLER EFFECT – INTERCHANGEABLE SOLUTIONS

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Program Description, Equations, Variables THIS PROGRAM PRODUCES INTERCHANGEABLE SOLUTIONS FOR BOTH CLASSICAL AND RELATIVISTIC DOPPLER SHIFTS. FOR PROBLEMS INVOLVING WAVE PROPAGATION THROUGH A MECHANICAL MEDIUM e.g., SOUND WAVES THROUGH AIR, ANY FIVE OF THE SIX VARIABLES MAY BE ENTERED BY KEYING THE APPROPRIATE USER-DEFINED BUTTON. THE DESIRED VALUE IS THEN DETERMINED BY PRESSING THE REMAINING USER-DEFINED KEY. CALCULATED VALUES ARE AUTOMATICALLY STORED FOR FURTHER USE.

RELATIVISTIC DOPPLER-SHIFT PROBLEMS e.g., ELECTROMAGNETIC RADIATION, THREE OF THE FOUR VARIABLES ARE ENTERED AS DESCRIBED ABOVE, THEN THE DESIRED VALUE IS THEN CALCULATED BY PRESSING THE FOURTH USER-DEFINEABLE KEY WITHOUT INTERVENING DATA ENTRY.

EQUATIONS USED ARE:

(CLASSICAL DOPPLER SHIFT)

$$f_L = f_o \frac{c}{c \pm v_o}$$

$$f_o = \frac{f_L (c \pm v_o)}{c}$$

$$c = \frac{f_o (v_L - v_m) - f_L (v_o - v_m)}{f_L - f_o}$$

$$v_L = \frac{c(f_L - f_o) + f_L (v_o - v_m)}{f_o} + v_m$$

$$v_m = \frac{f_L (c + v_o) - f_o (c + v_L)}{f_L - f_o}$$

$$v_o = \frac{(f_o - f_L)(c - v_m) + f_o v_L}{f_L}$$

(RELATIVISTIC DOPPLER SHIFT)

$$\nu' = \sqrt{\left(\frac{1 + v/c}{1 - v/c}\right)}\,\nu$$

$$\nu = \nu' \Big/ \sqrt{\frac{1 + v/v_\omega}{1 - v/v_\omega}}$$

$$v = c\left[\left(\frac{\nu'}{\nu}\right)^2 - 1\right] \frac{1}{1 + \left(\frac{\nu'}{\nu}\right)^2}$$

$$c = \frac{v\left[\left(\frac{\nu'}{\nu}\right)^2 + 1\right]}{\left(\frac{\nu'}{\nu}\right)^2 - 1}$$

Operating Limits and Warnings SIGNAL PROPAGATION AND MEDIUM VELOCITY MUST BE ALONG A STRAIGHT LINE PASSING THROUGH THE SOURCE AND THE RECEIVER. IF ANY PARAMETER HAS A ZERO VALUE, ZERO SHOULD BE INPUT IF A PRIOR RUN MAY HAVE STORED A NON-ZERO VALUE. ALL VELOCITIES MUST BE STATED IN CONSISTENT UNITS FOR EACH PROBLEM RUN

am Description II

Sketch(es)

OBSERVER'S VELOCITY		SOURCE'S VELOCITY		PROPAGATING MEDIUM'S VELOCITY	
OBSERVER MOVING TOWARD SOURCE	OBSERVER MOVING AWAY FROM SOURCE	SOURCE MOVING TOWARD OBSERVER	SOURCE MOVING AWAY FROM OBSERVER	MEDIUM MOVING TOWARD SOURCE	MEDIUM MOVING AWAY FROM SOURCE
+	−	−	+	+	−

CLASSICAL DOPPLER EFFECT

RELATIVE VELOCITY	
INCREASING SEPARATION	DECREASING SEPARATION
−	+

RELATIVISTIC DOPPLER EFFECT

Sample Problem(s)

PROBLEM NUMBER	CLASSICAL DOPPLER EFFECT (SOUND)					
	A SOURCE FREQUENCY	B SIGNAL VELOCITY	C OBSERVER'S VELOCITY	D PROPAGATING MEDIUM'S VELOCITY	E SOURCE VELOCITY	fo OBSERVED FREQUENCY
1	1000 Hz	330 M/S	40 M/S TOWARD SOURCE	0 M/S	0 M/S	?
2	?	330 M/S	0 M/S	0 M/S	60 M/S AWAY FROM OBSERVER	372 Hz.
3	15 kHz	?	60 ft/s AWAY FROM SOURCE	0 ft/s	80 ft/s TOWARD OBSERVER	15.3×10^3 Hz.
4	15 kHz	330 M/S	20 M/S AWAY FROM SOURCE	10 M/S TOWARD OBSERVER	30 M/S TOWARD OBSERVER	?
5	15 kHz	330 M/S	20 M/S TOWARD SOURCE	0 M/S	30 M/S TOWARD OBSERVER	?

