How to check your answers

SECTION A ANSWERS

For each question, the correct multiple choice response is provided and, where helpful, an additional explanation is provided to help students understand if they chose an incorrect answer.

SECTION B ANSWERS

Answers for calculation-based questions

For each calculation-based question, a full mark solution with mark allocations is provided. Where helpful, additional explanations are provided to help students understand the thought process behind each step.

- Exemplar responses with checklists for worded responses to help students work towards a full mark answer.
- Full mark answers with checklists for questions that require drawing or sketching.

Answers for questions requiring a worded response

For each question requiring a worded response, we provide:

- An **exemplar answer** that demonstrates how a student could respond to get full marks. The depth of the answer is derived from the wording of the question, the number of marks, and an analysis of examiners' reports from previous VCAA examinations. The answers are written in full sentences to model strong literacy and aid learning, although students may distill their responses into briefer phrases or dot points and still receive full marks.
- A **checklist** that identifies the function of each section of the response. This should help students to understand the exemplar answer and to compare it with the unique wording of their own response. The number of checklist items **does not** always correspond to the number of marks. There may be more than one checklist item per mark when there are multiple distinct elements required to earn a given mark.

In the example below, the VCAA examiner's report clearly states that there were two elements required to earn the only available mark.

Question 1a.

Marks	0	1	Average
%	56	44	0.5

Students were required to state that the charge is negative and to identify some process for finding this. A reference to a right-hand rule or similar was sufficient.

If students prefer writing answers as brief dot points, the checklist can be used to ensure they have still provided a complete and correct answer. When used with Edrolo's digital platform, students can use the checklist to self-mark short answer questions, and teachers can view this data to track class progress.

Question 1 (3 MARKS)

Two students set up a double slit experiment. Before turning on the laser, Jeffrey claims that a dark spot will occur in the centre of the pattern. Eva disagrees, claiming that the centre is always a bright band.

Evaluate Jeffrey and Eva's opinions. Justify your answer.

Exemplar responses show students what a full mark answer could look like

1 [Eva is correct.[1]] [The path difference is zero in the centre,[2]] [which means constructive interference occurs, and hence a bright band.[3]]

- I have explicitly addressed which student is correct.[1]
- I have used the relevant theory: path difference.[2]
- I have used the relevant theory: constructive interference.[3]

Numbers help students identify which part of the exemplar relates to which checklist item

Checklist items help students identify the function of the parts of the exemplar response so they can evaluate their own response more meaningfully and develop the skills to make their responses more coherent

Answers for questions requiring a drawn response

For each question requiring a drawn response (such as drawing a graph or vector arrows), we provide:

- An **exemplar answer** that demonstrates how a student could respond to get full marks.
- A **checklist** that identifies the key features of the drawn response that must be shown correctly to earn full marks. The number of checklist items does not always correspond to the number of marks.

Bonus questions

Underneath some exemplar answers, there is a box that contains an exam-style question and its corresponding answer. These extra questions are from Edrolo's Year 12 Physics textbook, which contains hundreds of exam-style questions, answers, and checklists. The bonus question aims to provide students with an example of a different type of question they may be asked on the same topic.

WANT MORE?

Here's another question to show the theory from a different perspective.

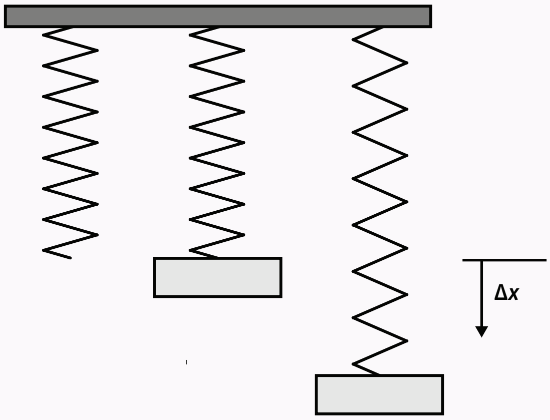
Study design dot point:

- analyse transformations of energy between kinetic energy, strain potential energy, gravitational potential energy and energy dissipated to the environment (considered as a combination of heat, sound and deformation of material):
  - strain potential energy: area under force-distance graph including ideal springs obeying Hooke's law: $E_s = \frac{1}{2}k\Delta x^2$

Related Edrolo Textbook Lesson: 3F – Page 155

Question 6

Ryle and Rushil hang a mass of 0.800 kg on the end of a spring with spring constant 12 N m^{-1}. They initially hold the mass at the unstretched length of the spring and then release it.



a Determine how far the spring stretches until the mass comes to rest, before moving upwards again. (3 MARKS)

b Calculate the maximum speed of the mass. (3 MARKS)

Answer

6 a $GPE_{top} = SPE_{bot}$

$mgh_{top} = \frac{1}{2}k(\Delta x_{bot})^2$ (1 MARK)

Since $h_{top} = \Delta x_{bot}$: $0.800 \times 9.8 \times \Delta x_{bot} = \frac{1}{2} \times 12 \times (\Delta x_{bot})^2$ (1 MARK)

$\Delta x_{bot} = 1.3$ m (1 MARK)

b $SPE_{mid} + KE_{mid} + GPE_{mid} = SPE_{bot}$ (1 MARK)

$\frac{1}{2} \times 12 \times 0.65^2 + \frac{1}{2} \times 0.800 \times v_{mid}^2 + 0.800 \times 9.8 \times 0.65 = \frac{1}{2} \times 12 \times 1.3^2$ (1 MARK)

$v_{mid} = 2.5$ m s^{-1} (1 MARK)

SECTION A – ANSWERS

1 B. The result is the vector sum of the field from the left-hand magnet, which points up and to the left at point P, and the field from the right-hand magnet, which points down and to the left.

