Neap

Trial Examination 2022

VCE Phyics Units 3&4

Written Examination

Suggested Solutions

SECTION A – MULTIPLE-CHOICE QUESTIONS

1	B
2	A
3	C
4	B
5	C
6	C
7	A
8	B
9	C
10	D
11	B
12	B
13	C
14	D
15	A
16	D
17	A
18	C
19	B
20	A

Question 1 B

$$\text{magnetic force} = B \times I \times L$$
$$= 0.20 \times 2.00 \times 0.50$$
$$= 0.20 \text{ N}$$

Question 2 A

Weight is a force, so it is measured in newtons (N).

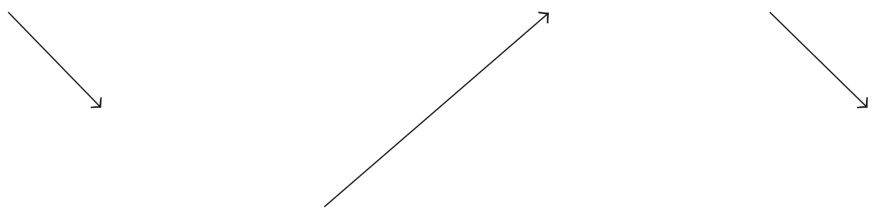
$$\text{weight (N)} = m \times g$$
$$= 2000 \times 0.30$$
$$= 600 \text{ N}$$

Question 3 C

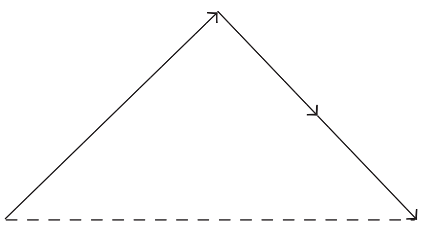
The direction of an electric field is that acting on a positive test charge at the position in question. Position X is equidistant from all three charges.

Thus, the fields due to +Q and –Q have the same strength, and the field due to +2Q is twice as strong as these fields. The vectors representing the fields are shown below.

field due to +Q field due to +2Q field due to –Q



The net electric field, represented by the dashed line, is found by summing the vectors.



Question 4 B

B is correct.

range = horizontal speed × time = $u\cos(\theta)$ × time of flight

The time of flight is determined vertically by the equation $-h = ut\sin(\theta) + \frac{1}{2}gt^2$, where $-h = s$, $g = a$ and $u\sin(\theta)$ = initial vertical speed. Thus, t is dependent on h, u, g and θ; **B** is the only option that includes only these variables.

A, **C** and **D** are incorrect. The range of the projectile does not depend on H.

Question 5 C

C is correct. The correct graph will have an area of 10 J under the graph line. Using the *x*- and *y*-coordinates shown in graph **C** gives:

$$\begin{aligned}\text{area} &= \frac{1}{2}\times 200\times 0.1\\ &= 10\ \text{J}\end{aligned}$$

A is incorrect. Using the *x*- and *y*-coordinates shown in graph **A** gives:

$$\begin{aligned}\text{area} &= \frac{1}{2}\times 100\times 1.0\\ &= 50\ \text{J}\end{aligned}$$

B is incorrect. Using the *x*- and *y*-coordinates shown in graph **B** gives:

$$\begin{aligned}\text{area} &= \frac{1}{2}\times 100\times 0.1\\ &= 5\ \text{J}\end{aligned}$$

D is incorrect. Using the *x*- and *y*-coordinates shown in graph **D** gives:

$$\begin{aligned}\text{area} &= \frac{1}{2}\times 200\times 1.0\\ &= 100\ \text{J}\end{aligned}$$

Question 6 C

Let left be positive in direction.

$$\begin{aligned}\Delta p &= p_{\text{final}} - p_{\text{initial}}\\ &= (0.20\times 1.5)-(0.20\times -2.0)\\ &= +0.70\\ &= 0.70\ \text{kg m s}^{-1}\ \text{to the left}\end{aligned}$$

Question 7 A

At speeds greater than $0.1c$, relativistic effects become significant. The kinetic energy formula $\text{KE} = \frac{1}{2}mv^2$ cannot be used.

$$\begin{aligned}\text{kinetic energy} &= (\gamma - 1)m_0c^2\\ &= (1.25-1)\times 1.67\times 10^{-27}\times (3.0\times 10^8)^2\\ &= 3.76\times 10^{-11}\ \text{J}\end{aligned}$$

Question 8 B

The transformer equation is used to relate the voltages.

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

$$\frac{V_s}{12} = \frac{40}{100}$$

$$\begin{aligned}V_s &= 12\times 0.4\\ &= 4.8\ \text{V RMS}\end{aligned}$$

The peak voltage is given by $4.8\times\sqrt{2} = 6.79$ V.

