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Year 12 *Trial Exam Paper*

2018

PHYSICS

Written examination

Worked solutions

This book contains:

- worked solutions
- mark allocations
- explanatory notes
- tips on how to approach the exam.

SECTION A – Multiple-choice questions

Question 1

Answer: D

Explanatory notes

An electron has electric charge and therefore could be deflected by an electric field. It also has mass and therefore could be deflected by a gravitational field. Finally, a moving electron is a moving charge and so may be deflected by a magnetic field.

Question 2

Answer: C

Explanatory notes

Gravitational field strength varies inversely proportional to the square of the distance between the centres of masses of Duke and the planet Zorb; that is, $g \propto \frac{1}{r^2}$.

In the first instance, at an altitude of r above the surface of the planet, Duke is $2r_{\text{Z}}$ from the centre of Zorb. This situation may be represented as $g_1 = \frac{k}{(2r_{\text{Z}})^2} = \frac{k}{4{r_{\text{Z}}}^2}$.

When Duke's altitude increases to $2r$, he is $3r$ from the centre of Zorb.

This situation may be represented as $g_2 = \frac{k}{(3r_{\text{Z}})^2} = \frac{k}{9{r_{\text{Z}}}^2}$.

Using the ratio $\frac{g_1}{g_2}$, the constants k and r can be eliminated and we end up with $\frac{g_1}{g_2} = \frac{9}{4}$.

As $g_1 = 9\ \text{N kg}^{-1}$, so $g_2 = 4\ \text{N kg}^{-1}$.

Tip

- *In questions involving a body orbiting a central body, it is vital to distinguish between the altitude of the orbiting body above the surface of the central body and the radial distance between centres of masses.*

Question 3

Answer: D

Explanatory notes

Depending on whether a magnetic body is present or not, and the magnetic polarity of any magnetic body that is significantly present within the magnetic field, the field may exert either no force (no magnetic body present), an attractive force (south pole significant within the field), or a repulsive force (north pole significant within the field).

Question 4

Answer: A

Explanatory notes

A static field is one whose field strength does not change with time, whereas a uniform field is one whose field strength does not change across a defined space. The gravitational field around a point mass fits the description of static and non-uniform because the field strength decreases as the square of the distance from the mass. The electric field between two plates at a constant potential difference is static because of the constant potential difference, but it is uniform within the confines of the two plates. The magnetic field around a solenoid connected to an AC power supply varies in time due to the alternating current, and therefore it is not static. The same could be said for the electric field between two plates connected to an AC power supply.

Question 5

Answer: B

Explanatory notes

Using Fleming's left-hand rule, the direction of the force on the current flowing from east to west, exerted by a magnetic field running south to north, is down.

Question 6

Answer: A

Explanatory notes

The EMF is given by $\mathcal{E} = -n\frac{\Delta(BA)}{\Delta t}$. All the suggested actions increase the EMF **except** for increasing the period (Δt), which reduces the EMF.

Question 7

Answer: C

Explanatory notes

Since power loss in the transmission line is $P_{\text{loss}} = I^2R$, lowering the current in the transmission line by stepping up the voltage will reduce the transmission loss.

Option A cannot be realised as there is always a resistance in the transmission line (apart from superconducting material).

Option B is incorrect as it is not necessary for the ratios to be the same.

Option D is incorrect as conservation of energy has nothing to do with the resistance of the transmission line.

Question 8

Answer: C

Explanatory notes

Rearranging the formula for centripetal force, $f_\mathrm{c} = \frac{mv^2}{r}$, the speed of the airliner is given by $v = \sqrt{\frac{f_\mathrm{c} r}{m}} = \sqrt{\frac{125\,500 \times 690}{15\,000}} = 76.0\ \mathrm{m\ s^{-1}}$.

Question 9

Answer: D

Explanatory notes

According to Newton's third law of motion, the force that Erica exerts on the seat is equal in magnitude but opposite in direction to the normal force exerted by the seat on Erica. The normal force, which is directed upwards, has a magnitude given by $N = m(g - a)$, where a is the downward acceleration. Substituting the values in gives $N = 55(9.8 - (-3)) = 704$ N. Hence, the force that Erica exerts on the seat is 704 N, acting downwards.

Tips

- *For questions involving the normal force of a lift (or a lift-like vehicle, such as the ride in this question), it is worth remembering that the normal force is the weight experienced by the occupant. Thus, when the lift is accelerating downwards, the normal force is reduced and the occupant feels 'lighter'; whereas when the lift is accelerating upwards, the normal force is increased and the occupant feels 'heavier'.*
- *When writing a vector equation for the net force of an object, always use the direction of motion as positive.*

Question 10

Answer: B

Explanatory notes

Erica has no kinetic energy at the beginning of her ride, nor at the end of the ride. Hence, the difference in her total mechanical energy is entirely the difference in her gravitational potential energy between the ground level and the highest level. Thus, the net work done on her is the same as increasing her potential energy; that is,
$W = \Delta Eg = mg\Delta h = 55 \times 9.8 \times 20 = 10\,780$ J.

It should be noted that when Erica was accelerated upwards, and while she was in motion, additional work was being done on her by the ride, but these are cancelled out as she slows down to a stop.

