Program Description I

Program Title RELATIVITY – INTERCHANGEABLE SOLUTIONS

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Program Description, Equations, Variables PROVIDES INTERCHANGEABLE SOLUTIONS FOR THE BASIC RELATIONSHIPS OF EINSTEIN'S SPECIAL RELATIVITY. ADDITIONALLY, INTERCHANGEABLE SOLUTIONS FOR $e = mc^2$ ARE PROVIDED. VALUES ARE ENTERED AND STORED AUTOMATICALLY BY KEYING THE ENTRY, THEN PRESSING A CORRESPONDING USER-DEFINEABLE KEY. PRESSING A USER-DEFINEABLE KEY WITHOUT AN IMMEDIATELY-PREVIOUS KEYBOARD ENTRY WILL CAUSE THE CALCULATION OF THE SELECTED PARAMETER AND ITS AUTOMATIC STORAGE FOR RE-USE. ANY OR ALL VALUES MAY BE CHANGED IN ANY SEQUENCE TO PERMIT THE CALCULATION OF CHANGED ANSWERS BASED ON MODIFIED ENTRIES. WHEN DEDICATED REGISTERS ARE FILLED FROM KEYBOARD ENTRY OR INTERNAL CALCULATIONS, WILL CALCULATE THE RELATIVISTIC KINETIC ENERGY OF MOVING MASS.

$$m = m_0\sqrt{\frac{1}{1-\frac{v^2}{c^2}}} \qquad t = t_0\sqrt{\frac{1}{1-\frac{v^2}{c^2}}} \qquad l = l_0\sqrt{1-\frac{v^2}{c^2}} \qquad v = c\sqrt{1-\frac{l^2}{l_0^2}}$$

$$v = c\sqrt{1-\frac{x_0^2}{x}} \qquad c = \frac{v}{\sqrt{1-\frac{x_0^2}{x^2}}} \qquad \beta = \sqrt{1-\frac{v^2}{c^2}} \qquad c = v\sqrt{1-\frac{l^2}{l_0^2}}$$

WHERE $X_0 = m_0$ OR t_0
$X = m$ OR t

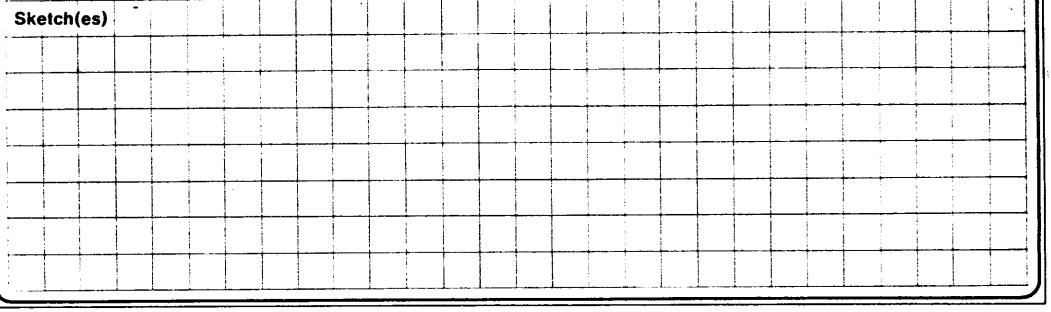
$$m_0 = m\sqrt{1-\frac{v^2}{c^2}} \qquad t_0 = t\sqrt{1-\frac{v^2}{c^2}} \qquad l_0 = l\sqrt{\frac{1}{1-\frac{v^2}{c^2}}} \qquad \Delta E = mc^2 - m_0c^2$$

Operating Limits and Warnings v MUST NOT BE EQUAL TO c. (v MUST NOT ROUND INTERNALLY TO EQUAL c) ENTRIES OR CALCULATIONS INVOLVING USER-DEFINEABLE KEYS A AND B MUST ALWAYS BE BASED ON CONJUGATE PARAMETERS i.e., m_0 AND m, t_0 AND t, OR l AND l_0. (DO NOT MIX m_0 AND l, OR t_0 AND l) UNITS MUST BE CONSISTENT. INTERNAL ROUTINE STORES ONLY SI VALUE FOR c.

BE CERTAIN TO SET FLAG 2 IMMEDIATELY PRIOR TO RECORDING CARD!

Program Description II

Sketch(es)



Sample Problem(s) 1) A SPACE SHIP TRAVELS AT A CONSTANT 99% OF THE SPEED OF LIGHT, RELATIVE TO THE EARTH. WHEN THE SHIP'S PASSENGERS HAVE AGED 1 YEAR, TRAVELLING AT THIS SPEED, HOW MUCH TIME WILL HAVE ELAPSED FOR EARTH'S INHABITANTS?