2 D. A set of measurements is more accurate than another set if its average is closer to the true value. A set of measurements is more precise than another set if it has a smaller range (all the values in the set are less spread).

3 B. The dependent variable is a variable that the experimenter measures (tension) and which is predicted to be affected by the independent variable (which is the length of the string in this case).

4 A. The resultant (net) force must always point towards the centre of the circle.

5 C

6 A. $KE = (\gamma - 1)E_{rest} \therefore \gamma - 1 = 4 \therefore \gamma = 5; L = \frac{L_0}{\gamma} = \frac{20}{5} = 4.0$ metres

7 C. $\Delta E = mc^2 = 3.2 \times 10^{-27} \times (3.0 \times 10^8)^2 = 2.9 \times 10^{-10}$ J

8 D

9 B. The longest wavelength photon corresponds to the lowest energy photon. From $n = 4$, the smallest change in energy that results in the emission of a photon is a transition from $n = 4$ to $n = 3$.

$\Delta E = \frac{hc}{\lambda} \therefore 12.8 - 12.1 = \frac{4.14 \times 10^{-15} \times 3.0 \times 10^8}{\lambda}$

$\lambda = 1.8 \times 10^{-6}$ m.

10 C. Trace the line of best fit to the intercept on the vertical axis. The magnitude of the intercept indicates the work function, which should be around 4.7 eV.

11 A. By the right-hand coil rule, the direction of the magnetic field at Wire 1 due to Wire 2 is into the page. By the right-hand palm rule (with thumb pointing right and fingers pointing into the page), the force must be up the page.

12 C. $F = nBIL = 1 \times 3.0 \times 10^{-2} \times 0.50 \times 1 = 1.5 \times 10^{-2}$ N

13 B. The EMF is proportional to the rate of change of magnetic flux. When the flux is a maximum or minimum, the EMF should be zero.

14 D

15 D

$F = (m + 2m) \times a \therefore a = \frac{F}{3m}$

For Block 1: $F_{net} = m \times a = m \times \frac{F}{3m} = \frac{F}{3}$

The sum of net forces should add to F. For Block 1, $F_{net} = \frac{F}{3}$.
For Block 2, $F_{net} = 2 \times \frac{F}{3}$.

16 C. GPE must increase with height, SPE must decrease with height (as extension decreases), KE must be zero at the top and bottom and be a maximum in the middle, and the total energy must be constant.

17 B. To complete the entire loop, the car must remain in contact at point P. When two surfaces are in contact, there must be a normal contact force.

18 B. $V_{RMS} = \frac{V_{peak}}{\sqrt{2}} = \frac{400}{\sqrt{2}} = 283$ V

19 A. $\Delta KE = -\Delta GPE$ = *area under graph × mass*

1 box = $1 \times 1 \times 10^9 = 1 \times 10^9$ J kg^{-1}

There are approximately 21 boxes under the graph between 10×10^9 and 4×10^9 m from the centre of the Sun.

$\Delta KE = 21 \times 1 \times 10^9 \times 200 = 4.2 \times 10^{12} = 4 \times 10^{12}$ J to one significant figure

20 A. $F_{net} = 0$ so $F_{drive} = mg\sin(\theta) = 1600 \times 9.8 \times \sin(40°) = 1.0 \times 10^4$ N

SECTION B – ANSWERS

1 a [Negative.[1]][Since the test charge is attracted to $+q$, its charge must have the opposite sign.[2]]

I have explicitly addressed whether the test charge is positive or negative.[1]

I have used the relevant theory: the relationship between the signs of charges and the attractive or repulsive nature of forces.[2]

b 100 N (1 MARK)

Direction C (to the right) (1 MARK)

The force on the stationary charge and the force on the test charge are a Newton's third law pair so the magnitudes must be equal and the directions must be opposite.

c The electrostatic force between charged particles follows an inverse square law.

$\frac{F_Y}{F_X} = \frac{r_X^2}{r_Y^2} \therefore \frac{F_Y}{F_X} = \frac{d^2}{(2d)^2} = \frac{1}{4}$ (1 MARK)

$F_Y = 25$ N (1 MARK)

d The test charge is attracted to both $+q_1$ and $+q_2$ so it experiences a force to the left due to $+q_1$ and a force to the right due to $+q_2$.