Question 11

Answer: C

Explanatory notes

Diffraction occurs when waves move through an aperture or bend around a corner.

Question 12

Answer: D

Explanatory notes

Since the wavelength remains the same, the wave equation, $v = f\lambda$, is rearranged to obtain the wavelength of the 440 Hz sound in air: $\lambda = \frac{v}{f} = \frac{340}{440} = 0.7727$ m. The speed of sound in trimix is obtained by substituting the values in the wave equation $v = 1300 \times 0.7727 = 1004.5$ m s^{-1}.

Question 13

Answer: D

Explanatory notes

All the experiments described in options A, B and C demonstrate the interactions of light and electrons, which are best explained using the particle model.

Question 14

Answer: C

Explanatory notes

Diffraction is a wave phenomenon, with the fringe spacing determined by the wavelength. Thus, this experiment demonstrates that the electron beam behaves in a wave-like manner despite being ordinarily thought of as a particle-like stream of matter. The similar fringe spacing is due to the fact that the electrons in the beam have a de Broglie wavelength that is similar to the wavelength of the X-ray.

Question 15

Answer: C

Explanatory notes

The energy associated with that photon of light is given by the equation
$E = \frac{hc}{\lambda} = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{560 \times 10^{-9}} = 2.218$ eV.

Tip

- *As the unit of energy used in the responses is the electron-volt, using the electron-volt second (eV s) version of Planck's constant could save some time by removing the extra step of converting the answer from joules to electron-volts, if the joule second (J s) version of Planck's constant had been used. It is also important, when deciding which version to use, to check the units of the quantities involved in formulas to ensure consistency.*

Question 16

Answer: B

Explanatory notes

Jamila made a correct observation of the experimental evidence for the Heisenberg uncertainty principle. Keenan's prediction is correct, as increasing the momentum of the electrons will result in less diffraction due to the smaller de Broglie wavelength; however, this has nothing to do with Heisenberg's uncertainty principle. Hence, Keenan is incorrect.

Question 17

Answer: C

Explanatory notes

The falling mass is constant; hence, the net force is constant, meaning that it is the controlled variable. The mass of the cart is manipulated, and the acceleration of the cart is measured. This leads to the conclusion that the mass of the cart is the independent variable (as it is manipulated), and the acceleration is the dependent variable (because its measured value depends on the mass of the cart).

Question 18

Answer: C

Explanatory notes

The absence of data points in the region of 0.5 m weakens the assumption of a linear relationship here.

Option A is incorrect as one may extrapolate a graph beyond the range of experimental data, based on the observed trend and the strength of the correlation between variables.

Option B is incorrect as actual measurements are not required, provided a causal link and a relationship could be modelled between the variables.

Option D demonstrates a reliance on a textbook rather than experimental evidence.

Question 19

Answer: C

Explanatory notes

The uncertainty for this set of three readings could be estimated as the standard deviation of the readings. The average of the readings is 441.467 (calculated from $\bar{x} = \frac{442.4 + 441.1 + 440.9}{3}$) and the standard deviation is 0.67 (calculated from $\sigma = \sqrt{\frac{\sum(\bar{x} - x)^2}{3}}$). Since the individual readings are precise to 0.1 Hz, the average and uncertainty of these readings should be stated to the same precision.

Question 20

Answer: C

Explanatory notes

A hypothesis is still useful even though experimental evidence showed that it could not be supported, as the lack of support for a hypothesis through evidence gained can lead to new ideas and theories being developed to explain an observed phenomenon.

SECTION B

Question 1a.

Worked solution

Use $g = \frac{GM}{r^2} = \frac{6.67 \times 10^{-11} \times 2.9 \times 10^{30}}{(1.4 \times 10^{12})^2} = 9.9 \times 10^{-5}$ N kg^{-1}.

Mark allocation: 2 marks

- 1 mark for correctly substituting values into the correct formula
- 1 mark for correct answer

Question 1b.

Worked solution

The acceleration of the planet is the same as the gravitational field strength at the orbital radius of the planet; that is, 9.9×10^{-5} m s^{-2}.

Mark allocation: 1 mark

- 1 mark for correct answer

Question 1c.

Worked solution

No. Referring to the satellite equation, $\frac{R^3}{T^2} = \frac{GM_{\text{central}}}{4\pi^2}$, the orbital radius and period are related to the mass of the central body, which is the star. Hence, the mass of the planet is not involved and, therefore, cannot be determined.

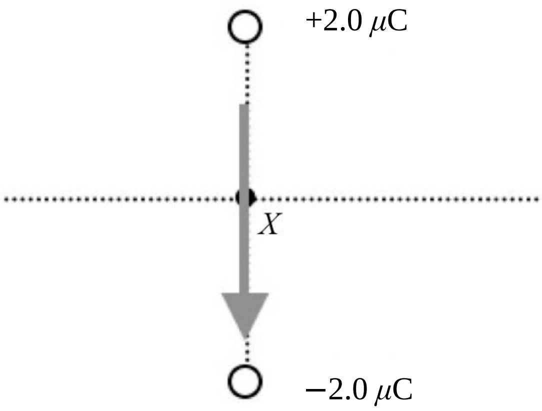
Mark allocation: 3 marks

- 1 mark for answering ‘No’
- 1 mark for using an appropriate equation, such as the satellite equation or $\frac{GMm}{r^2} = mg$
- 1 mark for appropriate explanation that the mass of the planet does not figure in the equation and so cannot be found

Note: It is also acceptable to explain that, since $a = g,$ it is not possible to determine the mass of the planet. In exactly the same way that it is not possible to determine the mass of an apple by allowing it to free-fall to Earth, the planet is in free-fall about the star.