	RELATIVISTIC DOPPLER EFFECT (ELECTROMAGNETIC RADIATION)			
	OBSERVED FREQUENCY fr	SOURCE FREQUENCY fe	RELATIVE VELOCITY	SIGNAL VELOCITY
6	3.000000999 09	3×10^9 Hz	100 M/S APPROACHING	3.00×10^8 M/S
7	2.999999 09	3×10^9 Hz	100 M/S RECEDING	3.00×10^8 M/S

Solution(s)

1) 1000 [A] 330 [B] 40 [C] 0 [D] 0 [E] [f] [a] → 1.12×10^3 Hz

2) 372 [f] [a] 330 [B] 0 [C] 0 [D] 60 [E] [A] → 440 Hz

3) 15.3×10^3 [f] [a] 15×10^3 [A] 60 CHS [C] 0 [D] 80 CHS [E] [B] → 1.08×10^3 ft/s

4) 15.0×10^3 [A] 330 [B] 20 CHS [C] 10 CHS [D] 30 CHS [E] [f] [a] → 15.5×10^3 Hz

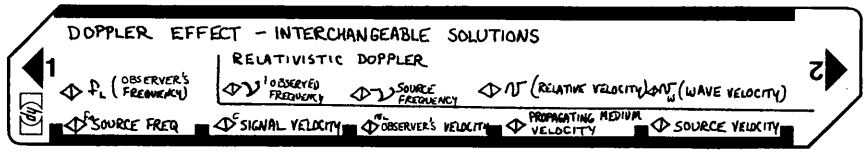
5) 15.0×10^3 [A] 330 [B] 20 [C] 0 [D] 30 CHS [E] [f] [a] → 17.5×10^3 Hz

6) DSP 9 3 EEX 9 [f] [c] 3 EEX 8 [f] [E] 100 [f] [D] [f] [B] → 3.000000999 09

7) 100 CHS [f] [D] [f] [B] → 2.999999000 09 (DSP 2 BEFORE RUNNING CLASSICAL PROBLE AGAIN)

Reference(s) FRANKLIN MILLER, JR., COLLEGE PHYSICS 4TH ED., HARCOURT, BRACE, JOVANOVICH, INC.

User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	LOAD SIDE 1 AND SIDE 2				
2	IF PROBLEM INVOLVES ELECTROMAGNETIC RADIATION,				
	GO TO STEP 5				
3	FOR CLASSICAL DOPPLER CASE, INPUT FIVE OF SIX	FREQUENCY PERCEIVED BY OBSERVER	f	A	f_L
	VARIABLES	FREQUENCY EMITTED BY SOURCE	A		f_o
		PROPAGATION VELOCITY	B		C
		OBSERVER'S VELOCITY	C		v_L
		PROPAGATING MEDIUM VELOCITY	D		v_m
		SOURCE VELOCITY	E		v_o
4	CALCULATE DESIRED VALUE BY DEPRESSING REMAINING		f_o-E		ANSWER
	USER-DEFINEABLE KEY WITHOUT PRIOR DATA ENTRY				
5	FOR RELATIVISTIC DOPPLER CASE, INPUT THREE	RECEIVED FREQUENCY	f	b	ν'
	OF THE FOUR VARIABLES	EMITTED FREQUENCY	f	C	ν
	(IT MAY BE NECESSARY TO CHANGE TO DSP 9 WHEN	RELATIVE VELOCITY	f	d	v_{rel}
	RELATIVE VELOCITY IS VERY SMALL)	PROPAGATION VELOCITY	f	e	v_{wave}
6	CALCULATE DESIRED VALUE BY DEPRESSING		f_b-f_o		ANSWER
	REMAINING USER-DEFINEABLE KEY WITHOUT				
	PRIOR DATA ENTRY				
7	FOR A NEW CASE, GO TO STEP 3 OR STEP 5				