2) RECALCULATE PROBLEM 1, BUT CHANGE THE SPACE SHIP'S SPEED TO 99.9999% OF LIGHT SPEED

3) AFTER CALCULATING THE ANSWER TO PROBLEM, YOU WISH TO DETERMINE THE TIME THAT ELAPSES ON THE SPACE SHIP WHILE TRAVELLING AT 0.999999 c WHILE EARTH'S INHABITANTS EXPERIENCE 20 YEARS.

4) FOR N = 99.9999c, WHAT IS THE VALUE OF β $\left(\sqrt{1-\frac{v^2}{c^2}}\right)$? (ASSUME PROBLEM 3 RESULTS IN STORAGE)

5) THE CREW OF A SPACESHIP MEASURES THEIR SHIP'S LENGTH AS 200 METRES WHILE TRAVELLING AT 0.999 c AWAY FROM THE EARTH, WHAT IS THE LENGTH OF THE SHIP FROM THE POINT OF VIEW OF AN EARTH BOUND OBSERVER?

6) THE MASS OF THE SPACESHIP IN PROBLEM 5 WAS 10^8 KG WHEN CONSTRUCTED IN ORBIT AROUND THE EARTH WHAT WOULD ITS MASS BE, AS ASSESSED BY AN EARTHBOUND OBSERVER, WHEN THE SHIP'S VELOCITY RELATIVE TO THE EARTH IS 0.999 c?

7) AN ELECTRON'S REST MASS IS 9.11×10^{-31} KG, WHAT IS THE ENERGY EQUIVALENT OF THIS MASS?

8) WHAT IS THE MASS EQUIVALENT OF 1.5×10^{-10} JOULES?

Solution(s) 1) 0.99 [E] x [C] 1 [A] [B] → 7.088812015 00 years

2) 0.999999 [E] x [C] [B] → 7.071067814 02 YEARS

3) 20 [B] [A] → 2.828427124 -02 → 20 ÷ → 1.414213562 -03 YEARS

4) [f] [e] → 1.414213562 -03

5) [E] .999 x [C] 200 [B] [A] → 8.942036010 METRES

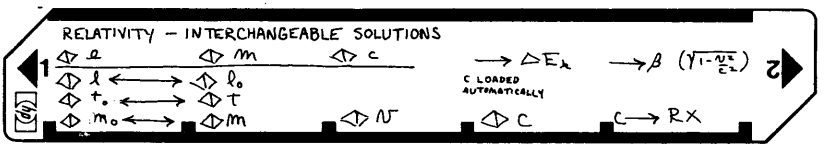
6) .999 [E] x [C] [EEX] 8 [A] [B] → 2.236627092 09 KILOGRAMS