Question 2a.

Worked solution



Mark allocation: 1 mark

- 1 mark for arrow pointing down

Explanatory notes

The direction of the electric field is the same as the direction of the force the field exerts on a small positive charge.

Question 2b.

Worked solution

A

Mark allocation: 1 mark

- 1 mark for correct answer

Explanatory notes

The negative charge would initially move in the opposite direction to the electric field vector.

Question 2c.

Worked solution

Use $F = \frac{kq_1q_2}{r^2} = \frac{8.99 \times 10^9 \times 2.0 \times 10^{-6} \times 2.0 \times 10^{-6}}{(0.50)^2} = 0.14$ N.

Mark allocation: 2 marks

- 1 mark for correctly substituting values into the correct formula
- 1 mark for correct answer

Question 3a.

Worked solution

Use $E = \frac{V}{d} = \frac{110}{0.12} = 9.2 \times 10^2$ V m^{-1}.

Mark allocation: 2 marks

- 1 mark for correctly substituting values into the correct formula
- 1 mark for correct answer

Question 3b.

Worked solution

Use work done, $W = Vq = \Delta E_K$. Since the initial kinetic energy is zero,
$Vq = \frac{1}{2}mv^2 \Rightarrow 110 \times 1.6 \times 10^{-19} = \frac{1}{2} \times 9.1 \times 10^{-31} \times v^2$.

Solve for v to obtain $v = 6.22 \times 10^6$ m s^{-1}.

Mark allocation: 3 marks

- 1 mark for relating the work done by the electric field on the electron to the change in kinetic energy
- 1 mark for correctly substituting values in the formula of that relationship
- 1 mark for correct answer

Question 3c.

Worked solution

The electrons in region Z require a force directed up the page. The current associated with the flow of electrons is directed to the left. Using the right-hand slap rule or Fleming's left-hand rule, the magnetic field should be directed out of the page.

Mark allocation: 3 marks

- 1 mark for identifying the correct direction of force
- 1 mark for identifying the correct direction of the current
- 1 mark for identifying the correct direction of the magnetic field

Tip

- *The direction of conventional current is opposite to the direction of the flow of electrons, which are negative charges. Electric current may be thought of as a flow of positive charges.*

Question 4a.

Worked solution

Use $F = \text{IlB} = 0.6 \times 0.12 \times 0.8 = 0.0576$ N.

Using the right-hand slap rule or Fleming’s left-hand rule, the direction of the force should be down (D).

Mark allocation: 3 marks

- 1 mark for correctly substituting values into the correct formula to obtain the force magnitude
- 1 mark for correct answer
- 1 mark for correctly identifying the direction

Question 4b.

Worked solution

Use $\mathcal{E} = -\frac{BA}{\Delta t} = -Blv = -0.8 \times 0.12 \times 0.15 = -0.0144$ V.

Mark allocation: 2 marks

- 1 mark for correctly substituting values into the correct formula to obtain the EMF magnitude
- 1 mark for correct answer

Tip

- *Although the often-used closed loop is not utilised here but rather a straight conductor, the conductor ‘sweeps’ out an area over a period of time, thereby giving the ratio of $\frac{A}{\Delta t}$ that is required in the equation. You need to look out for variations in the physical set-up of the questions, such as that given here, as part of your preparation.*

Question 4c.

Worked solution

from P to Q

Mark allocation: 1 mark

- 1 mark for correctly identifying the direction

Explanatory notes

Imagine a positive charge on the conductor between P and Q. As the conductor moves upwards, that positive charge represents a current moving upwards, in a magnetic field that is directed from left to right. That positive charge would experience a magnetic force on it. Using the right-hand slap rule or Fleming’s rule, the direction of the magnetic force is away from P towards Q.

Question 5a.

Worked solution

Use $V_{\text{p–p}} = 2V_{\text{RMS}}\sqrt{2} = 2 \times 240 \times \sqrt{2} = 679$ V.

Mark allocation: 1 mark

- 1 mark for correct answer

Question 5b.

Worked solution

Rearrange the formula for power, $P = VI$, to obtain $I = \frac{P}{V} = \frac{8.4 \times 10^5}{240} = 3500$ A.

Mark allocation: 2 marks

- 1 mark for correctly substituting values into the correct formula, to obtain the current
- 1 mark for correct answer

Note: Zero marks to be awarded if working is not shown.

Question 5c.

Worked solution

A turns-ratio of 100 would reduce the secondary current of T1 by the same ratio. The transmission line current would then be $3500 \div 100 \Rightarrow I_{\text{transmission}} = 35$ A.

The transmission loss of the power line is $P_{\text{loss}} = I^2R = 35^2 \times 3.0 = 3675$ W.

Mark allocation: 3 marks

- 1 mark for obtaining the correct transmission line current
- 1 mark for correctly substituting values into the correct formula to obtain the power loss
- 1 mark for correct answer

Question 6a.