Question 9 C

Method 1:

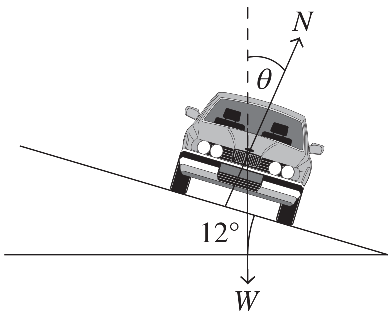
$$P_{\text{average}} = V_{\text{load RMS}} \times I_{\text{load RMS}}$$
$$= 4.8 \times \frac{1.23}{\sqrt{2}}$$
$$= 4.17 \text{ W}$$

Method 2:

$$P_{\text{average}} = P_{\text{supplied}}$$
$$P_{\text{supplied}} = V_{\text{battery}} \times I_{\text{battery}}$$
$$I_{\text{battery}} = \frac{N_s}{N_p} \times I_{\text{load}}$$
$$= \frac{40}{100} \times 1.23$$
$$= 0.492 \text{ A peak}$$
$$I_{\text{battery}} = \frac{0.492}{\sqrt{2}}$$
$$= 0.348 \text{ A RMS}$$
$$P_{\text{supplied}} = 12.00 \times 0.348$$
$$= 4.17 \text{ W}$$

Question 10 D

The forces acting on the vehicle are the road's normal reaction and the weight of the car.



Vertically, all forces add to 0.

$$N\cos(12°) - W = 0$$
$$N\cos(12°) = W$$

Horizontally, all forces add to the centripetal force.

$$F_{\text{centripetal}} = N\sin(\theta)$$

Replacing N leads to:

$$F_{\text{centripetal}} = \frac{W \times \sin(12)}{\cos(12)}$$
$$= W \times \tan(12°)$$

Question 11 B

The string is undergoing an odd harmonic vibration where the frequency $= \frac{nv}{4L}$ and the possible harmonic integer values are $n = 1, 3, 5, 7\ldots$ The harmonic shown corresponds to the fourth in the series where $n = 7$. All harmonics are odd integer multiples of the first harmonic $f_n = nf_1$ where $n = 1, 3, 5, 7\ldots$, assuming the string length, tension and thus wave speed do not change. Hence, $700 = 7f_1$, and so the first harmonic is $f_1 = 100$ Hz. The other possible harmonics are 300 Hz, 500 Hz, 700 Hz…

Question 12 B

B is correct. Heisenberg's uncertainty principle states that it is not possible to be precise about the momentum of a particle without being imprecise about its position when both quantities are in the same plane, and vice-versa.

A is incorrect. This option refers to different planes.

C and **D** are incorrect. These options refer to energy rather than momentum.

Question 13 C

C is correct. The production of light by the transition of electrons between energy levels in a material occurs in lasers.

A is incorrect. The operation of the light-emitting diode involves current flow (electrons) filling vacancies in a material requiring them to cross the band gap in a semi-conductor.

B is incorrect. Incandescent lamps involve heating a filament in a lamp that glows, releasing light.

D is incorrect. Synchrotrons involve accelerating electrons in a circle using magnetic fields where they are then released tangentially and emit light.

Question 14 D

D is correct. The spread of the pattern is reduced, indicating that there is less diffraction of the laser through the pinhole. The amount of diffraction depends on the quantity $\frac{\text{wavelength} \times (\text{pinhole} - \text{screen distance})}{\text{pinhole diameter}}$. Thus, a smaller wavelength of light was used.

A is incorrect. A smaller frequency implies a greater wavelength, which would increase the pattern spread.

B is incorrect. Deceasing the diameter of the pinhole would increase the spread of the pattern.

C is incorrect. The intensity of the light has no effect on the spread of the pattern.

Question 15 A

A is correct. The lowest frequency is recorded when the relative speed between the datalogger and the speaker is greatest and both carts are moving in the opposite direction to each other. This occurs because a soundwave travels at a constant speed relative to still air, regardless of the motion of the source and observer. By moving in opposite directions, the observer receives the longer wavelength, resulting in the lower frequency.

$$\begin{aligned}\text{relative speed in experiment 1} &= 3.0 - -3.0 \\ &= 6.0 \text{ m s}^{-1}\end{aligned}$$

B is incorrect.

$$\begin{aligned}\text{relative speed in experiment 2} &= 2.0 - 2.0 \\ &= 0 \text{ m s}^{-1}\end{aligned}$$

C is incorrect.

$$\begin{aligned}\text{relative speed in experiment 3} &= 2.0 - -2.0 \\ &= 4.0 \text{ m s}^{-1}\end{aligned}$$

D is incorrect.

$$\begin{aligned}\text{relative speed in experiment 4} &= 4.0 - 1.0 \\ &= 3.0 \text{ m s}^{-1}\end{aligned}$$

Question 16 D

The wave is transverse, so any particle movement occurs at a right angle (vertically) to the flow of energy (to the left). Thus, as the wave moves to the left, the position of X moves downwards.