$F_{net} = F_{+q2} - F_{+q1} = 100 - 25$ (1 MARK)

$F_{net} = 75$ N (1 MARK)

Direction: C (to the right) (1 MARK)

2 a $E = \frac{V}{d} = \frac{200}{0.50} = 400$ N C^{-1} (1 MARK)

$F = qE = 1.6 \times 10^{-19} \times 400$ (1 MARK)

$F = 6.4 \times 10^{-17}$ N (1 MARK)

b $\frac{1}{2}mv^2 = qV$

$\frac{1}{2} \times 9.1 \times 10^{-31} \times v^2 = 1.6 \times 10^{-19} \times 200$ (1 MARK)

Solving for v yields

$v = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 200}{9.1 \times 10^{-31}}} = 8.386 \times 10^6 = 8.4 \times 10^6$ m s^{-1} but no marks are awarded for this step since the final value is provided in the question.

c $r = \frac{mv}{qB} = \frac{9.1 \times 10^{-31} \times 8.386 \times 10^6}{1.6 \times 10^{-19} \times 5.0 \times 10^{-5}}$ (1 MARK)

$r = 0.95$ m (1 MARK)

This value is obtained when using the unrounded value for speed calculated in part b. If the value of speed rounded to two significant figures ($v = 8.4 \times 10^6$ m s^{-1}) is used, then the answer will be $r = 0.96$ m. This answer is also acceptable.

3 a A (anticlockwise) (1 MARK)

b [The magnetic field is directed to the left and the current travels from M to L.[1]][By the right-hand palm rule, this results in an upward force on this side.[2]]

I have stated the direction of the magnetic field and the direction of the current on one of the sides perpendicular to the magnetic field.[1]

I have used the relevant theory: right-hand palm rule to determine the direction of force.[2]

c [The motor would no longer function.[1]][The coil would turn one-quarter of a rotation where it would oscillate in the vertical position and eventually stop.[2]]

I have stated that the motor would not operate correctly anymore.[1]

I have described the position where the motor stops rotating.[2]

4 a $g = \frac{GM}{r^2} = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{(7.40 \times 10^6)^2}$ (1 MARK)

$g = 7.28$ N kg^{-1} (1 MARK)

b $v = \sqrt{\frac{GM}{r}} = \sqrt{\frac{6.67 \times 10^{-11} \times 6.0 \times 10^{24}}{7.4 \times 10^6}}$ (1 MARK)

$v = 7.4 \times 10^3$ m s^{-1} (1 MARK)

OR

$a = \frac{v^2}{r}$ where a is the acceleration due to gravity.

$7.28 = \frac{v^2}{7.40 \times 10^6}$ (1 MARK)

$v = 7.34 \times 10^3$ m s^{-1} (1 MARK)

This method involves consequential marks from **part a**.

c [Orbital period is related to radius by $T = \sqrt{\frac{4\pi^2 r^3}{GM}}$,[1]][so if the orbital radius decreases then the period must also decrease.[2]]

I have provided the correct relationship between orbital period and radius.[1]

I have explicitly addressed how the period must change when the radius decreases.[2]

5 a $\Phi_B = B_{\perp}A$

$2.0 \times 10^{-4} = B \times 0.40 \times 0.25$ (1 MARK)

$B = \frac{2.0 \times 10^{-4}}{0.40 \times 0.25} = 2.0 \times 10^{-3}$ T (1 MARK)

b $\varepsilon = N\frac{\Delta\Phi_B}{\Delta t}$

$\varepsilon = 500 \times \frac{2.0 \times 10^{-4} - 0}{8.0 \times 10^{-3}}$ (1 MARK)

$\varepsilon = 13$ V (1 MARK)

WANT MORE?

Here's another question to show the theory from a different perspective.

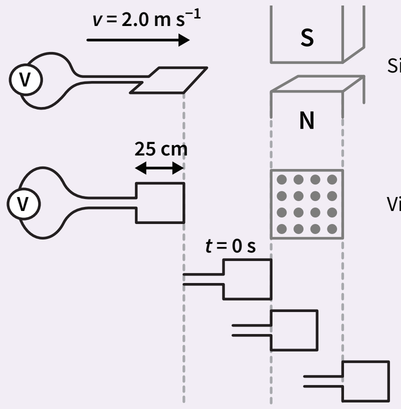
Study design dot point:

- investigate and analyse theoretically and practically the generation of electromotive force (emf) including AC voltage and calculations using induced emf: $\varepsilon = -N\frac{\Delta\Phi_B}{\Delta t}$, with reference to:
  - rate of change of magnetic flux

Related Edrolo Textbook Lesson: 7A – Page 245-246

Question 11b

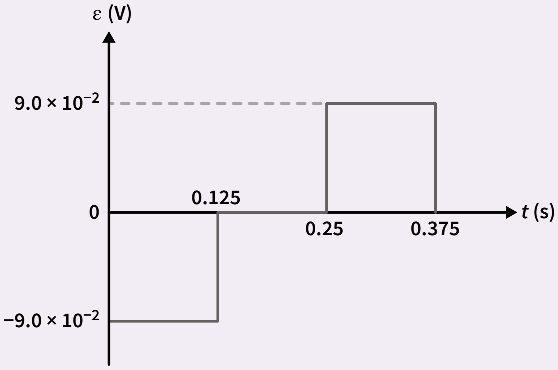
A square coil with 6 turns starts in a region with no magnetic field and then passes at a constant speed of 2.0 m s^{-1} into, through, and out of a uniform magnetic field (B = 3.0 × 10^{-2} T) between the poles of two bar magnets as indicated by the diagram. Assume that the uniform magnetic field is a square shape with side length of 50 cm, and the loop has a side length of 25 cm.