Worked solution

According to Newton's third law of motion, the force exerted on box A by box B is equal in magnitude but opposite in direction to the force exerted on box B by box A. Since the force on box B by box A is due to the weight of box A, the magnitude of the force on box A by box B is $m_{\mathrm{A}}g = 3 \times 9.8 = 29.4$ N.

Since the direction of the force on box B by box A is *down*, the direction of the force on box A by box B is *up*.

Mark allocation: 2 marks

- 1 mark for correct magnitude of the force
- 1 mark for correct direction of the force

Question 6b.

Worked solution

Taking down as positive, and considering the forces on box A: the net force on box A is the sum of its force due to gravity, and the force on box A by box B. Thus $\sum F = ma = 3 \times 3.5 = 10.5$, and $\sum F = W - F_{\text{on A by B}} = 10.5 \Rightarrow F_{\text{on A by B}} = W - 10.5 = 29.4 - 10.5 = 18.9$ N, and the direction of the force is *down*. Applying Newton's third law, the magnitude of the force on box B by box A is 18.9 N acting downwards.

Mark allocation: 3 marks

- 1 mark for equating the net force on box A to the sum of its force due to gravity and the normal force exerted by box B
- 1 mark for calculating the correct magnitude of the force
- 1 mark for correct direction of the force

Question 7a.

Worked solution

The total mechanical energy (E_T) of carriage C1 is the sum of its kinetic energy at P and its gravitational potential energy; that is:

$$E_T = E_K + E_g = \frac{1}{2}mv^2 + mgh = \frac{1}{2} \times 850 \times 3.5^2 + 850 \times 9.8 \times 9.5 = 84\,341 \text{ J.}$$

Since there is no energy loss due to friction, the E_T remains the same at point Q; however, there is no gravitational potential energy at this point, so all of $E_T = E_K$.

Solving for v in $E_K = \frac{1}{2}mv^2 = 84\,341$ J, we obtain $v = 14.1$ m s^{-1}.

Mark allocation: 3 marks

- 1 mark for correctly calculating the E_T
- 1 mark for identifying that the $E_T = E_K$ at point Q
- 1 mark for correct answer

Question 7b.

Worked solution

An isolated collision is modelled as one in which no net external forces, such as friction or air resistance, act. The only forces causing an effect on the momentum of the bodies in the system are those applied by other bodies in the system. Hence, the momentum of the system is conserved.

Mark allocation: 3 marks

- 1 mark for noting that no net external forces act
- 1 mark for noting that the only forces causing an effect on the momentum are those applied by interacting bodies within the system
- 1 mark for highlighting the outcome that the momentum of the system is conserved

Tips

- *Although gravity still acts on bodies in the system, it is cancelled by the normal forces in the system; hence, the system may still be considered isolated.*
- *It is also vital to distinguish the term 'isolated collision' from the term 'elastic collision'; elastic collision refers to the conservation of kinetic energy in the system. It is possible to conserve momentum without conserving kinetic energy.*

Question 7c.

Worked solution

Since momentum is conserved, $p_{\text{total, before}} = p_{\text{total, after}} \Rightarrow (p_1 + p_2)_{\text{before}} = (p_1 + p_2)_{\text{after.}}$

As C2 is stationary before the collision, and both carriages move away at a common speed after the collision, the equation above simplifies to $m_1 u_1 = (m_1 + m_2) v_{\text{common.}}$

Substituting in the values gives $850 \times 14.1 = (850 + 550) v_{\text{common}}$, and solving for the common speed gives $v_{\text{common}} = 8.56 \text{ m s}^{-1}$.

Mark allocation: 2 marks

- 1 mark for identifying conservation of momentum and deriving the equation involving the common speed after the collision
- 1 mark for correct answer

  Note: It is possible to award consequential marks for an answer based on a student's value obtained in **part a.**
  $v_{\text{common}} = 0.607 \times \text{Answer(a)}$

Question 7d.

Worked solution

The E_K of the combined carriages is given by $E_K = \frac{1}{2} m v^2 = \frac{1}{2} \times 1400 \times 8.56^2 = 51\ 290$ J.

As the carriages stop at point *R*, all of the E_K has converted to E_g , meaning $E_g = mgh = 51\ 290$ J.

Substituting in the values gives $1400 \times 9.8 \times h = 51\ 290$, and solving for the height gives $h = 3.74$ m.

Mark allocation: 3 marks

- 1 mark for obtaining the E_K of the combined carriages
- 1 mark for equating the E_K to the E_g at point *R*
- 1 mark for the correct answer for the height

Note: It is possible to obtain consequential marks for an answer based on a student's value obtained in **part c.**
Thus, $E_K = 700 \times (\text{Answer(c)})^2$
and $h = 0.05102 \times (\text{Answer(c)})^2$.

Tip

- *Although the collision is isolated (i.e. the momentum is conserved), it is not elastic in that kinetic energy is not conserved. Therefore, the total mechanical energy of the system has changed, and it would be erroneous to use the total mechanical energy at* P *and equating it to the total mechanical energy at* R.

Question 8a.