7) 9.11 [EEX] [CHS] 31 [f] [l] [f] [a] → 8.187659580 -14 JOULES

8) 1.5 [EEX] [CHS] 10 [f] [a] [f] [l] → 1.668975104 -27 KILOGRAMS

Reference(s) "COLLEGE PHYSICS" BY FRANKLIN MILLER, JR. IVth ED CHAPTER 7
HARCOURT, BRACE, JOVANOVICH

User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	LOAD CARD, SIDES ONE AND TWO			
	(FOR PROBLEMS BASED ON $e=mc^2$, GO TO STEP #5)			
2	ENTER ANY 3 OF 4 VARIABLES (SELECT ONLY	m_o, t_o, or l	A	m_o, t_o, or l
	CONJUGATE PAIRS FOR MASS, LENGTH, AND TIME) KEY THE	m, t, or l_o	B	m, t, or l_o
	NUMERICAL VALUE, THEN THE CORRESPONDING USER-	N	C	N
	DEFINEABLE KEY (C IS STORED AUTOMATICALLY IF NOMINAL VALUE REQUIRED)	C (SKIP ENTRY UNLESS VALUE CHANGE NEEDED)	D	C
3	CALCULATE THE REQUIRED VALUE BY SELECTING THE			
	REMAINING USER-DEFINEABLE KEY WITHOUT A PRIOR KEYBOARD			
	ENTRY			
4	FOR A NEW PROBLEM, GO TO STEP 2, CHANGE ONLY			
	THOSE ENTRIES THAT WILL BE DIFFERENT FOR THE			
	NEW PROBLEM.			
5	ENTER ANY 2 OF 3 VARIABLES, KEY VALUE THEN	e	f a	e
	CORRESPONDING USER-DEFINEABLE KEY. C IS	m	f b	m
	ENTERED AUTOMATICALLY, THIS ENTRY REQUIRED ONLY IF	C	f c	C
	C IS TO HAVE A VALUE OTHER THAN 299792456.2 m/s			
6	CALCULATE THE REQUIRED VALUE BY SELECTING THE			
	REMAINING USER-DEFINEABLE KEY WITHOUT PRIOR			
	KEYBOARD ENTRY			
7	OPTIONAL STEPS:			
	A) TO DISPLAY THE NOMINAL VALUE OF THE VELOCITY			
	OF LIGHT IN METRES PER SECOND		E	2.997924562 08
	B) TO CALCULATE N AS A SELECTED DECIMAL PERCENTAGE			
	OF C e.g., TO CALCULATE 99.999% OF THE VELOCITY	EX. .99999	E X	2.997894583 08
	OF LIGHT, THEN STORE AS V FOR SUBSEQUENT CALCULATION		C	2.997894583 08
	C) TO CALCULATE, THEN DISPLAY THE VALUE OF $\sqrt{1-\frac{v^2}{c^2}}$			
	AFTER N HAS BEEN ENTERED		f e	β
	D) TO REPLACE NOMINAL VALUE OF C WHEN PREVIOUS ENTRIES			
	OR CALCULATIONS HAVE CHANGED STORED VALUE		h SF	
			2	C NOMINAL WILL BE STORED IN R3, R7 DURING EXECUTION OF NEXT CALCULATION
	E) TO CALCULATE RELATIVISTIC CHANGE IN ENERGY FOR MASS			
	ACCERATED TO RELATIVISTIC SPEEDS		f d	ΔE

Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	f LBL 1	31 25 01	INDIRECT ADDRESS ASSIGNMENT SUBROUTINE
	h STI	35 33	
	h F3?	35 71 03	
	h F3?	35 71 03	
	h RTN	35 22	
	h R↓	35 53	
	STO(i)	33 24	
	R/S	84	
	f LBL A	31 25 11	◇ m_0 OR ◇ t_0 OR ◇ l — ENTER OR CALCULATE
010	h F2?	35 71 02	
	f GSB 4	31 22 04	
	0	00	
	f GSB 1	31 22 01	
	f GSB 2	31 22 02	
	RCL 1	34 01	
	X	71	
	STO(i)	33 24	
	h RTN	35 22	
	f LBL B	31 25 12	◇ m OR ◇ t OR ◇ l_0 — ENTER OR CALCULATE
020	h F2?	35 71 02	
	f GSB 4	31 22 04	
	1	01	
	f GSB 1	31 22 01	
	RCL 0	34 00	
	f GSB 2	31 22 02	
	÷	81	
	STO(i)	33 24	
	h RTN	35 22	
	f LBL C	31 25 13	◇ N ENTER OR CALCULATE VELOCITY ($N < C$)
030	h F2?	35 71 02	
	f GSB 4	31 22 04	
	h F3?	35 71 03	
	f GSB 5	31 22 05	
	2	02	
	f GSB 1	31 22 01	
	f GSB 3	31 22 03	
	RCL 3	34 03	
	X	71	
	STO(i)	33 24	
040	h RTN	35 22	
	f LBL D	31 25 14	◇ C ENTER OR CALCULATE VELOCITY OF LIGHT BASED ON VALUES FROM
	h F2?	35 71 02	
	f GSB 4	31 22 04	
	3	03	
	f GSB 1	31 22 01	
	RCL 2	34 02	
	f GSB 3	31 22 03	
	÷	81	
	STO(i)	33 24	
050	h RTN	35 22	
	f LBL 2	31 25 02	SUBROUTINE 2 $\sqrt{1-\frac{N^2}{C^2}}$
	1	01	
	RCL 2	34 02	
	RCL 3	34 03	
	÷	81	
	g x^2	32 54	
	−	51	
	f $\sqrt{x}$	31 54	
	h RTN	35 22	
060	f LBL 3	31 25 03	SUBROUTINE 3 $\sqrt{1-\left(\frac{X_0}{X}\right)^2}$
	1	01	
	RCL 0	34 00	
	RCL 1	34 01	
	÷	81	
	g x^2	32 54	
	−	51	
	f $\sqrt{x}$	31 54	
	h RTN	35 22	
	f LBL 4	31 25 04	SUBROUTINE 4 LOADS NOMINAL VALUE OF VELOCITY OF LIGHT IN METRES/SECOND INTO R3, R7, TEST-CLEARED FLAG 2 ENABLES THIS ROUTINE THE FIRST TIME C IS REQUIRED FOR CALCULATION, NOT ENABLED FOR SUBSEQUENT CALCULATIONS TO MINIMIZE COMPUTATION TIME. IF CONTENTS OF R3 OR R7 ARE CHANGED AND IT IS DESIRED TO RE-ENTER NOMINAL VALUE OF C, KEY h SF2 TO ARM SUBROUTINE 4 FOR NEXT CALCULATION
070	2	02	
	9	09	
	9	09	
	7	07	
	9	09	
	2	02	
	4	04	
	5	05	
	6	06	
	•	83	
080	2	02	
	STO 3	33 03	
	STO 7	33 07	
	h R↓	35 53	
	h RTN	35 22	
	f LBL E	31 25 15	→ C NOMINAL VALUE OF VELOCITY OF LIGHT RECALLED TO DISPLAY FOR USE AS REQUIRED
	h F2?	35 71 02	
	f GSB 4	31 22 04	
	RCL 3	34 03	
	h SF3	35 51 03	
090	h RTN	35 22	
	g LBL fa	32 25 11	◇ e ($e = mc^2$) ENTER OR CALCULATE ENERGY IN JOULES, EQUIVALENT OF MASS STORED IN REGISTER 6
	5	05	
	f GSB 1	31 22 01	
	h F2?	35 71 02	
	f GSB 4	31 22 04	
	RCL 6	34 06	
	RCL 7	34 07	
	g x^2	32 54	
	X	71	
100	STO(i)	33 24	
	h RTN	35 22	
	g LBL fb	32 25 12	◇ m ($e = mc^2$) ENTER OR CALCULATE MASS IN KILOGRAMS EQUIVALENT OF ENERGY STORED IN REGISTER 5
	6	06	
	f GSB 1	31 22 01	
	h F2?	35 71 02	
	f GSB 4	31 22 04	
	RCL 5	34 05	
	RCL 7	34 07	
	g x^2	32 54	
110	g ÷	81	
	STO(i)	33 24	
	h RTN	35 22	