On a set of axes similar to those provided, sketch a graph of the EMF in the coil against time. Appropriate values should be included on the graph. (3 MARKS)

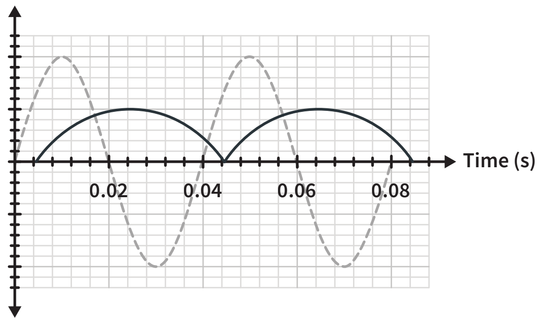
Answer

$\varepsilon = N\frac{\Delta\Phi_B}{\Delta t} = 6 \times \frac{1.875 \times 10^{-3}}{0.125} = 9.0 \times 10^{-2}$ V



- I have drawn a constant EMF when the rate of change of magnetic flux is constant.
- I have drawn zero EMF when the rate of change of magnetic flux is zero.
- I have used the opposite sign for the EMF when the flux is increasing compared to when the flux is decreasing.
- I have included the values of the maximum magnitudes of EMF.
- I have included the time for each stage of the motion.

c



- I have accounted for the effect of the reduced speed on the period: the period is doubled.
- I have accounted for the effect of the reduced speed on the amplitude: the amplitude is halved.
- I have accounted for the effect of replacing the slip rings with the split ring commutator: either the negative or the positive values are inverted.

6 [As the loop moves from position 1 to position 2, the magnetic flux which is directed into the page (in Figure 6b) decreases.[1]] [By Lenz's law, the induced magnetic field must be directed into the page to oppose the change in flux.[2]] [By the right-hand coil rule, the current flows in a clockwise direction.[3]]

- I have stated the direction and the change in flux through the loop.[1]
- I have applied Lenz's law to state the direction of the induced magnetic field.[2]
- I have applied the right-hand coil rule to state the direction of the induced current.[3]

7 Momentum is conserved.

$m_X v_X + m_Y v_Y = (m_X + m_Y)v_{final}$

Take right as the positive direction.

$4.5 \times 10^3 \times 5.0 + 3.5 \times 10^3 \times (-7.0) = (4.5 + 3.5) \times 10^3 \times v_f$ (1 MARK)

$v_f = \frac{4.5 \times 5.0 + 3.5 \times (-7.0)}{4.5 + 3.5} = -0.25$ m s^{-1}

Magnitude: 0.25 m s^{-1} (1 MARK)

Direction: left (1 MARK)

8 a $\frac{mv^2}{r} = mg - F_N$ (1 MARK)

$F_N = 0$ when the toy car loses contact with the track.

$\frac{mv^2}{0.10} = 3 \times 9.8 - 0$ (1 MARK)

Cancelling m on both sides of the equation and solving for v yields $v = \sqrt{9.8 \times 0.10} = 0.99$ m s^{-1} but no marks are awarded for this step since the final value is provided in the question.

b $KE_Q + GPE_Q + SPE_Q = KE_P + GPE_P + SPE_P$

$\frac{1}{2}k\Delta x^2 + 0 + 0 = \frac{1}{2}mv_P^2 + mgh_P + 0$ (1 MARK)

$\frac{1}{2} \times 235 \times \Delta x^2 = \frac{1}{2} \times 0.200 \times 0.99^2 + 0.200 \times 9.8 \times 0.10$ (1 MARK)

$\Delta x = \sqrt{\frac{0.200 \times 0.99^2 + 2 \times 0.200 \times 9.8 \times 0.10}{235}} = 0.05$ m = 5 cm (1 MARK)

9 Consider the connected masses as a single system. The only unbalanced force on the system is the force on m_2 due to gravity.

$a = \frac{F_{net}}{m_{total}} = \frac{0.30 \times 9.8}{0.20 + 0.30}$ (1 MARK)

$a = 5.88 \text{ m s}^{-2}$ (1 MARK)

Now consider m_1 only. The only unbalanced force is the tension force.

$F_{net} = m_1 a$

$F_T = 0.20 \times 5.88 = 1.2 \text{ N}$ (1 MARK)

An alternative approach is to use the acceleration to calculate the net force acting on m_2. This approach is slightly more complicated because m_2 has both the tension force and the gravitational force acting on it.