Worked solution

The friction force is the centripetal force on the parcel, which is given by

$$F_\mathrm{c} = \frac{mv^2}{r} = \frac{4.5 \times 17^2}{8} = 163 \text{ N.}$$

Mark allocation: 2 marks

- 1 mark for correctly substituting values into the correct formula
- 1 mark for correct answer

Question 8b.

Worked solution

Applying the same friction force, which provides the centripetal force on the parcel, we obtain a new equation for the new speed, $F_\mathrm{c} = \frac{m{v_2}^2}{r_2} = 163$ N.

Thus, the minimum radius would be $r_2 = \frac{m{v_2}^2}{F_\mathrm{c}} = \frac{4.5 \times 19^2}{163} = 10$ m.

Mark allocation: 3 marks

- 1 mark for equating the friction force to the new centripetal force equation
- 1 mark for correctly substituting values into the correct formula
- 1 mark for correct answer

Note: It is possible to award consequential marks for a student using the value of friction force obtained in **part a.**

$$r_2 = \frac{1624.5}{\text{Answer(a)}}$$

Question 9

Worked solution

Teng is correct (or Sophie is incorrect).

As the mass drops downwards, it accelerates and gains kinetic energy. At the halfway point, the mass stops accelerating downwards as the spring force equals the weight force of the mass; thus, the mass stops gaining kinetic energy. The mass will also start to slow down due to the increasing spring force; thus, the mass starts losing kinetic energy. Hence, the kinetic energy of the system reaches its maximum at the halfway point. Therefore, Teng is correct.

At the halfway point, the gravitational potential energy of the mass is halved, with the half lost having been converted into both the kinetic energy of the moving mass and the elastic potential energy of the spring. Hence, the majority of the total energy of the system is still *potential* energy. Therefore, Sophie is incorrect.

Mark allocation: 3 marks

- 1 mark for stating that Teng is correct
- 1 mark for correctly explaining why Teng is correct
- 1 mark for correctly explaining why Sophie is incorrect

Question 10a.

Worked solution

The conversion factor is to divide by 3.6; hence, $235\ \text{km h}^{-1} \div 3.6 = 65.3\ \text{m s}^{-1}$.

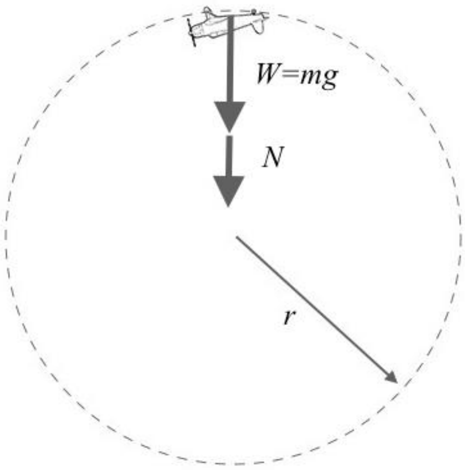
Mark allocation: 1 mark

- 1 mark for correct answer

Question 10b.

Worked solution

While Rhonda is flying upside down at the top of the loop, the centripetal force on her, which is the sum of her weight force and the normal force of her seat (both acting downwards), must be greater than or equal to her weight force (since N cannot be less than zero). That is, $\sum F = mg + N \geq F_\text{c}$ in order for her to perform the loop (see diagram below).



Therefore, $F_\text{c} = mg + N = 65 \times 9.8 + 853 = 1490$ N; and so $F_\text{c} = \frac{mv^2}{r} = 1490 \Rightarrow r = \frac{65 \times 65.3^2}{1490} = 186$ m.

Mark allocation: 2 marks

- 1 mark for correctly calculating the centripetal force of 1490 N
- 1 mark for correct answer to the radius

Note: It is possible for students to obtain consequential marks for calculations based on their answer in **part a.** Thus, $r = 0.0436 \times (\text{Answer a.})^2$

Question 11a.

Worked solution

In Earth's frame of reference the muon's lifetime is increased because it is moving relative to Earth's frame. The increase in time is called time dilation. This means that the muons travel farther in the atmosphere before they decay than would be predicted from classical physics, making it more likely for them to be detected.

Mark allocation: 3 marks

- 1 mark for identifying that the muon's lifetime increases in Earth's frame of reference
- 1 mark for identifying the increase in time as time dilation
- 1 mark for relating the increased lifetime to improved likelihood of detection

Tip

- *Distinguishing between frames of reference can be quite challenging and this is something to be practised in preparation for your exam.*

Question 11b.

Worked solution

In the frame of reference of the muon, the apparent length they traverse in the atmosphere is $l = 600$ m; whereas the proper length measured by the physicists is $l_0 = 20 \times 10^3$ m. The gamma factor, $\gamma = \frac{l_0}{l} = \frac{20 \times 10^3}{600} = 33.333$.

The speed of the muons is then calculated from the gamma factor to obtain $v = 0.99955c$.

