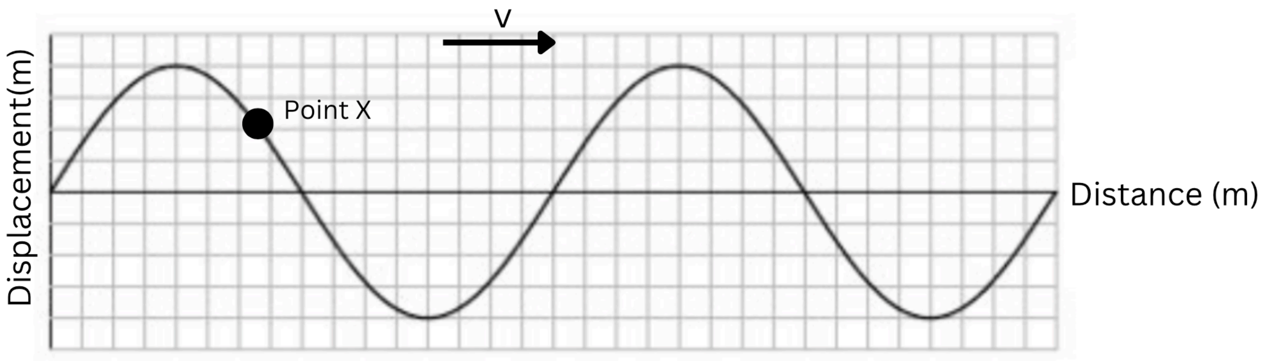
Unit 4 AOS 1 Diagnostic Quizzes

Quiz 1: Wave Basics

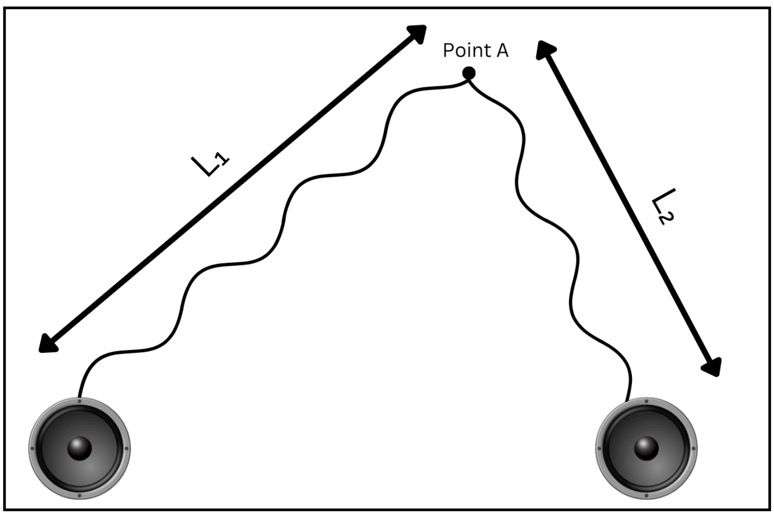
Q1) The diagram below shows a displacement-distance graph of a transverse wave travelling to the right. Which of the following is the correct direction of the instantaneous velocity of point X on the wave?



A. Upwards
B. Downwards
C. Left
D. Right

The following information applies to Questions 2-3.

Bob is dancing in a party room that has two speakers blasting loud music. The speakers emit coherent sound waves. He moves to point A where he notices the sound changing in intensity (loudness). At point A, Bob is L_1 metres away from the left speaker and L_2 metres away from from the right speaker, as shown in the diagram below.



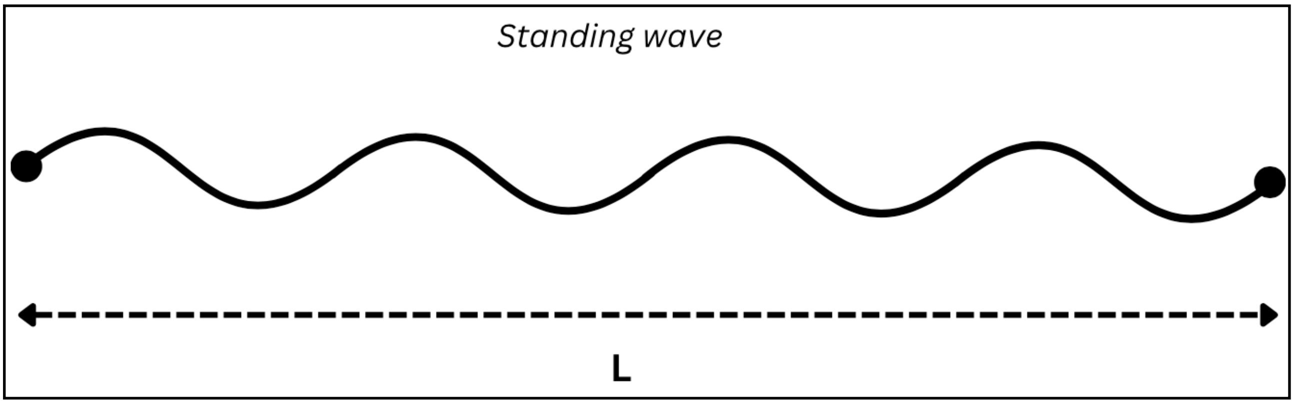
Q2) Using the information presented in the diagram, determine the path difference of the sound waves to point A in terms of the wavelength.