10 **a** Consider the horizontal direction:

$v_x = u_x = 16 \times \cos(60°) = 8.0 \text{ m s}^{-1}$

$v_x = \frac{s_x}{t} \therefore 8.0 = \frac{10.0}{t} \therefore t = 1.25 \text{ s}$ (1 MARK)

Consider the vertical direction:

$u_y = 16.0 \times \sin(60°) = 13.86 \text{ m s}^{-1}$

$s_y = u_y t + \frac{1}{2} a_y t^2 = 13.86 \times 1.25 + \frac{1}{2} \times (-9.8) \times 1.25^2$ (1 MARK)

$s_y = 9.7$ m. The rider will make it to the rooftop because she is 9.7 m above the ramp when she reaches the building, which is greater than the height of the rooftop from the top of the ramp (8.0 m). (1 MARK)

An alternative method is to show that the stunt rider falls below a height of 8.0 m at a horizontal distance that is greater than 10.0 m.

b Consider the vertical direction:

$v_y^2 = u_y^2 + 2a_y s_y$

$v_y^2 = 13.86^2 + 2 \times (-9.8) \times 8.0$ (1 MARK)

$v_y^2 = 35.3 \text{ m s}^{-1}$ (1 MARK)

Use vector addition with the horizontal and vertical components to find the magnitude of the velocity:

$v = \sqrt{v_x^2 + v_y^2} = \sqrt{8.0^2 + 35.3} = 10 \text{ m s}^{-1}$ (1 MARK)

OR

Use energy conservation:

$KE_i + GPE_i = KE_f + GPE_f$

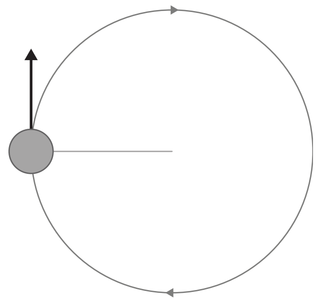
$\frac{1}{2} m v_i^2 + 0 = \frac{1}{2} m v_f^2 + mgh_f$ (1 MARK)

$\frac{1}{2} \times m \times 16.0^2 = \frac{1}{2} \times m \times v_f^2 + m \times 9.8 \times 8.0$ (1 MARK)

Cancel m on both sides of the equation.

$v_f = \sqrt{16.0^2 - 2 \times 9.8 \times 8.0} = 10 \text{ m s}^{-1}$ (1 MARK)

11 **a**



I have drawn an arrow that is a tangent to the circle, pointing directly up the page.

If the string breaks, there is no longer a centripetal force acting on the ball so it will continue moving in the direction it was moving when the string breaks.

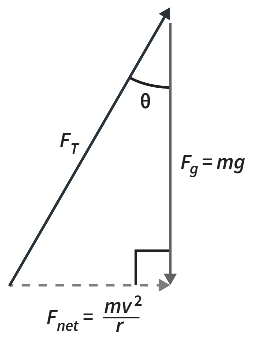
b Consider the forces in the vertical direction:

$F_g = F_T \times \cos(\theta)$

$4.1 \times 9.8 = 51 \times \cos(\theta)$ (1 MARK)

$\theta = \cos^{-1}\left(\frac{4.1 \times 9.8}{51}\right) = 38°$ (1 MARK)

c



For a ball on a string, the speed is related to the radius of the circle and the angle of the string from the vertical by the equation $v = \sqrt{rg \times \tan(\theta)}$ (which is derived by considering the relationship between the centripetal force and the force due to gravity: $\tan(\theta) = \frac{mv^2/r}{mg}$).

Determine the radius of the circle using the angle that the string makes with the vertical.

$r = 0.80 \times \sin(38°) = 0.49 \text{ m}$ (1 MARK)

$v = \sqrt{rg \times \tan(\theta)} = \sqrt{0.49 \times 9.8 \times \tan(38°)}$ (1 MARK)

$v = 1.9 \text{ m s}^{-1}$ (1 MARK)

12 [The students have incorrectly assumed that spring force at the maximum extension has the same magnitude as the force due to gravity $(F_s = F_g)$.[1]][These forces will have the same magnitude only when the weight is not accelerating (including being stationary).[2]] [At the maximum extension in the students' experiment, the weight is accelerating upwards so $F_{net} > 0$ which means $F_s > F_g$ at this point.[3]]

I have explicitly addressed the students' mistake: confusing the spring force with the force due to gravity.[1]

I have identified the specific situation when spring force is equal to the force due to gravity.[2]

I have used the relevant theory to justify why the two forces are not equal: Newton's 2nd law.[3]

WANT MORE?

Here's another question to show the theory from a different perspective.

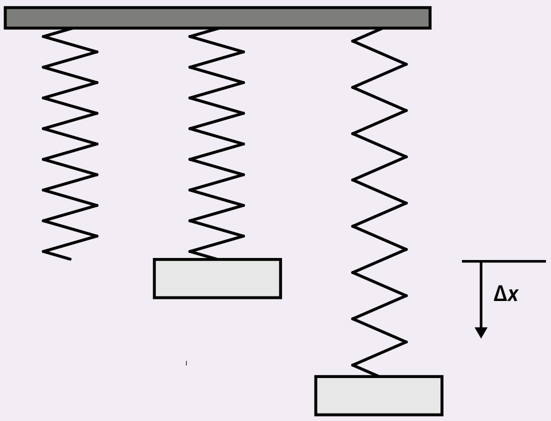
Study design dot point:

- analyse transformations of energy between kinetic energy, strain potential energy, gravitational potential energy and energy dissipated to the environment (considered as a combination of heat, sound and deformation of material):
  - strain potential energy: area under force-distance graph including ideal springs obeying Hooke's law: $E_s = \frac{1}{2}k\Delta x^2$