REGISTERS

0 m_0, t_0, or l	1 m, t, or l_0	2 N	3 C	4 —	5 e	6 m	7 c	8 Δ KE	9 $\sqrt{1-\frac{N^2}{C^2}}$
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Listing 11

STEP	KEY ENTRY	KEY CODE	COMMENTS
	g LBL fc	32 25 13	◇ c (ℓ = mc²)
	7	07	ENTER OR CALCULATE VALUE OF c BASED ON VALUE OF ENERGY STORED IN REGISTER 5 AND MASS VALUE STORED IN REGISTER 6
	f GSB 1	31 22 01	
	RCL 5	34 05	
	RCL 6	34 06	
	÷	81	
	f TX	31 54	
120	STO (i)	33 24	
	h RTN	35 22	
	g LBL fd	32 25 14	→ ΔE_k
	RCL 1	34 01	CALCULATES RELATIVISTIC CHANGE IN ENERGY OF MOVING MASS, BASED ON CALCULATED OR STORED VALUES BY ROUTINES CALLED BY LABELS A,B,C, AND D
	RCL 0	34 00	
	−	51	
	RCL 2	34 02	
	g x²	32 54	
	X	71	
	h RTN	35 22	
130	g LBL fe	32 25 15	→ β CALCULATES, DISPLAYS $\sqrt{1-\frac{v^2}{c^2}}$
	f GSB 2	31 22 02	
	R/S	84	
	f LBL 5	31 25 05	SUBROUTINE 5
	RCL 3	34 03	TESTS FOR VELOCITY INPUT ≤ c — DISPLAYS ERROR FOR ENTRIES THAT ARE INVALID
	g x≤y	32 71	
	g SIN⁻¹	32 62	
	h x≷y	35 52	
	h SF 3	35 51 03	
	h RTN	35 22	
140			
150			
160			
170			
180			
190			
200			
210			
220			

LABELS

A ◇ ℓ, r_gas, R_0	B ◇ ℓ_0, T, OR m	C ◇ VELOCITY	D ◇ VELOCITY OF LIGHT	E → NOMINAL c 2.997 924 58 ·2 X10⁸	0 —
a ◇ ℓ	b ◇ m	c ◇ c	d → ΔKE	e → β	1 —
0	1	2	3	4	2 CONTROLS INITIAL STORAGE OF IND. REG. FIRST CALC ONLY
5	6	7	8	9	3 INDIRECT-ADDRESS CONTROL

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☐
1	☐	☒	GRAD	☐	SCI	☒
2	☒	☐	RAD	☐	ENG	☐
3	☐	☒			n	9