A. 2λ
B. 0
C. λ
D. 1.75λ

Q3) It is later determined that Bob stands 2.5 m further from the left speaker compared to the right speaker. Given that the speed of sound is $340\ m\ s^{-1}$, determine the frequency of the sound waves.

A. 136 Hz
B. 68 Hz
C. 272 Hz
D. 238 Hz

Q4) The below diagram illustrates a standing wave formed on a string attached to two fixed ends. The length of the string, L, is known to be 30 cm.



Given that the frequency of the standing wave is halved, determine the new wavelength of the standing wave.

A. 7.5 cm
B. 15 cm
C. 30 cm
D. 60 cm

Q5) Standing waves are produced by the superposition of two waves with the:

A. The same amplitude and frequency, and opposite propagation directions.
B. The same amplitude and direction of propagation, but different frequencies.
C. The same amplitude, different frequencies, and opposite directions of propagation.
D. The same amplitude, frequency, and direction of propagation.

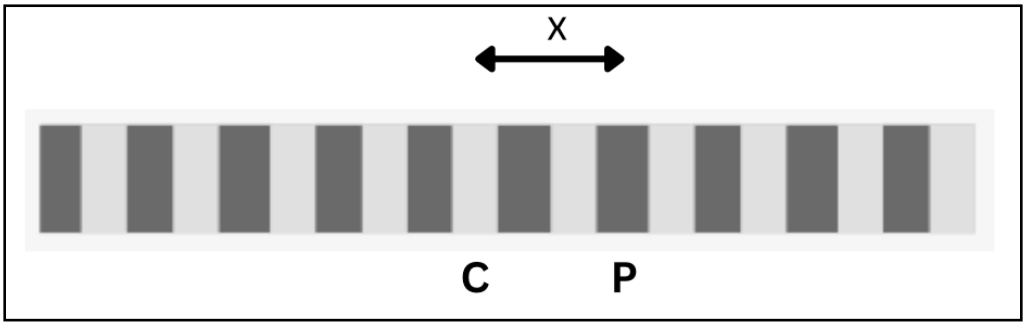
Quiz 2: The Young's Double Slit Experiment

Q1) A laser light has a wavelength 500 nm and is incident on double slits that are 2.5×10^{-4} m apart. The resulting interference pattern is visible on a screen 2.00 m behind the slits. What is the distance between adjacent bright bands?

A. 0.004 m
B. 0.03 m
C. 0.04 m
D. 0.3 m

The following information applies to Questions 2-4.

Scientists conduct an experiment similar to the Young's double slit experiment during which they shine monochromatic light through two slits, giving an interference pattern as shown below. The central bright band is labelled as band C and a nearby dark band is labelled as band P. The distance between the centres of these two bands, x, is measured to be 0.05 m.



Q2) Which of the following is the correct value for the fringe spacing, Δx?

A. 0.05 m
B. 0.025 m
C. 0.033 m
D. 0.1 m

Q3) Scientists used light of wavelength 780 nm in this experiment. Using this information, as well as the information provided in the diagram, determine the path difference from the two slits to point P.

A. 390 nm
B. 780 nm
C. 1170 nm
D. 195 nm

Q4) The scientists now decided to increase the frequency of the light used. Which of the following statements most accurately describes the effect of this change?

A. The energy of the light decreases
B. The distance *x* increases
C. The distance *x* decreases
D. The position of the central band, C, changes

Q5) James holds an electric torch towards a small hole in a cardboard box, resulting in a large circle of light seen on a far wall. He notices that if he changes the colour of the light, the diameter of the circle of light on the wall changes.