Related Edrolo Textbook Lesson: 3F – Page 155

Question 6

Ryle and Rushil hang a mass of 0.800 kg on the end of a spring with spring constant 12 N m^{-1}. They initially hold the mass at the unstretched length of the spring and then release it.



a Determine how far the spring stretches until the mass comes to rest, before moving upwards again. (3 MARKS)

b Calculate the maximum speed of the mass. (3 MARKS)

Answer

6 a $GPE_{top} = SPE_{bot}$

$mgh_{top} = \frac{1}{2}k(\Delta x_{bot})^2$ (1 MARK)

Since $h_{top} = \Delta x_{bot}$: $0.800 \times 9.8 \times \Delta x_{bot} = \frac{1}{2} \times 12 \times (\Delta x_{bot})^2$ (1 MARK)

$\Delta x_{bot} = 1.3$ m (1 MARK)

b $SPE_{mid} + KE_{mid} + GPE_{mid} = SPE_{bot}$ (1 MARK)

$\frac{1}{2} \times 12 \times 0.65^2 + \frac{1}{2} \times 0.800 \times v_{mid}^2 + 0.800 \times 9.8 \times 0.65 = \frac{1}{2} \times 12 \times 1.3^2$ (1 MARK)

$v_{mid} = 2.5$ m s^{-1} (1 MARK)

13 The scientists' frame measures the proper length. Convert from the distance measurement in the scientist's frame to the distance measurement in the particle's frame:

$L = \frac{L_0}{\gamma} = \frac{6.8 \times 10^{-4}}{4.0}$ (1 MARK)

$L = 1.7 \times 10^{-4}$ m (1 MARK)

Relate the time to the distance and the speed in the particle's frame:

$t_0 = \frac{L}{v} = \frac{1.7 \times 10^{-4}}{0.9682 \times 3.0 \times 10^{8}} = 5.9 \times 10^{-13}$ s (1 MARK)

OR

Relate the time to the distance and the speed in the scientists' frame:

$t = \frac{L_0}{v} = \frac{6.8 \times 10^{-4}}{0.9682 \times 3.0 \times 10^{8}} = 2.34 \times 10^{-12}$ s (1 MARK)

This time in the scientists' frame is the dilated time. Convert from the time measurement in the scientist's frame to the time measurement in the particle's frame:

$t = t_0 \gamma$

$2.34 \times 10^{-12} = t_0 \times 4.0$ (1 MARK)

$t_0 = 5.9 \times 10^{-13}$ s (1 MARK)

WANT MORE?

Here's another question to show the theory from a different perspective.

Study design dot point:

- model mathematically time dilation and length contraction at speeds approaching c using the equations:

  $t = t_0 \gamma$ and $L = \frac{L_0}{\gamma}$ where $\gamma = \left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}$

Related Edrolo Textbook Lesson: 4B – Page 155

Question 16

Two spacecraft are travelling towards each other. Spacecraft 1 has a beacon which flashes once every 5.00 seconds. An observer on spacecraft 2 detects the pulse periodically flashing every 5.72 seconds.

What is the relative speed of the two spacecraft? Give your answer in metres per second. (2 MARKS)

Answer

$t = t_0\gamma \;\therefore t = t_0 \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \;\therefore 5.72 = 5.00 \times \frac{1}{\sqrt{1-\frac{v^2}{(3.0\times10^8)^2}}}$ (1 MARK)

$v = 1.5 \times 10^8$ m s^{-1} (1 MARK)

14 For transformer T_1:

$\frac{V_{T_1,out}}{V_{T_1,in}} = \frac{5}{1} \;\therefore \frac{V_{T_1,out}}{5.0} = \frac{5}{1}$

$V_{T_1,out} = 25$ V (1 MARK)

For the transmission lines:

$V_{loss} = I_{line}R = 0.20 \times (3.0 + 3.0) = 1.2$ V (1 MARK)

For transformer T_2:

$V_{T_2,in} = V_{T_1,out} - V_{loss} = 25 - 1.2 = 23.8$ V (1 MARK)

$V_{T_2,out} = V_{globe}$

$\frac{V_{globe}}{V_{T_2,in}} = \frac{1}{5} \;\therefore \frac{V_{globe}}{23.8} = \frac{1}{5}$

$V_{globe} = 4.8$ V (1 MARK)

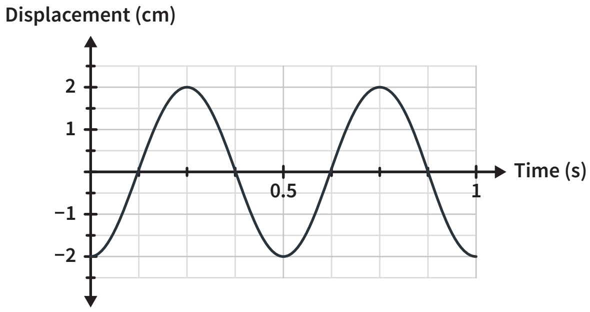
15 a From the provided graph, $\lambda = 4$ m.

