Neap:

PHYSICS VCE UNITS 3&4
DIAGNOSTIC TOPIC TESTS 2017

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

TOTAL 45 MARKS (45 MINUTES)

Student's Name: _____ Teacher's Name: _____

Directions to students

Write your name and your teacher's name in the spaces provided above.
Answer all questions in the spaces provided.

Use $c = 3.0 \times 10^8$ m s^{-1}.

Question 1 (2 marks)

State the first postulate in Einstein's theory of special relativity.

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Question 2 (3 marks)

A spacecraft is travelling at a speed of 0.3*c* away from a stationary observer. A light beam is emitted at speed *c* in the direction of motion of the spacecraft and is observed by the stationary observer.

Compare the predictions of classical physics and Einstein's theory of special relativity about the speed of the light beam as measured by the stationary observer. Indicate which of the two models is correct about the observation of the speed of the light beam.

Question 3 (4 marks)

Calculate the Lorentz factor (to two decimal places) for the following two situations.

a. A racing car travelling at a speed of 270 km h^{-1}. 2 marks

b. An electron travelling at 0.97 times the speed of light. 2 marks

Question 4 (8 marks)

a. In Einstein's theory of special relativity, proper time and proper length are defined according to a specific condition.

State that condition. 1 mark

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b. What happens to measured time intervals and measured lengths when the observer is moving relative to the measurement process? 2 marks

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A high-energy particle physicist is examining high-energy particles in a synchrotron. One such particle is travelling at 99% of the speed of light and the physicist observes it to have a half-life of 20 ms.

c. Determine the particle's half-life in its own reference frame. 3 marks

ms

One linear section of the synchrotron is 200 m long, as measured in the Earth's reference frame.

d. What is the length of the linear section of the synchrotron as measured in the particle's reference frame? 2 marks

m

Question 5 (3 marks)

A spacecraft being piloted by beings from another civilisation speeds through our solar system and travels past planet Earth at 0.8*c*. The proper length of the spacecraft is 400 m.

a. Determine the length of the spacecraft as it passes by Earth as measured by humans on Earth. 2 marks

m

b. If the spacecraft lands on Earth and remains stationary, what would be the measured length of the spacecraft as measured by humans on Earth? 1 mark

m

Question 6 (4 marks)

The half-life of a muon (subatomic particle) is 2.2×10^{-6} seconds; that is, when this time interval has passed after the release of the muon, it decays into other particles. Muons are produced in the upper atmosphere when cosmic rays collide with molecules present there.

A muon that is released at a speed of $0.99c$ would expect to travel 653 m downwards toward Earth before it decays into other particles.

a. From the frame of reference of an observer on Earth, explain why the muon is expected to travel further than 653 m. 2 marks

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b. From the frame of reference of the muon, explain why the muon is expected to travel further than 653 m. 2 marks

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Question 7 (12 marks)

A proton (of rest mass 1.67×10^{-27} kg) is accelerated in a linear accelerator such that it gains 200 MeV of energy.

a. Determine the rest mass energy of the proton in MeV. 3 marks

MeV

b. Determine the mass energy of the proton in MeV. 2 marks

MeV

c. Determine the mass of the proton after it has been accelerated. 3 marks

kg

d. Determine the Lorentz factor in the acceleration of the proton. 2 marks

e. At what fraction of the speed of light is the proton travelling after receiving an energy of 200 MeV. Express your answer to two significant figures. 2 marks

Question 8 (2 marks)

One of the conclusions from Einstein's theory of special relativity is the physics around the equation $E = mc^2$.

State two important outcomes concerning mass, energy and speed that result from this equation.

Question 9 (7 marks)

The main nuclear fusion reaction that creates the energy in our Sun is:

4 hydrogen atoms $\rightarrow$ a helium atom + 2 positrons.

The masses of these particles are given below.

- The mass of 4 hydrogen atoms is 6.6928×10^{-27} kg.
- The mass of a helium atom is 6.6438×10^{-27} kg.
- The mass of 2 positrons is 1.8220×10^{-30} kg.

a. Calculate the total mass of the helium and 2 positrons after the fusion reaction and comment on its comparison with the mass of the 4 hydrogen atoms. 3 marks

kg

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b. Calculate the mass energy of the mass difference, in MeV, after the fusion reaction and explain the form of this energy after its production. Express your answer to three significant figures. 4 marks

MeV