Neap

Trial Examination 2022

VCE Physics Unit 3

Written Examination

Suggested Solutions

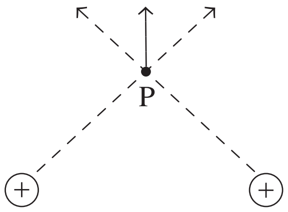
SECTION A – MULTIPLE-CHOICE QUESTIONS

1	A
2	A
3	B
4	C
5	A
6	D
7	B
8	B
9	D
10	C

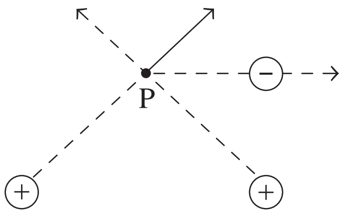
SECTION A

Question 1 A

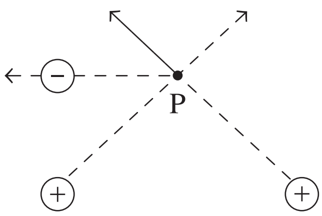
A is correct. At point P, the horizontal components of the electric fields due to the charges cancel out, leaving the vertical component shown in the diagram below.



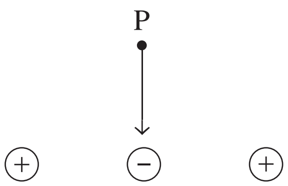
Placing a negative charge at point Q will increase the horizontal component of the vector to the right, as shown in the diagram below.



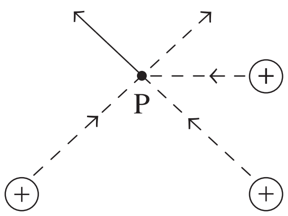
B is incorrect. Placing a negative charge at point R would have the opposite effect to placing a negative charge at point Q. The horizontal component of the vector would increase to the left, as shown in the diagram below.



C is incorrect. At point S, the electric fields of the two positive charges cancel out. Placing a negative charge at point S will result in the vector pointing down, as shown in the diagram below.



D is incorrect. Placing a positive charge at point Q would have the same effect as option **B**, as shown in the diagram below.



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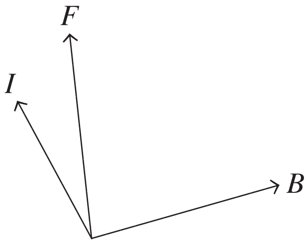
Question 2 A

The direction of the current is perpendicular to the direction of the magnetic field. Therefore, a non-zero force will act on the wire.

The magnitude of the force is given by:

$$\begin{aligned} F &= nIVB \\ &= 1 \times 2 \times 0.1 \times 0.01 \\ &= 0.002 \text{ N} \end{aligned}$$

The direction of the force is into the page, according to the right-hand rule, as shown in the diagram below.



Question 3 B

B is correct. As the magnet approaches the hollow tube, there is an increasing external flux to the right. A current is induced in the coil to generate a flux to the left that opposes the increasing flux to the right. Using the right-hand rule, the thumb points in the direction of the generated flux (to the left) and the curl of the fingers represents the direction of the induced current. Thus, the current will flow from right to left on the straight section of the wire, corresponding to a positive current. The induced current approaches a maximum just outside of the hollow tube, then decreases as the magnet enters and approaches the centre. When the magnet exits out of the hollow tube, there is a decreasing external flux to the right. A current is induced in the coil to generate a flux to the right to oppose the decreasing external flux to the right. Using the right-hand rule, the current will flow from left to right on the straight section of the wire, corresponding to a negative current.

A is incorrect. This option shows the initial current as negative, which corresponds to an induced current in the left to right direction. This would not occur, as a negative current would generate a flux that does not oppose the original increase in external flux.

C is incorrect. This option shows the direction of the EMF remaining the same as the magnet enters and exits the hollow tube.

D is incorrect. This option shows the correct directions of the induced current as the magnet passes through the tube. However, the induced EMF should start from zero and increase to a maximum in a sinusoidal-like manner; the graph shows the induced EMF starting at a maximum. Additionally, this option shows the magnitude of the induced current remaining constant as the magnet enters and exits the hollow tube.

Question 4 C

The area under the curve between 2×10^8 and 3×10^8 gives the change in gravitational potential energy. The area can be approximated using a trapezoid.

$$\begin{aligned} \Delta U_g &= \frac{0.5 + 1.0}{2} \times 1 \times 10^8 \\ &= 7.5 \times 10^7 \text{ J} \\ &= 7.5 \times 10^4 \text{ kJ} \end{aligned}$$

Question 5 A

A is correct. Orbital speed, given by $v^2 = \frac{GM}{R}$, is inversely related to the radius of orbit. The orbital radius after adjustment A will be smaller than the orbital radius after adjustment B; therefore, the orbital speed of the space probe after adjustment A will be greater than the orbital speed after adjustment B.