Question 17 A

In order of increasing frequency, the categories of light are TV, microwave, infra-red, UV. The light with the shortest wavelength will diffract the least. This corresponds to the light with the highest frequency, which is UV.

Question 18 C

C is correct, and **A** and **B** are incorrect. Electrons make their way through the double-slit arrangement one at a time and strike the screen at a particular localised position, which attests to their particle nature. Although the electrons strike the screen, there are selective areas where electrons strike and areas where no electrons strike, which causes a pattern that is similar to those produced by objects with a wave nature.

D is incorrect. The actual behaviour of the electrons passing through only one of the slits cannot be confirmed by experiment. The particles cannot be interfering with each other because they arrive at the screen at different times.

Question 19 B

B is correct. Precise data means that the results have a narrow range or are all very close in value. Non-valid data implies that the results as a whole are not close to the true value and do not accurately measure the intended quantity. The data from student 2 is precise, but it does not match the expected value.

A is incorrect. The data from student 1 shows four precise data points and one that is a random error.

C is incorrect. The data from student 3 shows precise and valid data.

D is incorrect. The data from student 4 shows a large range, so it is not precise.

Question 20 A

A is correct. Systematic errors occur when all results are different to the expected value by the same amount. Random errors result in data have a variation of differences to the expected value. The data from student 1 shows four systematic errors and one random error.

B is incorrect. The data from student 2 shows only systematic errors.

C is incorrect. The data from student 3 shows high accuracy and very few or no errors.

D is incorrect. The data from student 4 shows random errors only, due to the range of results.

SECTION B

Question 1 (7 marks)

a. The work done by the electric field transforms to a gain in kinetic energy of the electron.

$$\text{work done} = qEd = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

The electron is initially at rest, so $u = 0$.

$$1.6\times10^{-19}\times E\times0.300 = \frac{1}{2}\times9.11\times10^{-31}\times\left(5.93\times10^{6}\right)^2$$ 1 mark

$$4.8\times10^{-20}\times E = 1.6017\times10^{-17}$$

$$E = \frac{1.6017\times10^{-17}}{4.8\times10^{-20}}$$ 1 mark

$$= 3.34\times10^{2}\ \text{N C}^{-1}$$ 1 mark

b. The force acting on the electron is the magnetic force, which results in circular motion.

$$\text{force} = \frac{mv^2}{r}$$

$$= \frac{9.11\times10^{-31}\times\left(5.93\times10^{6}\right)^2}{0.015}$$ 1 mark

$$= 2.14\times10^{-15}\ \text{N}$$ 1 mark

c. $$\text{centripetal force} = Bvq = \frac{mv^2}{r}$$

$$B\times5.93\times10^{6}\times1.6\times10^{-19} = 2.13\times10^{-15}$$ 1 mark

$$B = \frac{2.13\times10^{-15}}{9.48\times10^{-13}}$$

$$= 2.25\times10^{-3}\ \text{T}$$ 1 mark

Note: This answer is not consequential on ***part b.*** *The equation* $B = \frac{mv}{qr}$ *can be used independently of* ***part b.***

Question 2 (6 marks)

a. Using $a = \frac{GM_{\text{earth}}}{r^2}$, where r = the orbital radius, gives:

$r = \text{Earth radius} + \text{altitude}$

$= 6.38 \times 10^6 + (400 \times 10^3)$

$= 6.78 \times 10^6$ m — 1 mark

$a = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{(6.78 \times 10^6)^2}$ — 1 mark

$= 8.68 \text{ m s}^{-2}$ — 1 mark

b. The relationship is $(\text{period})^2 = \text{constant} \times (\text{orbital radius})^3$. — 1 mark

Spiralling inwards reduces the orbital radius of the ISS. — 1 mark

This has the effect of reducing the period of the orbit. — 1 mark

Question 3 (7 marks)

a. **Terminal A:** +

Terminal B: –

1 mark

Note: Both terminals must be labelled to receive the mark.

b. Given the direction of rotation of the coil, the side LM is moving vertically upwards and the side JK is moving vertically downwards in the instant shown. This indicates the direction of the magnetic forces on those sides. — 1 mark

Using the right-hand palm rule for the side LM: — 1 mark

- The external magnetic field is to the right (represented by the right-hand fingers).
- The magnetic force is upwards (represented by the force out of the right palm).
- The corresponding current must be from L to M (using the right thumb).

The conventional current flows into terminal B, which must be negative, and thus the current must pass from terminal A (positive) into the coil. — 1 mark

c. Each brush of the coil touches one of the copper half-rings, forming a closed circuit. This allows the current to pass through the coil, enabling forces to act on it and causing it to turn.