Jamie changes the colour of light from red to blue. Which of the following statements is correct?

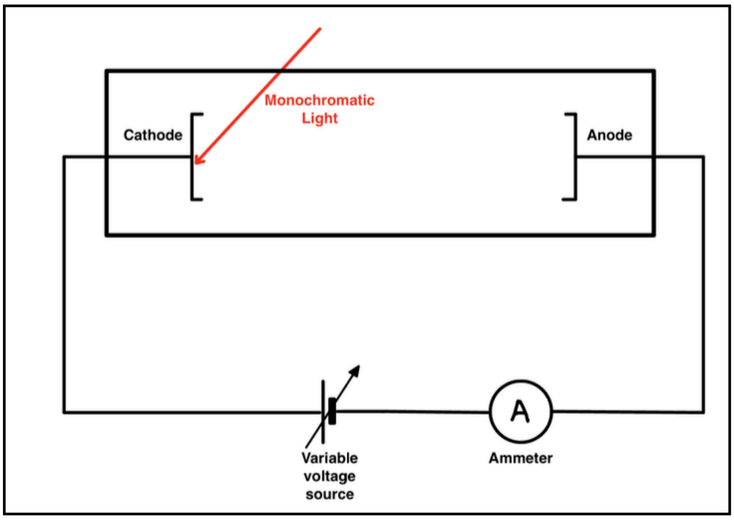
A. The diameter of the circular pattern increases
B. The diameter of the circular pattern remains the same
C. The brightness of the circular pattern increases
D. The diameter of the circular pattern decreases

Quiz 3: The Photoelectric Effect Experiment

Q1) In a photoelectric experiment, metal of work function 2.5 eV is used. Light with energy 3.9 eV is used to eject the electrons. What is the maximum kinetic energy of the ejected electrons?

A. 1.4 eV
B. 2.9 eV
C. 2.5 eV
D. 6.4 eV

Q2) The diagram below illustrates a photoelectric cell.

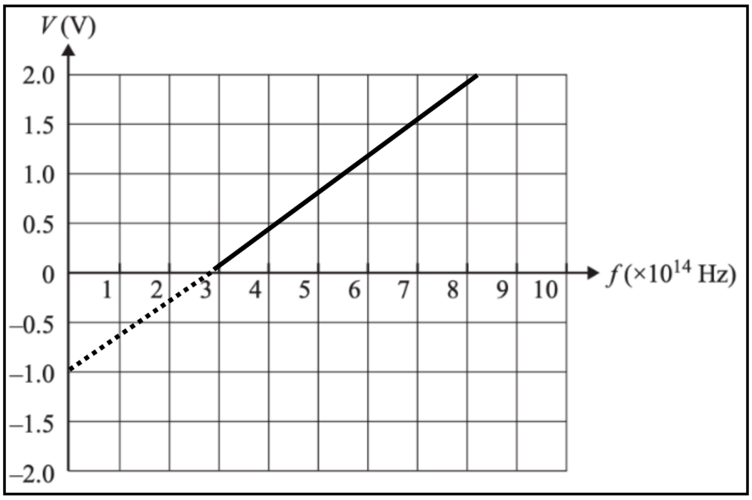


Given that no voltage is applied using the variable voltage source, which of the following would be the effect of increasing the brightness of the light used in the experiment?

A. The kinetic energy of the ejected electrons would increase
B. Fewer electrons would be ejected per second from the cathode
C. The ammeter reading would increase
D. It would take longer for the electrons to absorb the brighter light and therefore be ejected

The following information applies to Questions 3-4.

Students repeat Einstein's photoelectric effect experiment in class. During this experiment, they increase the frequency of the light and measure the effect this has on the stopping voltage, V, required keep the current at zero. They plot their results as shown below.



Q3) Using the data presented in the above stopping voltage-frequency graph, determine the work function of the metal used in joules.

A. $1.6 \times 10^{-19}\ J$
B. $4.8 \times 10^{-19}\ J$
C. $3.6 \times 10^{-19}\ J$
D. $4.5 \times 10^{-19}\ J$

Q4) The students make changes to the experiment. They increase the brightness of the light used as well as reduce the work function of the metal. What is the effect on the graph?

A. The linear graph changes to a curved graph
B. The graph is translated vertically downwards
C. The horizontal intercept of the graph decreases in magnitude
D. The graph is unchanged

Q5) Jack and Jill are conducting the photoelectric effect experiment at their school lab, during which they analyse the effect of changing light frequency on electron emission. They note that no photocurrent is detected if the frequency is decreased beyond a certain point, sparking a tense debate.