Mark allocation: 3 marks

- 1 mark for correctly identifying the apparent length and proper length
- 1 mark for correctly evaluating the gamma factor
- 1 mark for correct answer for the speed of the muons, to five significant figures

Tips

- *Unlike time dilation, length contraction is perceived by observers in both reference frames that are moving relative to each other, and this can contribute to some confusion. For example, consider two reference frames, A and B, that are moving relative to each other. From the perspective of an observer in A, the length of an object in B that is measured by an observer in B is the proper length; whereas the observer in A would perceive the object in B to have a shorter length, the apparent length. Likewise, an observer in B would also perceive length contraction for objects in A, as measured by an observer in A.*
- *It is important that you do not go back and forth between frames of reference in your analysis of the physical situation.*
- *In the question, muons 'perceive' the length they traverse through Earth's atmosphere as 600 m, whereas the proper length as measured by physicists in Earth's reference frame is 20 km. It is important that you do not view the measurement of 600 m as a proper length of the atmosphere measured in a muon's frame of reference; it is the apparent length of the atmosphere measured by a muon.*

Question 12a.

Worked solution

Substituting in the values into Snell's law, $n_1 \sin\theta_1 = n_2 \sin\theta_2$, we obtain
$1.00 \sin 28° = n_{\text{oil}} \sin 18.5°$, leading to $n_{\text{oil}} = 1.48$.

Mark allocation: 2 marks

- 1 mark for correctly substituting values into Snell's law
- 1 mark for correct answer

Question 12b.

Worked solution

The refracted angle is larger than the incident angle. As the laser beam is travelling from a medium of higher refractive index (oil) into a medium with a lower refractive index (water) it moves faster, so the laser beam will move away from the normal (resulting in a larger refracted angle).

Mark allocation: 3 marks

- 1 mark for correctly identifying that the refracted angle is larger than the incident angle
- 1 mark for highlighting that the light is travelling from a more refractive medium to a less refractive medium
- 1 mark for correctly identifying the effect as moving away from the normal or resulting in a larger refracted angle

Question 13a.

Worked solution

Danica

Mark allocation: 1 mark

- 1 mark for correctly identifying that Danica is at the start

Explanatory notes

Due to the Doppler effect, a sound source (the car) moving away from an observer results in a lower sound frequency.

Question 13b.

Worked solution

decrease

Mark allocation: 1 mark

- 1 mark for correctly identifying a reduction in the sound frequency

Explanatory notes

The Doppler effect is more pronounced at higher speeds. Since the car is travelling more slowly towards Lewis, the effect he observed earlier is less pronounced and the frequency recorded will decrease.

Question 14a.

Worked solution

increase

Mark allocation: 1 mark

- 1 mark for correctly identifying the increase in the fringe spacing

Explanatory notes

Diffraction effect (and the fringe spacing) increases with the increasing wavelength of the laser used.

Question 14b.

Worked solution

decrease

Mark allocation: 1 mark

- 1 mark for correctly identifying the decrease in the fringe spacing

Explanatory notes

The fringe spacing decreases as the slit separation is increased.

Question 14c.

Worked solution

interference

Mark allocation: 1 mark

- 1 mark for correctly identifying the interference pattern

Explanatory notes

Each slit of the double slit acts as a point source of waves, and the waves from these sources constructively and destructively interfere with each other, resulting in the alternating bright and dark fringes known as an interference pattern.

Question 14d.

Worked solution

The pattern is an interference pattern, which is evidence of wave behaviour.

At locations where waves interact constructively there are bright regions, but where they interact destructively there are dark regions.

Constructive interference occurs when the path difference between the screen and the sources is an integer number of wavelengths $(n\lambda)$, whereas destructive interference occurs when this path difference is $(n-1)\lambda$.

Mark allocation: 3 marks

- 1 mark for identifying interference patterns as a wave phenomenon
- 1 mark for explaining how interference patterns arise from constructive and destructive interferences
- 1 mark for explaining how path difference between the two slits and the screen causes the interferences

Question 15a.

Worked solution

The stopping voltage gives the energy of the photoelectrons, $E = Vq$; thus, substituting the values gives $1.47 \times 1.6 \times 10^{-19} = 2.35 \times 10^{-19}$ J.

Mark allocation: 1 mark

- 1 mark for correct answer

Question 15b.

Worked solution

Use $E_{\text{electron}} = E_{\text{photon}} - W$, where $E_{\text{photon}} = hf \Rightarrow 4.14 \times 10^{-15} \times 6.45 \times 10^{14} = 2.67$ eV. The energy of the photoelectron is provided by the stopping voltage data in the question: 1.47 eV.

Rearranging the equation above to $W = E_{\text{photon}} - E_{\text{electron}} \Rightarrow 2.67 - 1.47 = 1.2$ eV.

Mark allocation: 3 marks

- 1 mark for correctly calculating the energy of each photon
- 1 mark for correctly substituting values into the equation relating the photon energy, photoelectron energy and work function
- 1 mark for correct answer to the work function

Tips

- *It is important to distinguish between the photoelectron energy (i.e. the kinetic energy of the photoelectron ejected from the metal) and the photon energy (i.e. the energy of a light photon, the 'input' energy). One way to check that you have correctly identified each is that the photon energy is always higher than the photoelectron energy.*
- *Also, by noting that the photoelectron energy is given in electron-volts, using the electron-volt second (eV s) version of Planck's constant could save some time by removing the need to convert from joules to electron-volts.*

Question 15c.

Worked solution

decrease

Mark allocation: 1 mark

- 1 mark for correctly identifying the decrease in the stopping voltage

Explanatory notes

The light is now of a lower frequency, hence photons have less energy. The stopping voltage will now be less than before.