As the coil turns, at every half rotation, each brush disconnects from the half-ring and reconnects to the other half-ring. — 1 mark

This causes the direction of the current relative to the coil to reverse. — 1 mark

This relative reversal of current every half-cycle causes the forces on the sides JK and LM to also reverse, which is necessary to maintain continuous rotation. — 1 mark

Question 4 (8 marks)

a. $\text{EMF} = N\left(\frac{\Delta\phi}{\Delta t}\right)$

$= N\left(\frac{\Delta BA}{\Delta t}\right)$

$= 100 \times \left(\frac{(5.0 \times 10^{-1} \times 0.020) - 0}{0.10}\right)$

2 marks

1 mark for correct substitution.

1 mark for correct calculation.

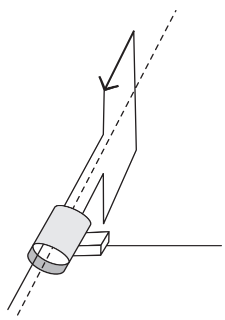
$= 10 \text{ V}$

1 mark

b. As the magnets are pulled away, the external magnetic flux through the coil (which points to the right) is reduced. 1 mark

The coil opposes this change in external flux by providing its own flux in the same direction as the external flux to compensate for the loss. 1 mark

Thus, using the right-hand rule, the right-hand thumb points in the direction of the induced flux (to the right) and the curl of the fingers represents the direction of the induced current. Therefore:



1 mark

Note: Award the final mark for the statement and arrow drawn on the diagram.

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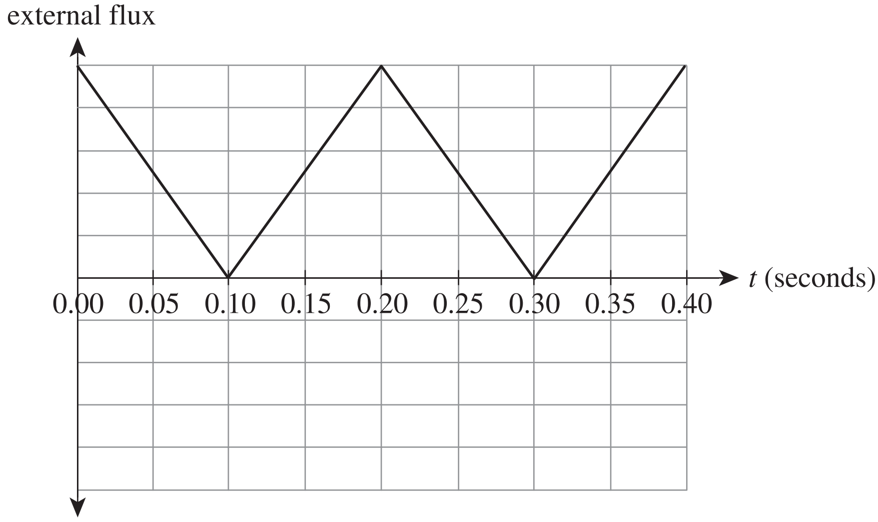
c. To understand the solution, it is easier (but not required) to sketch the external flux versus time graph first.

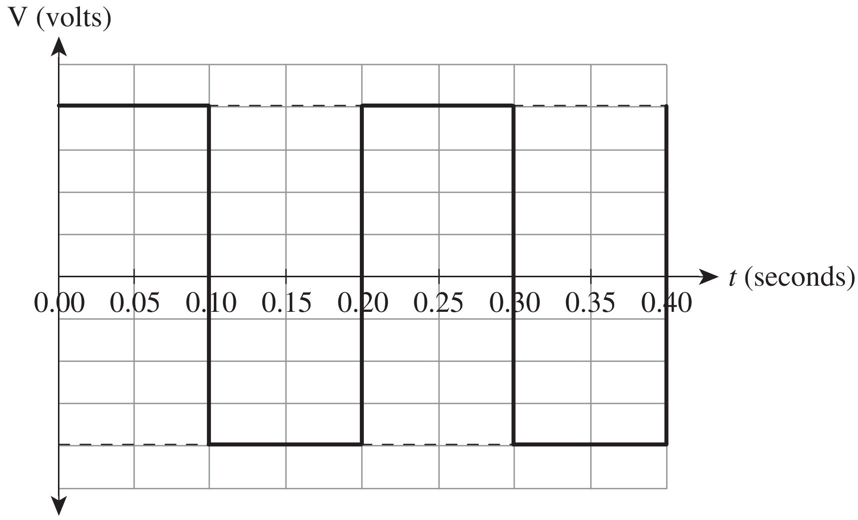
At $t = 0$, 0.2 and 0.4 seconds, the flux is maximum.

At $t = 0.1$ and 0.3 seconds, the flux is zero.



The EMF develops as the negative rate of change (gradient) of the external flux versus time graph.

Therefore, the required voltage versus time graph is:



2 marks

1 mark for alternating the voltage (symmetry and constant values must be shown).

1 mark for showing both cycles with the correct period of 0.20 s.

Note: Accept the inverted equivalent answer as shown by the dashed line.