$v = f\lambda$

$8 = f \times 4$ (1 MARK)

$f = 2$ Hz (1 MARK)

b With $\lambda = 4$ m and $v = 8$ m s^{-1} we can determine that the period is 0.5 s. From the provided graph, point X is at the lowest position when $t = 0$ s so the graph must start at the minimum displacement of −2 cm.



I have drawn a sinusoid starting from its minimum value (a negative cosine graph).

I have drawn a sinusoid with a period of 0.5 seconds.

I have drawn a sinusoid with an amplitude of 2 cm.

c [A string can be made to resonate when it is forced to oscillate at one of its natural frequencies of vibration[1]][so that the superposition of the travelling wave and its reflection forms a standing wave.[2]]

I have described the cause of resonance: forced oscillations matching the natural frequency.[1]

I have described the effect of resonance on a string: superposition of a travelling wave and its reflection resulting in a standing wave.[2]

d [No.[1]][For a string with one fixed end, a standing wave will form only if the string length, L, is an odd multiple of $\frac{\lambda}{4}$. In this case, $L = 6$ m is not an odd multiple of $\frac{\lambda}{4} = \frac{4}{4} = 1$ m.[2]]

I have explicitly addressed whether a standing wave will form.[1]

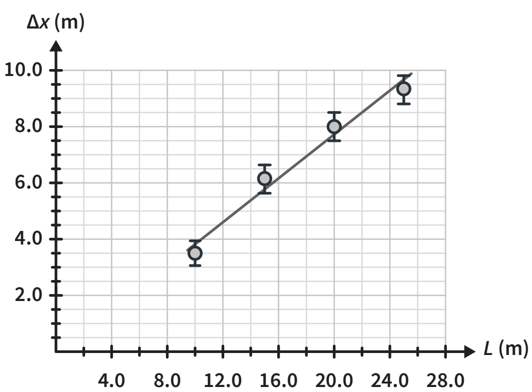
I have used the relevant theory: the relationship between string length and wavelength for strings with one fixed end.[2]

16 a Independent variable: Perpendicular distance from speakers, L (1 MARK)

Dependent variable: Spacing between maxima, Δx (1 MARK)

Controlled variable: The separation of the speakers **OR** the frequency of the sound (1 MARK)

b



I have labelled the horizontal axis with the independent variable, the vertical axis with the dependent variable, and included correct units.

I have included an appropriate and consistent scale on both axes.

I have plotted each data point.

I have drawn correctly sized uncertainty bars.

I have drawn a straight line of best fit which passes through all uncertainty bars.

c Use any two points from the line of best fit that are far apart to calculate the gradient.

$gradient = \frac{y_2 - y_1}{x_2 - x_1} = \frac{8.5 - 5.5}{22.0 - 14.0} = 0.375$ (1 MARK)

$gradient = \frac{rise}{run} = \frac{\Delta x}{L}$

Δx and L are related by the formula $\Delta x = \frac{\lambda L}{d}$

$\frac{\Delta x}{L} = \frac{\lambda}{d} \quad \therefore gradient = \frac{\lambda}{d}$ (1 MARK)

$0.375 = \frac{\lambda}{2.0} \quad \therefore \lambda = 0.75$ m (1 MARK)

Depending on the line of best fit drawn, gradients between 0.35 and 0.40 are acceptable, which corresponds to an allowable range of wavelengths between 0.70 m and 0.80 m.

17 [The 300 Hz sound will have a greater intensity at point Q.[1]] [To reach Q, the sound has to diffract.[2]][Diffraction is greater when the ratio $\frac{\lambda}{w}$ is greater. Since the 300 Hz sound has the greater wavelength, it will diffract more.[3]]

I have explicitly addressed which frequency will have the greater intensity at point Q.[1]

I have identified the relevance of diffraction to this situation.[2]

I have applied the theory to this situation: the effect of the different frequencies on the extent of diffraction.[3]

18 a [The wave model fails to predict the existence of a minimum (threshold) frequency of light for ejecting photoelectrons, indicated by the horizontal axis intercept.[1]][According to the wave model, light is a continuous distribution of energy,[2]][so an electron should be able to accumulate enough energy over time to be ejected from the metal regardless of the frequency.[3]]

I have explicitly addressed the specific point on the graph that the wave model cannot predict: the threshold frequency.[1]

I have used the relevant theory: the continuous nature of waves.[2]

I have explicitly addressed the incorrect prediction of the wave model.[3]

b Use two points that are far apart on the line of best fit to calculate the gradient:

$h = \frac{rise}{run} = \frac{4.0 - 0}{(19.5 - 10.5) \times 10^{14}}$ (1 MARK)

$h = 4.4 \times 10^{-15}$ eV s (1 MARK)

Depending on the data points used to calculate the gradient, $h = 4.5 \times 10^{-15}$ eV s is also an acceptable answer.

c The magnitude of the horizontal axis intercept of the current versus potential difference graph has the same numerical value as the maximum electron kinetic energy when measured in eV.