Program Listing

032500

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	g LBL f a	32 25 11	◇ OBSERVER'S FREQUENCY f_L (CLASSICAL) ENTER OR CALCULATE $f_L = f_o \frac{c}{c+v_o}$
	STO Ø	33 00	
	h F3?	35 71 03	
	h RTN	35 22	
	RCL 1	34 01	
	RCL 2	34 02	
	RCL 3	34 03	
	RCL 4	34 04	
	−	51	
010	+	61	
	X	71	
	RCL 2	34 02	
	RCL 5	34 05	
	RCL 4	34 04	
	−	51	
	+	61	
	÷	81	
	STO Ø	33 00	
	h RTN	35 22	
020	f LBL A	31 25 11	◇ SOURCE FREQUENCY f_o (CLASSICAL) ENTER OR CALCULATE $f_o = \frac{f_L(c+v_o)}{c}$
	STO 1	33 01	
	h F3?	35 71 03	
	h RTN	35 22	
	RCL Ø	34 00	
	RCL 2	34 02	
	RCL 5	34 05	
	RCL 4	34 04	
	−	51	
	+	61	
030	X	71	
	RCL 2	34 02	
	RCL 3	34 03	
	RCL 4	34 04	
	−	51	
	+	61	
	÷	81	
	STO 1	33 01	
	h RTN	35 22	
	f LBL B	31 25 12	◇ SIGNAL VELOCITY * c (CLASSICAL) ENTER OR CALCULATE $c = \frac{f_o(v_L - v_m) - f_L(v_o - v_m)}{f_L - f_o}$
040	STO 2	33 02	
	h F3?	35 71 03	
	h RTN	35 22	
	RCL 1	34 01	
	RCL 3	34 03	
	RCL 4	34 04	
	−	51	
	X	71	
	RCL 0	34 00	
	RCL 5	34 05	
050	RCL 4	34 04	
	−	51	
	X	71	
	−	51	
	RCL Ø	34 00	
	RCL 1	34 01	
	−	51	

* e.g., VELOCITY OF SOUND IN AIR

STEP	KEY ENTRY	KEY CODE	COMMENTS
	÷	81	
	STO 2	33 02	
	h RTN	35 22	
060	f LBL C	31 25 13	◇ OBSERVER'S VELOCITY v_L (CLASSICAL) ENTER OR CALCULATE $v_L = \frac{c(f_L - f_o) + f_L(v_o - v_m)}{f_o} + v_m$
	STO 3	33 03	
	h F3?	35 71 03	
	h RTN	35 22	
	RCL 2	34 02	
	RCL 0	34 00	
	RCL 1	34 01	
	−	51	
	X	71	
	RCL 0	34 00	
070	RCL 5	34 05	
	RCL 4	34 04	
	−	51	
	X	71	
	+	61	
	RCL 1	34 01	
	÷	81	
	RCL 4	34 04	
	+	61	
	STO 3	33 03	
080	h RTN	35 22	
	f LBL D	31 25 14	◇ PROPAGATING MEDIUM VELOCITY * (CLASSICAL) v_m ENTER OR CALCULATE $v_m = \frac{f_L(c+v_o) - f_o(c+v_L)}{f_L - f_o}$
	STO 4	33 04	
	h F3?	35 71 03	
	h RTN	35 22	
	RCL Ø	34 00	
	RCL 2	34 02	
	RCL 5	34 05	
	+	61	
	X	71	
090	RCL 1	34 01	
	RCL 2	34 02	
	RCL 3	34 03	
	+	61	
	X	71	
	−	51	
	RCL Ø	34 00	
	RCL 1	34 01	
	−	51	
	÷	81	
100	STO 4	33 04	
	h RTN	35 22	
	f LBL E	31 25 15	◇ SOURCE VELOCITY v_o (CLASSICAL) ENTER OR CALCULATE $v_o = \frac{(f_o - f_L)(c - v_m) + f_o v_L}{f_L}$
	STO 5	33 05	
	h F3?	35 71 03	
	h RTN	35 22	
	RCL 1	34 01	
	RCL Ø	34 00	
	−	51	
	RCL 2	34 02	
110	RCL 4	34 04	
	−	51	
	X	71	

* WIND VELOCITY FOR PROBLEMS INVOLVING SOUND IN MOVING AIR

REGISTERS

0 OBSERVER'S FREQ. f_L	1 SOURCE FREQ f_o	2 SIGNAL VELOCITY c (SPEED OF SOUND, ETC)	3 OBSERVER'S VELOCITY v_L	4 PROPAGATING MEDIUM VELOCITY v_m	5 SOURCE VELOCITY v_o	6 OBSERVED FREQUENCY ν'	7 SOURCE FREQUENCY ν	8 RELATIVE VELOCITY v_{rel}	9 WAVE VELOCITY v_w SPEED OF LIGHT, ETC.
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

