2022

NAME:

SOLUTIONS

Total Marks: 36

Time Allowed: 45 minutes

(Formula sheet and scientific calculator permitted)

**Question 1** 

(8 marks)

- (a) In a Christmas parade, elves on the back of a float moving at 9.00 ms<sup>-1</sup> East are tossing a ball around. Pepper throws the ball at 7.00 ms<sup>-1</sup>
  - in the direction of the float's movement, (i)
  - (ii) in the opposite direction to the float's movement.

Determine the velocity of the ball relative to a spectator watching the parade pass by in each case. [2]

(i) 16.00 ms - 'East /
(ii) 2-00 ms - East /

(b) In a futuristic parade, the float speed is 0.900 c and Pepper throws the ball at 0.700 c. Pepper throws the ball in the same two directions as in part (a).

Determine the velocity of the ball relative to a spectator watching the parade pass by in each case. [6]

$$(i) \qquad u = \frac{v + u'}{1 + vu'}$$

$$= \frac{0.9c + 0.7c}{1 + 0.9 \times 0.7}$$

≈ 0.982 e East ~

$$(ii) \qquad u = \frac{v + ul}{(t + vu)}$$

$$= 0.9c + (-0.7c)$$

$$1 + (0.9)(-0.7)$$

= 0.541 C East /

Answer T (true) or F (false) for each of the following statements.

(a) The amount of kinetic energy of an object measured in an inertial frame is the same as in the frame of a stationary observer. [1]

F

(b) The speed of light measured in an inertial frame is the same as in the frame of a stationary observer.

[1]

(c) The speed of a moving ball measured in an inertial frame is the same as in the frame of a stationary observer.

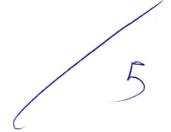
[1]

(d) The momentum of a moving ball measured in an inertial frame is the same as in the frame of a stationary observer. [1]

(e) The distance to a given destination measured in an inertial frame is the same as in the frame of a stationary observer. [1]

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Question 3 (6 marks)

A proton is accelerated from rest to a speed of 0.970 c in a linear accelerator by a large voltage. What voltage 45 required?

$$E_{K} = \frac{mc^{2}}{\sqrt{1-v_{c1}^{2}}} - mc^{2}$$

$$= mc^{2} \left( \frac{1}{\sqrt{1-0.97^{2}}} - 1 \right) V$$

$$\approx 3.11345 mc^{2}$$

$$= 3.11345 \times 1.67 \times 10^{-27} \times (3 \times 10^{8})^{2}$$

$$\approx 4.6795 \times 10^{-10} \text{ J} V$$

Now Ex = 
$$\frac{E_{T}}{2}$$

$$= \frac{4-6795 \times 10^{-10}}{1.6 \times 10^{-19}} V$$

Question 4 (12marks)

Two spaceships travelling at the same speed approach each other at a relative speed of 0.860 c, as measured by a stationary observer.

(a) Show that the common speed of the two spaceships, as measured by the stationary observer, is approximately 0.569 c.

Let 
$$u = xc$$
,  $v = -xc$ 

Thun  $u' = \frac{u-v}{1-uv}$ 

i.e  $0.86c = \frac{xc - (-xc)}{1-x(-x)}$ 

$$= \frac{2\pi c}{(+\pi)^2}$$

$$= \frac{2\pi c}{(+\pi)^2}$$

$$= 0.86$$

$$= 0.86 + 0.86x^2$$

$$= 0.86$$

The length of each spaceship is 28.0 m in its own frame.

- (b) What is the length of one of the ships, as measured by
  - (i) the stationary observer?

[2]

$$l = l_0 \sqrt{1 - v_{c1}^2}$$

$$= 28 \sqrt{1 - 0.569}, \sqrt{2}$$

$$= 23.0 \text{ M}$$

(ii) the other ship?

[4]

Don't 
$$u' = \frac{u - v}{1 - uv}$$
  
need  $= 0.569 c - (-0.569)$   
 $= \frac{1 - 138 c}{1 + 0.569^2} = 0.860 c$   
 $= \frac{1 - 0.860^2}{1 + 0.860^2}$ 

~ 14-3 m

A period of 60.0 minutes elapses, as measured on one spaceship.

(c) What time has elapsed, as measured by the stationary observer?

[2]

$$t = \frac{t_0}{\sqrt{1 - v_{i2}^2}}$$

$$= \frac{60 \text{ min}}{\sqrt{1 - 0.569^2}}$$

$$= \frac{73.0 \text{ mins}}{\sqrt{1 - 0.569^2}}$$

Question 5 (5 marks)

One of the experimental verifications of Einstein's Theory of Special relativity is the momentum change in accelerated high-speed electrons.

To what final speed must an electron initially travelling at 0.600 c be accelerated in order to achieve a 50.0 % increase in momentum?

New momentum = 
$$1.5 \times 0lol$$
 mamentum /

 $\sqrt{1-v_{12}^{2}} = 1.5 \times \frac{m \times 0.6c}{\sqrt{1-0.62}}$ 

(where  $v$  is new speed)

 $v = \frac{0.9c}{0.8}$ 
 $v = 1.125 \sqrt{1-v_{12}^{2}} = c$ 
 $v^{2} = 1.265 625 (1-v_{12}^{2})c^{2}v$ 
 $v^{3} = 1.265 625 c^{2} - 1.265 625 v^{2}$ 
 $v = 0.747c$ 

- End of Questions -

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