$KE_{max} = 2.5$ eV (1 MARK)

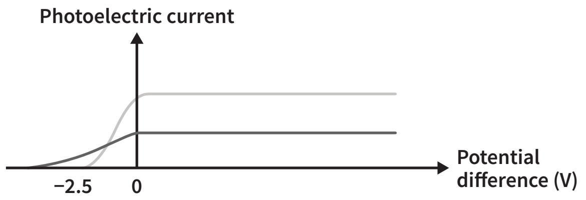
From the max. kinetic energy vs frequency graph, when $KE_{max} = 2.5$ eV, $f = 16 \times 10^{14}$ Hz (1 MARK)

OR

$KE_{max} = h(f - f_0)$ $\therefore 2.5 = 4.4 \times 10^{-15} \times (f - 10.5 \times 10^{14})$ (1 MARK)

$f = 16 \times 10^{14}$ Hz (1 MARK)

d

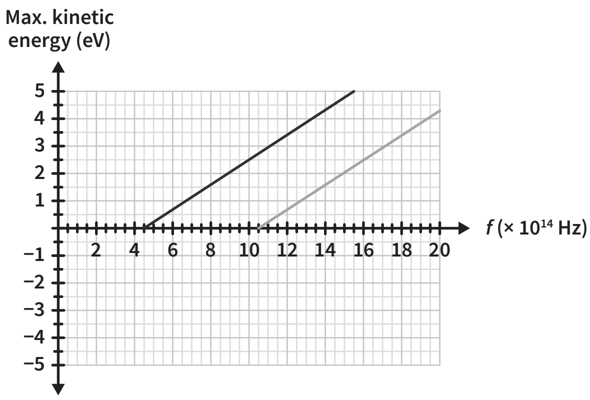


I have drawn a graph with a lower saturation (maximum) current.

I have drawn a graph with a horizontal intercept that is further to the left (more negative).

A higher frequency means that each electron absorbs a photon with more energy so the photoelectrons have more kinetic energy, which means the magnitude of the cut-off potential is greater. A lower intensity means less photons are absorbed so less electrons are ejected, which means the current is reduced.

e



I have drawn a straight line that is parallel to the original (the gradient is the same).

I have drawn a straight line that is shifted upwards/to the left compared with the original.

A smaller work function means that electrons escape with more energy. The gradient corresponds to Planck's constant, which should be the same regardless of the work function.

19 Since X is a dark band, $S_1X - S_1X = \left(n - \frac{1}{2}\right)\lambda$ where n is the number of the dark band counted from the centre ($n = 1, 2, 3, \ldots$).

$9.00 \times 10^{-9} = \left(2 - \frac{1}{2}\right)\lambda$ (1 MARK)

$\lambda = 6.00 \times 10^{-9}$ m (1 MARK)

Since Y is a bright band, $S_1Y - S_2Y = n\lambda$ where n is the number of the bright band counted from the centre ($n = 0, 1, 2, 3, \ldots$).

$S_1Y - S_2Y = 2 \times 6.00 \times 10^{-9} = 1.20 \times 10^{-8}$ m (1 MARK)

20 For the electron:

$KE = 500 \text{ eV} = 500 \times 1.6 \times 10^{-19} \text{ J} = 8.0 \times 10^{-17}$ J

$KE = \frac{p^2}{2m}$

$8.0 \times 10^{-17} = \frac{p^2}{2 \times 9.1 \times 10^{-31}}$

$p = \sqrt{8.0 \times 10^{-17} \times 2 \times 9.1 \times 10^{-31}} = 1.21 \times 10^{-23}$ kg m s^{-1} (1 MARK)

The momenta of the electrons and the X-ray photons must be the same ($p_e = p_X$) (1 MARK)

For the X-ray photon:

$E = pc = 1.21 \times 10^{-23} \times 3.0 \times 10^8 = 3.6 \times 10^{-15}$ J

$E = 2.3 \times 10^4$ eV (1 MARK)

OR

For the electron:

$KE = 500 \text{ eV} = 500 \times 1.6 \times 10^{-19} \text{ J} = 8.0 \times 10^{-17}$ J

$KE = \frac{p^2}{2m}$

$8.0 \times 10^{-17} = \frac{p^2}{2 \times 9.1 \times 10^{-31}}$

$p = \sqrt{8.0 \times 10^{-17} \times 2 \times 9.1 \times 10^{-31}} = 1.21 \times 10^{-23}$ kg m s^{-1} (1 MARK)

$\lambda = \frac{h}{p} = \frac{6.63 \times 10^{-34}}{1.21 \times 10^{-23}} = 5.48 \times 10^{-11}$ m

The wavelengths of the electrons and the X-ray photons must be the same ($\lambda_e = \lambda_X$) (1 MARK)

For the X-ray photon:

$E = \frac{hc}{\lambda} = \frac{4.14 \times 10^{-15} \times 3.0 \times 10^8}{5.48 \times 10^{-11}} = 2.3 \times 10^4$ eV (1 MARK)

21 [A stable orbit only exists if the electron can form a standing wave, which occurs if the de Broglie wavelength of the electron fits the orbit an integer number of times ($2\pi r = n\lambda, n = 1, 2, 3, \ldots$).[1]] [Electron energies are quantised because they are the energies corresponding to these wavelengths.[2]]

I have used the relevant theory: electrons forming standing waves depending on the de Broglie wavelength.[1]

I have related the discrete allowable wavelengths to the quantisation of energy levels.[2]