Question 15d.

Worked solution

stay the same

Mark allocation: 1 mark

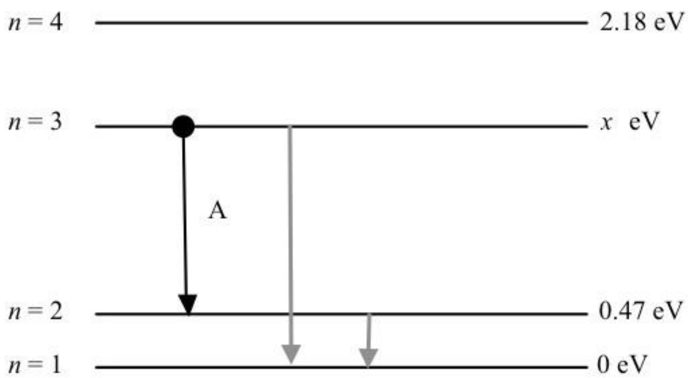
- 1 mark for correct answer

Explanatory notes

The intensity of the light will only affect the magnitude of the current of the photoelectrons (provided the light frequency is above the threshold frequency), not their energy. Thus the stopping voltage will remain the same.

Question 16a.

Worked solution



Mark allocation: 2 marks

- 1 mark for each correct arrow (up to 2 marks)

Note: If more than two arrows are provided, remove a mark for each incorrect arrow (minimum 0 marks); e.g. 2 correct and 1 incorrect, award 1 mark.

Question 16b.

Worked solution

The energy of the emitted photon can be obtained from the momentum via the equation $E = pc \Rightarrow 7.1 \times 10^{-28} \times 3 \times 10^{8} = 2.13 \times 10^{-19}$ J.

This is equivalent, in electron-volts, to $2.13 \times 10^{-19}/(1.6 \times 10^{-19}) = 1.33$ eV.

The energy of the photon is the difference in the energy levels between $n = 3$ and $n = 2$; that is, $x - 0.47 = 1.33 \Rightarrow x = 1.8$ eV.

Alternatively, the wavelength of the photon may be calculated from

$\boldsymbol{p = \frac{h}{\lambda} \Rightarrow \lambda = 6.63 \times 10^{-34}/7.1 \times 10^{-28} = 9.34 \times 10^{-7}}$ m,

and the energy of the photon is then

$\boldsymbol{E = \frac{hc}{\lambda} = 6.63 \times 10^{-34} \times 3 \times 10^{8}/9.34 \times 10^{-7} = 2.13 \times 10^{-19}}$ J, as before.

Mark allocation: 3 marks

- 1 mark for obtaining the energy of the photon using the momentum
- 1 mark for equating the energy of the photon with the difference in the energy levels
- 1 mark for correct answer

Question 16c.

Worked solution

The electrons in atoms such as those in element Z can absorb only quanta of energy that correspond to the difference in energy between any two levels. Since the energy of the beam of photons does not match any of the quanta that could be absorbed by element Z, the photons will pass through the sample without transferring energy to the electrons.

Mark allocation: 2 marks

- 1 mark for stating that the electrons can absorb only quanta of energy that correspond to differences between energy levels
- 1 mark for highlighting that the photon energy does not correspond to any quanta that could be absorbed

Question 17a.

Worked solution

Use the equation $E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{2.0 \times 10^{-10}} = 9.95 \times 10^{-16}$ J.

Mark allocation: 2 marks

- 1 mark for correctly substituting values into the correct equation
- 1 mark for correct answer

Question 17b.

Worked solution

From the de Broglie wavelength, we can obtain the velocity of the electrons by rearranging the equation $\lambda = \frac{h}{p} = \frac{h}{mv} \Rightarrow v = \frac{h}{m\lambda} = \frac{6.63 \times 10^{-34}}{9.1 \times 10^{-31} \times 2.0 \times 10^{-10}} = 3.643 \times 10^{6}$ m s^{-1}.

The kinetic energy of the electrons is obtained from

$$E_{\mathrm{K}} = \frac{1}{2}mv^2 = \frac{1}{2} \times 9.1 \times 10^{-31} \times (3.643 \times 10^{6})^2 = 6.04 \times 10^{-18} \text{ J.}$$

Mark allocation: 3 marks

- 1 mark for correctly substituting values into the correct equation to obtain the velocity of the electrons
- 1 mark for correct answer to the velocity of the electrons
- 1 mark for correct answer for the kinetic energy

Tip

- *For questions involving light and matter waves, remember that, when the wavelengths of both the light waves (such as ultraviolet, X-rays or gamma rays) and the matter waves are the same, their momentums should also be the same. However, the energy of the light waves are higher than those for matter waves, as shown in this question.*

Question 18a.

Worked solution

The percentage uncertainty is $\frac{2}{183} \times 100\% = 1.09\% \Rightarrow 1.1\%$.

Mark allocation: 1 mark

- 1 mark for correct answer, to one decimal place

Question 18b.

Worked solution

The uncertainty of each measurement is added. Thus, the difference is
$(183 - 154) \pm (2 + 3) = 29 \pm 5$ cm.

Mark allocation: 2 marks

- 1 mark for adding the absolute uncertainties correctly
- 1 mark for correct answer, both the difference and the uncertainty

Question 18c.