032509 Program Listing

STEP	KEY ENTRY	KEY CODE	COMMENTS
	RCL 1	34 01	
	RCL 3	34 03	
	X	71	
	+	61	
	RCL Ø	34 00	
	÷	81	
	STO 5	33 05	
120	h RTN	35 22	
	g LBL f b	32 25 12	◇ $\mathcal{V}'$ OBSERVED FREQUENCY (RELATIVISTIC) ENTER OR CALCULATE $\mathcal{V}' = \left(\sqrt{\frac{1+N/c}{1-N/c}}\right)\mathcal{V}$
	STO 6	33 06	
	h F3?	35 71 03	
	h RTN	35 22	
	f GSB 1	31 22 01	
	RCL 7	34 07	
	X	71	
	STO 6	33 06	
	h RTN	35 22	
130	g LBL f c	32 25 13	◇ $\mathcal{V}$ SOURCE FREQUENCY (RELATIVISTIC) ENTER OR CALCULATE $\mathcal{V} = \mathcal{V}' \sqrt{\frac{1+N/c}{1-N/c}}$
	STO 7	33 07	
	h F3?	35 71 03	
	h RTN	35 22	
	f GSB 1	31 22 01	
	h 1/x	35 62	
	RCL 6	34 06	
	X	71	
	STO 7	33 07	
	h RTN	35 22	
140	g LBL f d	32 25 14	◇ N RELATIVE VELOCITY (RELATIVISTIC) ENTER OR CALCULATE $N = C\left[\left(\frac{\mathcal{V}'}{\mathcal{V}}\right)^2 - 1\right]\frac{1}{1+\left(\frac{\mathcal{V}'}{\mathcal{V}}\right)^2}$
	STO 8	33 08	
	h F3?	35 71 03	
	h RTN	35 22	
	f GSB 2	31 22 02	
	RCL 9	34 09	
	X	71	
	STO 8	33 08	
	h RTN	35 22	
	g LBL f e	32 25 15	◇ C (WAVE VELOCITY) (RELATIVISTIC) ENTER OR CALCULATE $C = N\frac{\left[\left(\frac{\mathcal{V}'}{\mathcal{V}}\right)^2 + 1\right]}{\left(\frac{\mathcal{V}'}{\mathcal{V}}\right)^2 - 1}$
150	STO 9	33 09	
	h F3?	35 71 03	
	h RTN	35 22	
	f GSB 2	31 22 02	
	h 1/x	35 62	
	RCL 8	34 08	
	X	71	
	STO 9	33 09	
	h RTN	35 22	
	f LBL 1	31 25 01	SUBROUTINE #1 CALCULATES $\sqrt{\frac{1+N/c}{1-N/c}}$
160	1	01	
	RCL 8	34 08	
	RCL 9	34 09	
	÷	81	
	+	61	
	h LST X	35 82	
	1	01	
	h x⇄y	35 52	
	−	51	

STEP	KEY ENTRY	KEY CODE	COMMENTS
	÷	81	
170	f √x	31 54	
	h RTN	35 22	
	f LBL 2	31 25 02	SUBROUTINE #2 CALCULATES $\frac{\left(\frac{\mathcal{V}'}{\mathcal{V}}\right)^2 - 1}{\left(\frac{\mathcal{V}'}{\mathcal{V}}\right)^2 + 1}$
	RCL 6	34 06	
	RCL 7	34 07	
	÷	81	
	g x²	32 54	
	↑	41	
	↑	41	
	1	01	
180	−	51	
	h x⇄y	35 52	
	1	01	
	+	61	
	÷	81	
	h RTN	35 22	
190			
200			
210			
220			

LABELS

A	B	C	D	E
a	b	c	d	e
0	1 SUBROUTINE 1	2 SUBROUTINE 2	3	4
5	6	7	8	9

FLAGS

0	
1	
2	
3	DATA ENTRY

SET STATUS

FLAGS	ON	OFF
0	☐	☒
1	☐	☒
2	☐	☒
3	☐	☒

TRIG	
DEG	☒
GRAD	☐
RAD	☐

DISP	
FIX	☐
SCI	☐
ENG	☒
n	3