Question 5 (6 marks)

a. The power that is available to the globe is the power that is present at the primary of transformer T2. Thus:

power available to globe = power supplied to the secondary of transformer T1 − power loss in lines

$= (V_{\text{sec of T1}} \times I_{\text{line}}) - I^2_{\text{line}} \times R_{\text{line}}$ 1 mark

$= (4.0 \times 10 \times 1.0) - (1.0^2 \times 5.0)$ 1 mark

$= 40 - 5$

$= 35\ \text{W}$ 1 mark

b. voltage available to the globe $= V_{\text{sec of T2}} = \dfrac{v_{\text{prim of T2}}}{10}$ (step down transformer)

$V_{\text{prim of T2}} = V_{\text{sec of T1}} - V_{\text{loss}}$

$= (4.0 \times 10) - (1.0 \times 5.0)$

$= 35\ \text{V}$ 1 mark

$V_{\text{sec of T2}} = \dfrac{V_{\text{prim of T2}}}{10}$

$= \dfrac{35}{10}$

$= 3.5\ \text{V}$ 1 mark

OR

$V_{\text{sec of T2}} = \dfrac{\text{power available to globe}}{I_{\text{line}}}$

$= \dfrac{35\ \text{W}}{1.0}$ 1 mark

$= 3.5\ \text{V}$ 1 mark

Since this value is less than 3.6 V, the globe will not operate brightly. 1 mark

Note: Do not award the mark for the final statement if supporting figures/calculations are not provided. If the calculations are incorrect and a result between 3.6 V and 4.0 V is achieved, 1 mark may be awarded for a consequentially correct statement.

Question 6 (3 marks)

Using energy conservation, total mechanical energy = TME:

$\text{TME}_{\text{lowest point}} = \text{TME}_{\text{release position}}$

Let the lowest point be zero for the vertical height measurement.

The distance fallen by the block is equal to the distance the spring is compressed.

$\frac{1}{2}kx^2 = mgx$ 1 mark

$\frac{1}{2} \times 50 \times d^2 = 0.4 \times 9.8 \times d$

$d = \dfrac{2 \times 0.4 \times 9.8}{50}$ 1 mark

$d = 0.16\ \text{m}$ 1 mark

Note: Deduct a maximum of 1 mark if answer is not given to two significant figures.

Question 7 (5 marks)

a. work done by the spring = change in kinetic energy of the block

= increase in elastic potential energy of the spring

elastic potential energy of spring $= \frac{1}{2}kx^2$ 1 mark

$= \frac{1}{2} \times 50 \times 0.15^2$

$= 0.56$ J 1 mark

b. **Method 1:**

The total energy the block can pass onto the spring is:

$\frac{1}{2}mv^2 = \frac{1}{2} \times 0.4 \times 2.0^2$

$= 0.80$ J 1 mark

This would cause a compression of:

$\frac{1}{2}kx^2 = 0.80$

$x = \sqrt{\frac{2 \times 0.80}{50}}$

$= 0.18$ m 1 mark

Hence, the block is not able to compress the spring by 0.20 m.

Method 2:

A compression of 0.20 m would require energy equal to:

$E = \frac{1}{2} \times 50 \times 0.20^2$

$= 1.0$ J 1 mark

The associated speed of the block is given by:

$\frac{1}{2}mv^2 = 1.0$ J 1 mark

$v = \sqrt{\frac{2 \times 1.0}{0.4}}$

$= 2.23$ m s^{-1}

This speed is greater than the actual speed of the block, so the compression cannot occur.

c. The block's momentum is transferred to a second body, the spring–Earth system. 1 mark

Question 8 (5 marks)

a. Using energy conservation, total mechanical energy (TME):

$TME_{\text{lowest point}} = TME_{\text{release position}}$

Let the lowest point be zero for the vertical height measurement.

$\frac{1}{2}mv^2 = mgh$ (the mass can be factored out) 1 mark

$v = \sqrt{2gh}$

$= \sqrt{2 \times 9.8 \times 0.30}$ 1 mark

$= 2.42 \text{ m s}^{-1}$

b. Using Newton's second law:

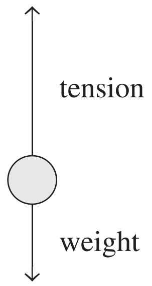
$\Sigma F = \text{tension} - mg$

$= \frac{mv^2}{r}$ 1 mark

$\text{tension} - 0.200 \times 9.8 = \frac{0.200 \times 2.42^2}{1.00}$ 1 mark

$\text{tension} = 1.96 + 1.176$

$= 3.14 \text{ N}$ 1 mark



Note: A diagram is not required but may be used as part of the working.

Question 9 (4 marks)

a. In the vertical direction, let positive be downwards.

The time taken is given by $s = ut + \frac{1}{2}at^2$.

