ALL SAINTS' COLLEGE

Ewing Avenue, Bull Creek, Western Australia

Year 12 Physics ATAR | Special Relativity | 2017

Time allowed: 50 minutes
Total marks available: 50
Show calculation answers to 3 significant figures

Student Name:_____

Question 1 **(5 marks)**

Valentina Vladimirovna Tereshkova is a retired Russian cosmonaut, engineer, and politician. She is the first woman to have flown in space, having been selected from more than 400 applicants and five finalists to pilot Vostok 6 on 16 June 1963. She completed 48 orbits of the Earth in her three days in space.

(a) While orbiting the Earth in a spacecraft at a constant speed is Valentina in an inertial frame of reference? Explain your answer. (2)

(b) Considering only special relativistic effects, would she observe the clocks on Earth as running faster, slower or at the same speed as an identical clock on her spacecraft? Circle your answer and provide an explanation.

Slower Faster Same speed

Explanation (3)

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Question 2 **(8 marks)**

An observer on a spaceship travels at a speed of 0.800 c relative to an observer at rest on Earth. The observer on the spaceship measures a time of 1.00 μs for a photon to travel from the back of their spaceship to the front of their spaceship.

(a) Calculate the length of the spaceship as measured by the observer on the spaceship.

(2)

(b) Calculate the length of the spaceship as measured by an observer on Earth. (3)

(c) Calculate the time that it takes the photon to travel from the back to the front of the spaceship as measured by an observer on Earth. (3)

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Question 3 **(5 marks)**

Astronomers using NASA's Kepler Space Telescope discovered the first Earth-size planet orbiting a star in the "habitable zone". The habitable zone is the range of distance from a star where liquid water might pool on the surface of an orbiting planet. The discovery of Kepler-186f confirms that planets the size of Earth exist in the habitable zone of stars other than our sun.

Kepler-186f resides in the Kepler-186 system and the astronomers on Earth measured the star to be at a distance of 500 light-years from Earth. The star is in the constellation Cygnus which is also home to four companion planets, which orbit a star half the size and mass of our sun. The star is classified as an M dwarf, or red dwarf, a class of stars that makes up 70 percent of the stars in the Milky Way galaxy.

(a) Calculate the time, in the frame of reference of an observer on Earth, that it takes a spaceship to travel from Kepler-186f to Earth at 0.900 c. Note that 1 light year is the distance light travels in one year. (2)

(b) Calculate the time that passes on the spaceship whilst making the journey. (3)

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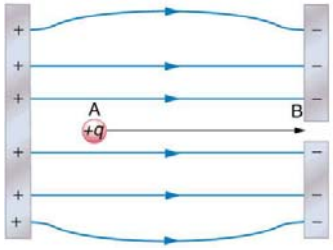
Question 4 **(9 marks)**

A proton is accelerated from rest by a uniform electric field between two charged plates. The relativistic momentum of the proton after being accelerated by the charged plates is 1.03×10^{-18} kg m s^{-1}.



(a) Calculate the final speed of the proton.

(5)

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(b) If the proton is accelerated from rest and the final speed of the proton is 0.900 c, calculate the potential difference between the plates. Hint: You may need the equation

$$\frac{m_0 c^2}{\sqrt{1-\frac{v^2}{c^2}}} = KE + m_0 c^2$$

(4)

Question 5 **(3 marks)**

A person on the website https://physics.stackexchange.com asked the following question:

"I've read in numerous places that the Large Hadron Collider is capable of accelerating protons at $0.999999991\ c$, which mathematically works out to being 3 metres per second slower than the speed of light. That seems so incredibly close to the speed of light, that it's hard for me to understand why we can't quite get all the way there."

Explain why the protons accelerated by the Large Hadron Collider cannot reach the speed of light.

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Question 6 **(7 marks)**

Aneutronic fusion is any form of fusion power in which neutrons carry no more than 1% of the total released energy. Successful aneutronic fusion would greatly reduce problems associated with neutron radiation such as ionizing damage, neutron activation and requirements for biological shielding, remote handling and safety.

Some proponents see a potential for dramatic cost reductions by converting energy directly to electricity. However, the conditions required to harness aneutronic fusion are much more extreme than those required for the conventional deuterium–tritium (D-T) nuclear fuel cycle.

One example of an aneutronic reaction is the deuterium-lithium-6 reaction

$$^{2}_{1}H + ^{6}_{3}Li \rightarrow 2^{4}_{2}He + energy$$

(a) Calculate the energy released by the above reaction. (4)

where

- mass of deuterium nucleus = 3.34358×10^{-27} kg,
- mass of lithium-6 = 9.98834×10^{-27} kg,
- mass of helium-4 = 6.64466×10^{-27} kg,
- mass of neutron = 1.67500×10^{-27} kg.

(b) If the energy is released as two identical photons, calculate the frequency of the photons. (3)

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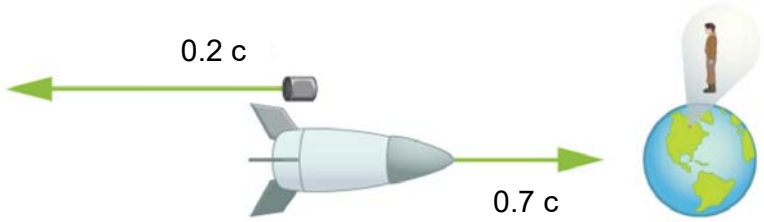
Question 7 **(7 marks)**

A spaceship travels towards an observer on Earth at a speed of 0.700 c. As the spaceship approaches Earth it ejects a weather satellite. The velocity of the satellite relative to the observer on Earth is 0.200 c away from the Earth.



(a) Calculate the velocity of the satellite relative to an observer on the spaceship. (3)

(b) An observer on the spaceship measures the depth of the Earth's atmosphere to be 7.1 km. Calculate the depth of the atmosphere as measured by an observer on the weather satellite. (4)

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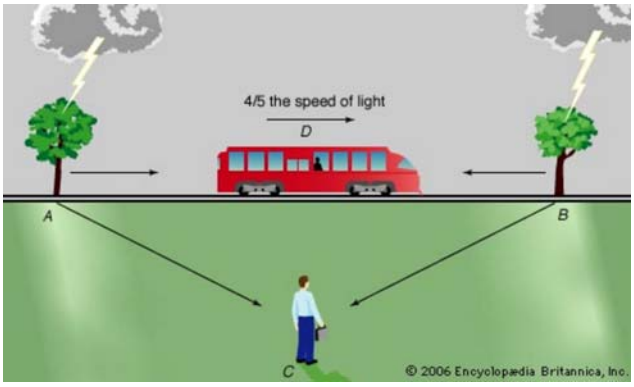
Question 8 **(6 marks)**

Alice stands in the middle of a train at Position D moving at speed 0.800 c to the right relative to Bob who is stationary on Earth and stands at Position D. When Alice is in line with Bob two bolts of lightning strike Tree A and Tree B simultaneously in Alice's frame of reference. Both Alice and Bob are midway between the trees when the lightning stuck.



(a) Does Bob see the lightning strike Tree A or Tree B first or does he see the lightning strike Tree A and B simultaneously in his frame of reference? Circle your answer and provide an explanation.

Tree A first Tree B first Simultaneously

(3)

Explanation

(b) Does Bob see the light from Tree A or Tree B strike Alice first or does he see the light from Tree A and B strike Alice simultaneously? Circle your answer and provide an explanation.

Tree A first Tree B first Simultaneously

(3)

Explanation

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