Neap:

PHYSICS VCE UNITS 3&4
DIAGNOSTIC TOPIC TESTS 2017

TEST 6: HOW FAST CAN THINGS GO? (III)

SUGGESTED SOLUTIONS AND MARKING SCHEME

Question 1 (2 marks)

The laws of physics are the same in all inertial (at rest or travelling at constant velocity) frames of reference. 1 mark

If a frame of reference travels at a constant velocity relative to a second frame of reference, it cannot be determined as to which is moving, which is stationary, or if both are moving.

However, the laws of physics will apply to both frames. 1 mark

Question 2 (3 marks)

Classical physics predicts that the observer measures the speed of light to be c and that the speed of light relative to the spacecraft is $0.7c$. 1 mark

Einstein's theory of special relativity postulates the speed of light to be constant relative to all inertial frames of reference and so both the stationary observer and the spacecraft measure the speed of light to be c. 1 mark

Special relativity is correct. 1 mark

Question 3 (4 marks)

a. $$\text{Lorentz factor} = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$= \frac{1}{\sqrt{1-\left(\frac{75}{3\times 10^8}\right)^2}}$$ 1 mark

$$= 1.00$$ 1 mark

Note: $270\ km\ h^{-1} = \frac{270}{3.6}\ m\ s^{-1}$

$= 75\ m\ s^{-1}$

b. Lorentz factor $= \dfrac{1}{\sqrt{1 - \dfrac{v^2}{c^2}}}$

$= \dfrac{1}{\sqrt{1 - 0.97^2}}$ 1 mark

$= 4.11$ 1 mark

Question 4 (8 marks)

a. These are the time interval and length that are measured by an observer at rest relative to the clock or to the length measured. 1 mark

b. When an observer moves past a reference frame in which a time interval occurs, the observer measures the time interval to be longer than that measured in the rest frame. 1 mark
When an observer moves past a reference frame in which a length is being measured along the line of motion, the length is measured to be shorter than in the rest frame. 1 mark

c. measured time $= \dfrac{\text{proper time}}{\sqrt{1 - \dfrac{v^2}{c^2}}}$

measured time = 20 ms 1 mark

$20 = \dfrac{\text{proper time}}{\sqrt{1 - 0.99^2}}$ 1 mark

proper time $= 20\sqrt{1 - 0.99^2}$

$= 2.82$ ms 1 mark

d. measured length = proper length $\sqrt{1 - \dfrac{v^2}{c^2}}$

proper length = 200 m 1 mark

measured length $= 200 \times \sqrt{1 - 0.99^2}$

$= 28.21$ m 1 mark

Question 5 (3 marks)

a. measured length = proper length $\sqrt{1 - \dfrac{v^2}{c^2}}$

$= 400 \times \sqrt{1 - 0.8^2}$ 1 mark

$= 240$ m 1 mark

b. As it is stationary, the proper length of the spacecraft is observed.
400 m 1 mark

Question 6 (4 marks)

a. As we observe the muon travelling, its proper time half-life is dilated by the Lorentz factor. 1 mark

Thus, as distance travelled = speed × time, its time of travel is greater and so it is expected to travel further in the frame of reference of Earth. 1 mark

b. In the frame of reference of the muon, distances on Earth are contracted by the Lorentz factor. 1 mark

Thus, in the same time, if the Earth distances are measured less, then a greater distance is travelled by the muon. 1 mark

Question 7 (12 marks)

a. $E = m_0c^2$

$= 1.67 \times 10^{-27} \times (3 \times 10^8)^2$ 1 mark

$= 1.503 \times 10^{-10}$ J

$= \dfrac{1.503 \times 10^{-10}}{1.6 \times 10^{-13}}$ MeV 1 mark

$= 939.38$ MeV 1 mark

b. mass energy = rest mass energy + kinetic energy

$= 939.38 + 200$ 1 mark

$= 1139.38$ MeV 1 mark

Note: Consequential on answer to ***Question 7a.***

c. $E = mc^2$

$m = \dfrac{1139.38 \times 1.6 \times 10^{-13}}{(3 \times 10^8)^2}$ 2 marks

$m = 2.03 \times 10^{-27}$ kg 1 mark

Note: Consequential on answer to ***Question 7b.***

d. $m = m_0 \times \gamma$

$\gamma = \dfrac{m}{m_0}$

$= \dfrac{2.03 \times 10^{-27}}{1.67 \times 10^{-27}}$ 1 mark

$= 1.21$ 1 mark

Note: Consequential on answer to ***Question 7c.***

e. $\gamma = \dfrac{1}{\sqrt{1 - \dfrac{v^2}{c^2}}}$

$\therefore 1.21 = \dfrac{1}{\sqrt{1 - \dfrac{v^2}{c^2}}}$ 1 mark

$\dfrac{v}{c} = \sqrt{1 - \dfrac{1}{\gamma^2}}$

$= \sqrt{1 - \left(\dfrac{1}{1.21}\right)^2}$

$= 0.56$ 1 mark

Question 8 (2 marks)

One outcome is that mass and energy are equivalent or interchangeable. 1 mark

$E = mc^2 = m_0c^2 + E_{\text{kinetic}}$

Another is that all particles have a rest mass/energy and when they are accelerated and receive a kinetic energy, their masses increase according to the above equation. 1 mark

Question 9 (7 marks)

a. mass of helium + mass of 2 positrons $= 6.6438 \times 10^{-27} + 1.8220 \times 10^{-30}$

$= 6.6456 \times 10^{-27}$ kg 1 mark

This is less than the mass of the 4 hydrogen atoms. 1 mark

Some of the mass of the 4 hydrogen atoms has been converted to energy. 1 mark

b. mass difference $= 6.6928 \times 10^{-27} - 6.6456 \times 10^{-27}$

$= 4.72 \times 10^{-29}$ kg 1 mark

$E = mc^2$

$= \dfrac{4.72 \times 10^{-29} \times (3 \times 10^8)^2}{1.6 \times 10^{-13}}$ 1 mark

$= 26.54$ MeV 1 mark

$= 26.5$ MeV 1 mark

Award 1 mark for three significant figures.