Given that $a = 9.8 \text{ m s}^{-2}$, $u = 0$, $s = 10.0 - 3.0 = 7.0$ m:

$7.0 = 0 + \frac{1}{2} \times 9.8 \times t^2$ 1 mark

$t = \sqrt{\frac{2 \times 7.0}{9.8}}$

$= 1.2 \text{ s}$ 1 mark

Note: Deduct a maximum of 1 mark if the final answer is not given to two significant figures.

b. Horizontally, the ball travels at constant speed. The time taken is 1.2 s (from **part a.**) and the horizontal distance is 30.0 m. 1 mark

$$\text{horizontal speed} = \frac{\text{horizontal distance}}{\text{time}}$$
$$= \frac{30.0}{1.2}$$
$$= 25 \text{ m s}^{-1}$$
1 mark

Note: Consequential on answer to ***Question 9a.***

Question 10 (6 marks)

a. Using momentum conservation, let to the right be positive.

total momentum as a unit = total momentum after separation

momentum = mass × velocity

$$(1.5 + 2.5) \times 2.0 = (1.5 \times 1.0) + 2.5 \times v$$
1 mark

$$8 = 1.5 + 2.5v$$
1 mark

$$v = \frac{6.5}{2.5}$$
$$= 2.6 \text{ m s}^{-1}$$
1 mark

b. The expansion of the spring releases stored potential energy that transforms to kinetic energy for the system. 1 mark

Thus, the separation of the carts cannot be elastic (total kinetic energy of the system before and after the event would be the same) 1 mark
nor can it be inelastic (total kinetic energy of the system is greater before the event than after). 1 mark

Question 11 (5 marks)

a.
$$\gamma = \sqrt{\frac{1}{1 - \frac{v^2}{c^2}}}$$
$$= \sqrt{\frac{1}{1 - 0.850^2}}$$
$$= \sqrt{\frac{1}{0.2775}}$$
1 mark

$$= 1.90$$
1 mark

Note: A maximum of 1 mark is subtracted if the response is not given to three significant figures.

b. According to the command centre on Earth, the distance is given by: distance = speed × time of travel, where the time of travel is the dilated time measured by the astronauts (as the event measurement has occurred in their frame of reference).

Light travels 1 light year in 1 year of time at the speed of light.

According to the command centre:

$t = 1.90 \times 1.78$ years

$= 3.382$ years — 1 mark

At $0.85c$:

distance travelled $= 0.85 \times 3.382$ — 1 mark

$= 2.87$ light years — 1 mark

Note: Consequential on answer to ***Question 11b.***

OR

distance $= \left(0.850 \times 3.0 \times 10^8\right) \times (1.90 \times 1.78 \times 365.25 \text{ d} \times 24 \text{ h} \times 60 \text{ m} \times 60 \text{ sec})$

$= 2.720 \times 10^{16}$ m — 1 mark

1 light year $= 3 \times 10^8 \times 365.25 \text{ d} \times 24 \text{ h} \times 60 \text{ m} \times 60 \text{ sec}$

$= 9.467 \times 10^{15}$ m — 1 mark

Thus:

number of light years $= \dfrac{2.720 \times 10^{16}}{9.467 \times 10^{15}}$

$= 2.87$ light years — 1 mark

Question 12 (5 marks)

a. The path that Jane walks along is such that she hears a very soft sound at any position on the path. This indicates that the waves meeting at each position cancel out as a result of destructive interference. — 1 mark

The compressions from the wave from one speaker simultaneously meet the rarefactions from the wave from the other speaker to result in near-zero amplitude and thus near-zero loudness. — 1 mark

b. The path difference from each speaker at position A is 8.5 – 4.5 = 4.0 m.

In order for Jane to hear loud (high-intensity) sounds at this position, the path difference must be = λ, 2λ, 3λ, *n*λ, where *n* = an integer. — 1 mark

Finding the path difference:

$n\lambda = n\dfrac{v}{f}$

$= n\dfrac{340}{f}$

$= 4.0$

$f = n\dfrac{340}{4.0}$

$= 85n$ (where $n = 1, 2, 3\ldots$) — 1 mark

Thus, the possible frequencies are 85 Hz, 170 Hz, 255 Hz and so on. — 1 mark

Note: Accept any two relevant frequencies.

Question 13 (4 marks)

a. $n_{\text{plastic}} \times \sin(i) = n_{\text{air}} \times \sin(r)$, where $i = 41°$ is the critical angle for which $r = 90°$.