According to Jack:

'The presence of a minimum frequency in the emission of electrons supports the particle model of light as it suggests that light has discrete amounts of energy.'

According to Jill:

'The experimental finding is insufficient to support either model since light as a wave would also have discrete amounts of energy, so a minimum frequency needed to emit the electrons would be expected either way.'

Which of the following options correctly evaluate the two statements?

A. Jill is correct and Jack is incorrect since waves, similar to particles, also have limited energy and cannot be expected to emit electrons all the time.
B. Jack is correct and Jill is incorrect since the wave model describes light as a continuous transfer of energy which should emit any electron given enough time.
C. Neither Jack nor Jill is correct since experimental errors are likely to have occurred during the experiments, rendering the results void and not suitable for making any conclusions.
D. Jack is correct and Jill is incorrect since the particle model describes light as having limited amounts of energy relating to the brightness of the light.

Quiz 4: Wave-Particle Duality

Q1) In the single slit experiment using light, light of energy 3.5×10^{-15} eV is used. Determine the momentum of the light.

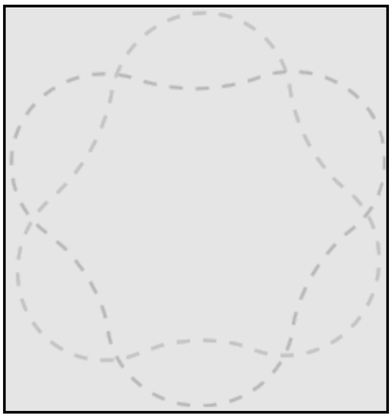
A. $1.17 \times 10^{-23}\ kg\ m\ s^{-1}$
B. $1.87 \times 10^{-42}\ kg\ m\ s^{-1}$
C. $1.95 \times 10^{-30}\ kg\ m\ s^{-1}$
D. $2.42 \times 10^{5}\ kg\ m\ s^{-1}$

Q2) A beam of electrons is produced in an electron gun. The de Broglie wavelength of each electron is 0.36 nm. An experiment is undertaken to compare the diffraction of these electrons and X-rays. With a similar gap spacing, the diffraction patterns are found to be nearly identical.

Which of the following is the closest to the momentum of the light?

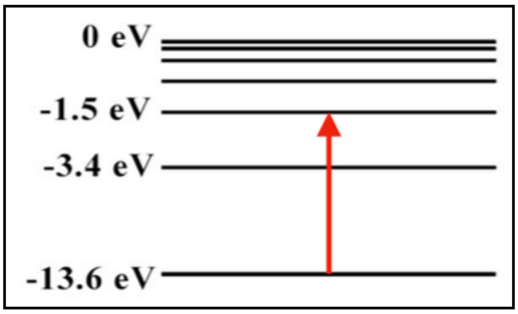
A. $1.8 \times 10^{-24}\ kg\ m\ s^{-1}$
B. $3.6 \times 10^{-24}\ kg\ m\ s^{-1}$
C. $1.2 \times 10^{10}\ kg\ m\ s^{-1}$
D. $4.0 \times 10^{-24}\ kg\ m\ s^{-1}$

Q3) The below diagram illustrates an electron standing wave in a hydrogen atom. Assuming that the 1st energy level is the lowest energy level, in which energy level (electron shell) is this electron in? (Note: this question is beyond the current study design)



A. 1^{st} energy level
B. 3^{rd} energy level
C. 5^{th} energy level
D. 6^{th} energy level

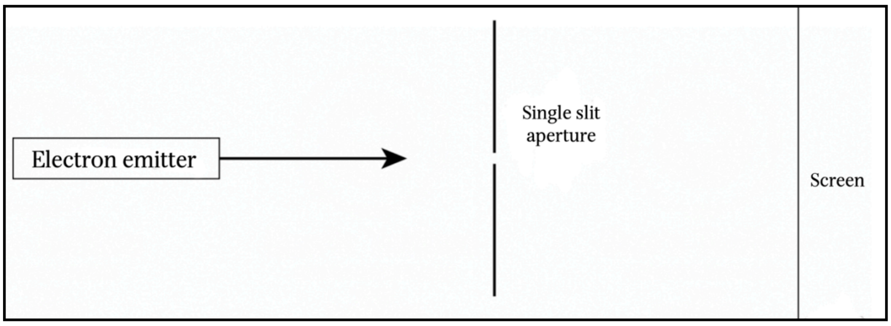
Q4) The diagram below shows the electron levels of the hydrogen atom. An electron transition is represented by the arrow.