Worked solution

The percentage uncertainty of each measurement is added. Thus, the ratio is

$(154 \div 183) \pm (1.9\% + 1.1\%) = 0.8415 \pm 3\% \Rightarrow 0.8415 \pm 0.0256 \Rightarrow 0.84 \pm 0.03$.

Mark allocation: 2 marks

- 1 mark for adding the percentage uncertainties correctly
- 1 mark for correct answer, both the ratio and the uncertainty

Note: The uncertainty must not be left as a percentage.

Question 19a.

Worked solution

The dependent variable is the time taken to hit the bottom, or *t*.

The independent variable is the depth of oil, or *x*.

Mark allocation: 2 marks

- 1 mark for correct dependent variable
- 1 mark for correct independent variable

Tip

- *The dependent variable is the variable that responds to changes in the independent variable. Since the depth of oil is changed, while the time taken to hit the bottom responds to the changes in the depth, their roles as independent or dependent variables can be distinguished.*

Question 19b.

Worked solution

There are many possible answers.

It may be a physical characteristic of the oil: the oil temperature, type of oil, or the viscosity of the oil.

It may be a physical characteristic of the ball: ball mass, ball diameter, surface roughness of ball, or the ball density.

Mark allocation: 1 mark

- 1 mark for a correct choice

Question 19c.

Worked solution

When repeat measurements are made, it is expected that each measurement will cluster about the 'true value', provided there is no systematic error involved.

Repeat measurements also give insight into the random error associated with a measurement by providing an estimate of the uncertainty of the measurement.

Mark allocation: 1 mark

- 1 mark for an acceptable explanation for repeat measurements

Question 19d.

Worked solution

The dimension of the uncertainty bar for that data point is approximately 0.8 s, so the uncertainty is ± 0.4 s. However, a range of answers between 0.30 to 0.45 s is acceptable. 0.5 s is not acceptable as the uncertainty bar is clearly less than 1 s.

Mark allocation: 1 mark

- 1 mark for correct answers within range (between 0.30 s and 0.45 s)

Question 19e.

Worked solution

Time taken to fall is proportional to the square root of the depth of oil; $t \propto \sqrt{x} \Rightarrow t = k\sqrt{x}$.

Mark allocation: 1 mark

- 1 mark for correct choice

Explanatory notes

The data look best modelled as $t \propto \sqrt{x}$.

The first option is an inverse relationship, where *t* reduces towards zero as *x* is increased.

The second option is a parabola, where *t* increases exponentially as *x* is increased.

Question 19f.

Worked solution

Using the third model, $z = \sqrt{x}$:

***z* = new variable to test the model chosen**
0.32
0.45
0.89
1.10
1.41
1.73

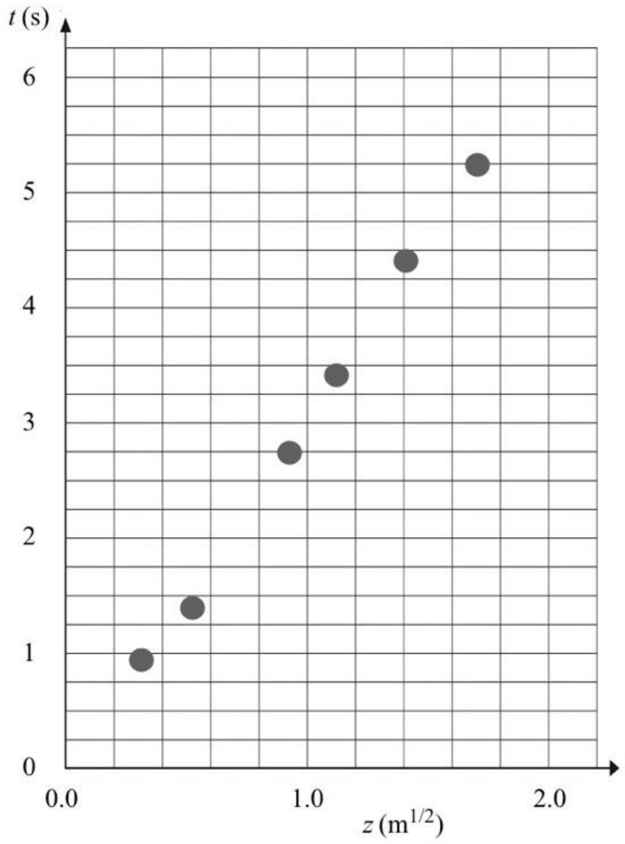
Mark allocation: 2 marks

- 1 mark for any three correct calculations
- 1 mark for a further two correct calculations

Note: Consideration should be given to correct calculations of the wrong model chosen from **part e.** (consequential marks)

Question 19g.

Worked solution



Mark allocation: 2 marks

- 1 mark for correct scale and labelling of the *x*-axis
- 1 mark for correctly plotting the data

Note: Consideration should be given to correctly plotting the wrong model chosen in **part e.** (consequential marks)

Question 19h.

Worked solution

Since the graph appears to be linear, it supports the hypothesis that the time, *t*, varies proportionally with the square root of *x*.

Mark allocation: 1 mark

- 1 mark for appropriately supporting their choice of answer

END OF WORKED SOLUTIONS