$n_{\text{plastic}} \times \sin(41°) = 1.00 \times \sin(90°)$ 1 mark

$$n_{\text{plastic}} = \frac{1.00}{0.6561}$$
$$= 1.52$$ 1 mark

b. As the ray of white light passes through the prism, it disperses into its seven colour categories (red, orange, yellow, blue, green, indigo and violet). 1 mark

Red, which has the lowest frequency, disperses/deviates the least. Violet, which has the highest frequency, disperses/deviates the most. The refractivity of the material varies slightly based on the frequency of the colour. 1 mark

Question 14 (8 marks)

a. The oscillator vibrates at a particular frequency and propagates a transverse wave along the string, which strikes the pulley and reflects to interfere with the oncoming identical transverse wave. 1 mark

This is the condition that creates the standing wave that is observed where the positions of maximum vibration and minimum (zero) vibration remain fixed. 1 mark

Such a wave can only exist when the frequency of the oscillator matches the natural vibration frequency of the string. This phenomenon is called resonance. 1 mark

b. The natural vibration frequencies are given by $f_n = \frac{nv}{2L}$. Given that $L = 0.650$ m,

$f_3 = 291$ Hz and $n = 3$:

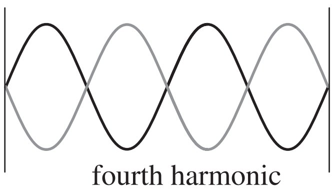
$$v = \frac{2Lf_3}{n}$$
$$= \frac{2 \times 0.65 \times 291}{3}$$ 1 mark
$$= 126 \text{ m s}^{-1}$$ 1 mark

c. The figure shows the third harmonic, which has a frequency of 291 Hz.

The fundamental frequency is $\frac{1}{3}$ of the third harmonic. That is, $\frac{291}{3} = 97$ Hz. 1 mark

$\frac{388}{97} = 4$; thus, 388 Hz represents the fourth harmonic, 1 mark

so a standing wave with four envelopes would be observed. 1 mark



fourth harmonic

Question 15 (9 marks)

a. The particle model for light describes light as a collection of indivisible and massless packets of energy called photons that can be either fully absorbed by electrons or not absorbed at all. Their energy is directly dependent on their frequency, given by $E = hf$. 1 mark

The three plateaus on the positive voltage side of the graph indicate that the greater the intensity of light, the greater the rate of electron emission (current). The intensity of light is directly proportional to the number of photons present in it per second. 1 mark

Given that an electron will only absorb one photon, the number of electrons emitted per second is directly proportional to the intensity of the light. The three plateaus on the positive voltage side agree with the electron-intensity direct proportion relationship. 1 mark

The stopping voltage relates to the kinetic energy of the fastest electrons. 1 mark

The maximum kinetic energy of the electrons is the result of the difference between the absorbed photon (energy) and the energy needed to liberate electrons from the metal (work function, W), as described by $KE_{\text{max}} = hf - W$.

Thus, the maximum kinetic energy and, consequently, the stopping voltage depend only on the frequency of light in the experiment regardless of the intensity. This is reflected by the same stopping voltage value for the same light colour (frequency) across different intensities. 1 mark

b. Using $qV_0 = hf - W$ and ignoring the value of q when using the eV equivalent for energies gives:

$$1.5 = \left(4.14 \times 10^{-15} \times f\right) - 2.2$$ 1 mark

$$f = \frac{1.5 + 2.2}{4.14 \times 10^{-15}}$$

$$= 8.9 \times 10^{14} \text{ Hz}$$ 1 mark

c. **Method 1:**

Light with a frequency of 2.5×10^{14} Hz has a photon energy of:

$4.14 \times 10^{-15} \times 2.5 \times 10^{14} = 1.04$ eV. 1 mark

Given that this energy is less than the work function of 2.2 eV, the light will not cause photoelectron emission as it will not be absorbed due to its low energy. 1 mark

Method 2:

The minimum frequency that will cause photoelectron emission is:

$$f_c = \frac{W}{h}$$

$$= \frac{2.2}{4.14 \times 10^{-15}}$$

$$= 5.31 \times 10^{14}$$ 1 mark

Given that 2.5×10^{14} Hz is less than this frequency, the photon will not have enough energy to be absorbed, so this light will not cause photoelectron emission. 1 mark

Question 16 (3 marks)

The momentum of the photon is given by $p = \dfrac{E}{c}$.

$$p = \frac{50 \times 1.6 \times 10^{-19}}{3.0 \times 10^{8}}$$

$= 2.7 \times 10^{-26}$ kg m s^{-1} 1 mark

The momentum of the electron is given by $p = \dfrac{h}{\lambda}$.

$$p = \frac{6.63 \times 10^{-34}}{0.663 \times 10^{-9}}$$

$= 1.00 \times 10^{-24}$ kg m s^{-1} 1 mark

Therefore, the electron has greater momentum. 1 mark

Note: Do not award the mark for the final statement if supporting calculations are not provided.