In order for this transition to occur, the corresponding electron must absorb a photon of a particular frequency. Which of the following is the correct frequency of the absorbed photon?

A. 3.6×10^{15} Hz
B. 2.9×10^{15} Hz
C. 3.9×10^{15} Hz
D. 4.6×10^{15} Hz

Q5) A single slit experiment is conducted with an electron emitted aimed at a single slit aperture, as shown in the diagram below.



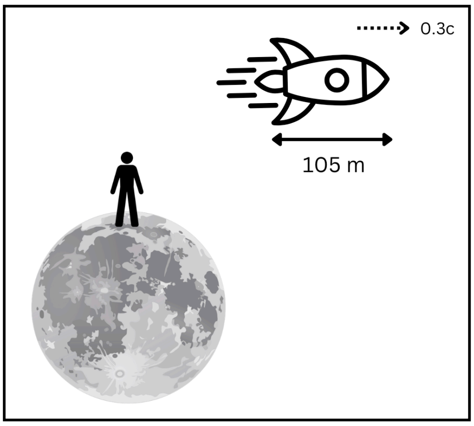
A diffraction pattern is seen on the screen. Which of the following modifications would increase the diameter of the diffraction pattern?

A. Increase the momentum of the electrons
B. Decrease the kinetic energy of the electrons
C. Decrease the wavelength of the electrons
D. Decrease the distance from the single slit aperture and the screen.

Quiz 5: Special Relativity

Q1) Jamie is a US astronaut standing on the Moon. He spots a spaceship leaving the Earth towards Mars for the human colonisation of the red planet. From Jamie's frame of reference, the length of the spaceship, travelling at a relative speed of 0.3c, is 105 m.

Determine the length of the spaceship from Jamie's frame of reference if it landed on the Moon and was stationary relative to Jamie. The value of c is $3.00 \times 10^8\ m\ s^{-1}$.



A. 110 m
B. 100 m
C. 95 m
D. 105 m

Q2) Which of the following statements regarding the Michelson-Morley experiment is true?

A. The result of this experiment was the basis for Einstein's first postulate.
B. Michelson and Morley detected different speeds of light from different directions towards the Earth.
C. The conclusion of this experiment was that the ether does not exist since the speed of light varies depending on the motion of the Earth.
D. The result of this experiment led to the idea that the speed of light is constant for all observers in inertial frames of reference.

Q3) Scientists at CERN are investigating the motion of fast moving unstable particles in a linear particle accelerator. Scientists observe that a certain particle, travelling at 0.9c, travels a linear distance of 4.5×10^{-4} m before decaying into other particles.

Which of the following is the correct lifetime of the particles from the particles' frame of reference?

A. $1.7 \times 10^{-12}\ s$
B. $1.4 \times 10^{12}\ s$
C. $7.3 \times 10^{-13}\ s$
D. $2.9 \times 10^{12}\ s$

Q4) A star ongoing nuclear fusion is transforming energy at a rate of $3.5 \times 10^{26}\ W$. Determine how much mass the star loses in one day.

A. $3.89 \times 10^{9}\ kg$
B. $3.36 \times 10^{14}\ kg$
C. $5.55 \times 10^{13}\ kg$
D. $7.34 \times 10^{10}\ kg$

Q5) A positron and an electron experience a collision, resulting in complete annihilation of the particles and emission of two gamma rays. The mass of a positron and an electron is $m_e = 9.11 \times 10^{-31}$ kg. Assuming that the initial kinetic energy of the particles is negligible, which of the following is the energy of each gamma ray?

A. $8.20 \times 10^{-14}\ J$
B. $2.70 \times 10^{-22}\ J$
C. $6.57 \times 10^{-22}\ J$
D. $1.60 \times 10^{-13}\ J$

Answers:

Quiz 1:

Question	Answer	Notes
1	A	Imagine the transverse wave is slightly translated horizontally to the right. Now compare the difference in the vertical position of point X is the original wave and the translated wave. Point X has to move upwards.
2	C	$L_1 = 3.75\lambda$ and $L_2 = 2.75\lambda$ based on the diagram. The difference of these distances will give you the path difference.
3	A	$p.d. = \lambda = 2.5$ m. The wave equation can be used to determine the frequency of the sound waves.
4	B	$n \propto f$. Therefore, if the frequency is halved then the harmonic number is also halved, going from n = 8 to n = 4. The length of the string remains constant. The formula $\lambda = \frac{2L}{n}$ can be used to find λ.
5	A	Standing waves are formed due to two coherent travelling waves moving in opposite directions, resulting in <u>interference of the waves at every point.</u>

Quiz 2:

Question	Answer	Notes
1	A	$d = 2.5 \times 10^{-4}$, $L = 2.00$. The fringe separation formula needs to be used to find Δx.
2	C	The fringe spacing is the distance between consecutive dark bands or bright bands. From the diagram, $x = 1.5\Delta x$.
3	C	Point P is a dark band hence destructive interference occurs. The position of the node at point P corresponds to a value of n. Since P is the second node from the centre, n = 1 (second lowest value). The path difference formula, $p.d. = (n + \frac{1}{2})\lambda$, can be used after this.
4	C	$\Delta x = \frac{\lambda L}{d} = \frac{vL}{fd}$ (after substituting wave equation into the formula). Therefore, $\Delta x \propto \frac{1}{f}$. Hence a larger frequency results in the bands being closer to each other.
5	D	Cooler colours, such as blue, have a larger frequency than warmer colours such as red. Since the frequency increases, the wavelength of the light must decrease. Using diffraction relationship - $diffraction \propto \frac{\lambda}{w}$ - a smaller wavelength results in lesser extent of diffraction of light through the hole.

Quiz 3:

Question	Answer	Notes
1	A	Use formula $KE_{max} = E_{photon} - \phi$.
2	C	The brightness of light relates to the number of photons emitted each second, therefore it relates to the number of electrons ejected from the metal each second.
3	A	$KE_{max} = V_s$ if the kinetic energy is in eV. Therefore all the stopping voltage values (y values) of the graph are equal to the kinetic energy of the electrons in eV. These need to be converted to joules. The work function corresponds to the vertical intercept of the graph.
4	C	Increasing the brightness of light has no effect on the energy of the light, therefore it does not affect the graph. Changing the work function results in a vertical translation of the graph.
5	B	The existence of a threshold frequency goes against the idea that light is a continuous transfer of energy which should eject any electron given that the electron has enough time to accumulate sufficient energy to overcome the work function.

Quiz 4:

Question	Answer	Notes
1	B	Use the formula $E = pc$ to determine the momentum using the energy of light. Note that the energy must be converted to joules before using the formula since the formula involves momentum which cannot be expressed In eV.
2	A	When light and particles experience the same diffraction pattern, we can conclude two things: 1. They have the same wavelength 2. They have the same momentum You can determine the momentum of the electrons which would be the same as the momentum of the light.
3	B	For an electron standing wave to exist, this condition must be met: $n\lambda = 2\pi r$. In this case, there are 3 wavelengths that can fit along the circumference of the electron shell, so $n = 3$. <u>NOTE: The value of n corresponds to the electron shell</u>.
4	B	$\Delta E = -1.5 - (-13.6) = 12.1\ eV$. We can then equate this to the energy of a photon to determine the frequency.
5	B	$KE = \frac{p^2}{2m}$. Decreasing the kinetic energy would decrease the momentum. Since $\lambda = \frac{h}{p}$, a lower momentum corresponds to a higher de Broglie wavelength hence a larger diffraction pattern.

Quiz 5:

Question	Answer	Notes
1	A	Since the length of the spaceship is 'moving' from Jamie's frame of reference (perspective), he measures the contracted length. When the spaceship lands on the moon, it is no longer moving from Jamie's perspective so he measures the proper length. We need to find the **proper length**.
2	D	The Michelson-Morley experiment was the basis for the second postulate, as described by option D.
3	C	Scientists measure the proper length, therefore they will measure the dilated time: $t = \frac{L_0}{v} = \frac{4.5 \times 10^{-4}}{0.9c} = 1.67 \times 19^{-12}\ s$. To determine the proper time measured by the particles we need to find the Lorentz factor first: $\gamma = 2.29$. The proper time is: $t_0 = \frac{t}{\gamma} = 7.3 \times 10^{-13}\ s$.
4	B	$\Delta E = mc^2 = Pt$. Therefore $m = \frac{Pt}{c^2}$. Here the time used should be in seconds. $1\ day = 86400\ s$.
5	A	Using the formula, $\Delta E = mc^2$, the total released energy is $\Delta E = (2 \times 9.11 \times 10^{-31})(3.00 \times 10^8)^2 = 1.64 \times 10^{-13}\ J$ Halving this total energy gives: $E_{gamma} = 8.20 \times 10^{-14}\ J$.