Question 17 (6 marks)

a. The emitted photon has a wavelength of 579 nm. Its energy is given by:

$$E = \frac{hc}{\lambda}$$

$= \dfrac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{579 \times 10^{-9}}$ 1 mark

$= 2.15$ eV 1 mark

Since the electron has dropped to a lower level of –3.71 eV and light has been emitted:

$E_{\text{missing}} - (-3.71) = 2.15$

$= -1.56$ eV 1 mark

b. The electron has a mass and speed as it is present in an energy level and thus has particle properties. 1 mark

Its energy is also manifested as a standing wave 1 mark
whereby the circumference of the energy level is the whole number of de Broglie wavelengths possessed by the electron, so it has wave properties. 1 mark

Question 18 (13 marks)

a. **Independent variable:** mass attached to spring 1 mark

Dependent variable: period of oscillation or time of 20 oscillations 1 mark

Controlled variable: spring initially unextended OR mass released from the same position in all trials 1 mark

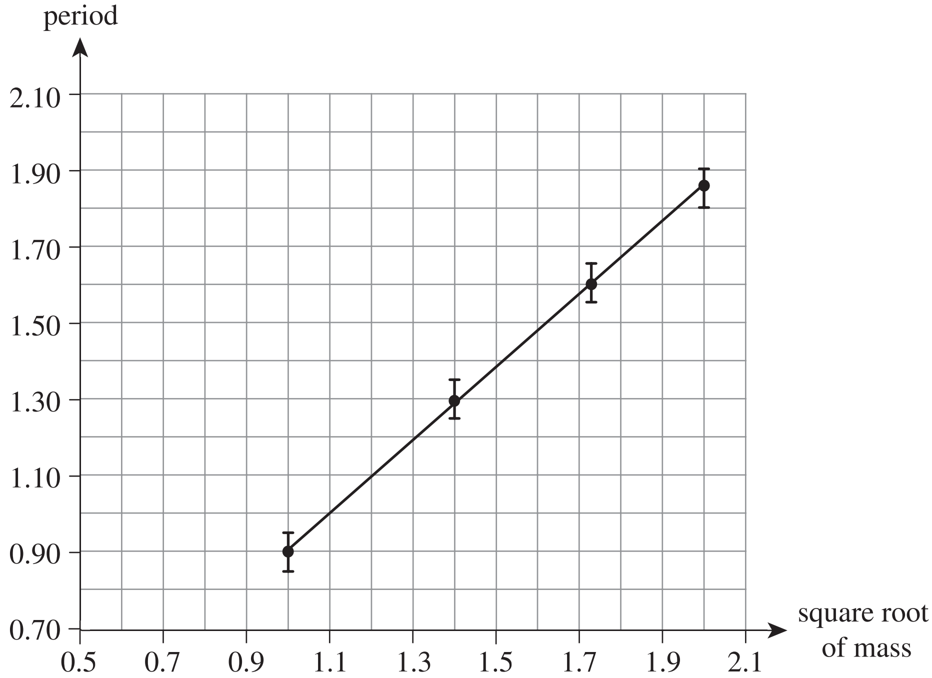
b. **i.**

M (kg)	$\sqrt{M}\left(\text{kg}^{\frac{1}{2}}\right)$	Period (seconds)
1.00	$\sqrt{1.00} = 1.00$	0.90
2.00	$\sqrt{2.00} = 1.41$	1.30
3.00	$\sqrt{3.00} = 1.73$	1.60
4.00	$\sqrt{4.00} = 2.00$	1.85

1 mark

Note: All four values must be correct to at least one decimal place to be awarded the mark.

ii.



6 marks

1 mark for constructing the y-axis scale.
1 mark for constructing the x-axis scale.
1 mark for plotting all points.
1 mark for showing the correct size of the uncertainty bars based on the scale.
1 mark for labelling the axes (units not required).
1 mark for drawing an appropriate line of best fit that passes through the uncertainty bars.
Note: Consequential on answer to ***Question 18b.i.***

iii. The equation $T = 2\pi\sqrt{\frac{M}{k}}$ can be represented as $T = \text{gradient} \times \sqrt{M}$, where $\text{gradient} = \frac{2\pi}{\sqrt{k}}$.

$$k = \left(\frac{2\pi}{\text{gradient}}\right)^2$$

1 mark

$$\text{gradient} = \frac{1.85 - 0.90}{2.00 - 1.00} = 0.95$$

$$\text{maximum value} = \frac{(1.85 + 0.05) - (0.90 - 0.05)}{2.00 - 1.00} = 1.05$$

$$\text{minimum value} = \frac{(1.85 - 0.05) - (0.90 + 0.05)}{2.00 - 1.00} = 0.85$$

1 mark

1 mark for finding the gradient. (Accept responses in the range 0.85–1.05.)

Note: Results will vary based on the accuracy of the graph drawn in ***Question 18b.ii.***

$$k = \left(\frac{2\pi}{0.95}\right)^2 = 43.74$$

$$\text{maximum } k \text{ value} = \left(\frac{2\pi}{0.85}\right)^2 = 54.64 \text{ N m}^{-1}$$

$$\text{minimum } k \text{ value} = \left(\frac{2\pi}{1.05}\right)^2 = 35.81 \text{ N m}^{-1}$$

1 mark

1 mark for finding the value of k. (Accept responses in the range 36–55.)

Note: Results will vary based on the accuracy of the graph drawn in ***Question 18b.ii.***