B is incorrect. The area under the graph is proportional to the energy gained or lost. The area for adjustment A is less than the area for adjustment B. Hence, the differences in energy of the two adjustments is unequal.

C is incorrect. The gravitational field strength after adjustment A is 0.5 N kg^{-1}; after adjustment B, it is 0.25 N kg^{-1}.

D is incorrect. Centripetal acceleration is equivalent to the gravitational field strength. From option **C**, the centripetal acceleration of the space probe after adjustment A is greater than the centripetal acceleration after adjustment B.

Question 6 D

D is correct. The net force in circular motion is towards the centre of the circular path. At the toy car's current position, the direction is down.

A is incorrect. As the toy car is undergoing centripetal acceleration, the net force is not zero.

B is incorrect. The net force is towards the centre of the circular path, which is down. The velocity of the toy car would be to the left.

C is incorrect. The toy car would come off the track if the normal force were zero.

Question 7 B

At the top of the loop, the only force acting on the car is its weight, which provides the centripetal force.

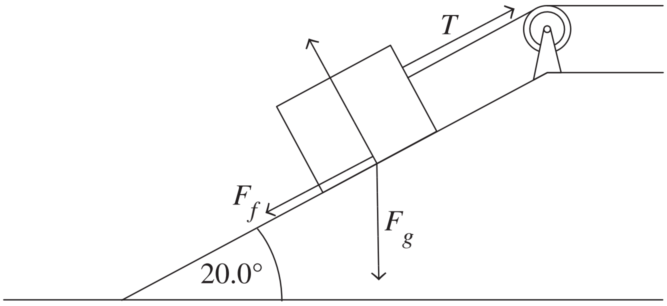
$$
\begin{aligned}
F_c &= mc \\
&= \frac{mv^2}{r} \\
v &= \sqrt{9.8 \times 0.1} \\
&= 0.9899 \text{ m s}^{-1}
\end{aligned}
$$

The initial kinetic energy of the toy car is converted to gravitational potential energy to increase the height of the car by 10 cm and the kinetic energy stored in the car at the top of the loop.

$$
\begin{aligned}
E_\text{k}(\text{initial}) &= U_g + E_\text{k}(\text{final}) \\
\frac{1}{2}mv_i^2 &= mg\Delta h + \frac{1}{2}mv_f^2 \\
v_i &= \sqrt{0.9899^2 + 2 \times 9.8 \times 0.1} \\
&= 1.71 \text{ m s}^{-1}
\end{aligned}
$$

Question 8 B

The force diagram for the 10 kg block is shown in the diagram below.



$$\Sigma F = 0$$
$$T - F_f - F_g \sin(20) = 0$$
$$T = 5.0 + 10 \times 9.8 \times \sin(20)$$
$$= 38.5 \text{ N}$$

Question 9 D

$$\text{number of seconds in one day} = 24 \times 60 \times 60$$
$$= 86\,400 \text{ s}$$
$$\text{mass loss per day} = 4 \times 10^{12} \times 86\,400$$
$$= 3.456 \times 10^{17} \text{ g}$$

Mass loss is due to the mass being converted into energy.

$$E = mc^2$$
$$= 3.456 \times 10^{14} \times \left(3 \times 10^8\right)^2$$
$$= 3.11 \times 10^{31} \text{ J}$$

Question 10 C

C is correct. At $t = 0$, the displacement is at –max and the velocity is zero. The maximum velocity occurs when the mass is at its equilibrium position; that is, when the displacement is zero. This corresponds to graph **C**.

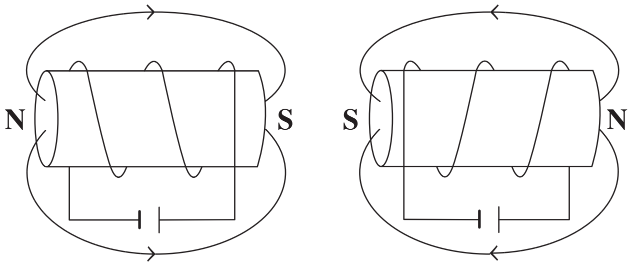
A is incorrect. This graph shows the initial velocity at +max and the initial displacement at –max. This is not possible because the maximum velocity occurs when the mass is at its equilibrium position, which is when the displacement is zero.

B is incorrect. This graph shows the initial velocity at –max and the initial displacement at +max, which is not possible.

D is incorrect. This graph shows the correct initial velocity; however, the initial displacement corresponds to the mass starting at the maximum extension, not at the initial position.

SECTION B

Question 1 (2 marks)



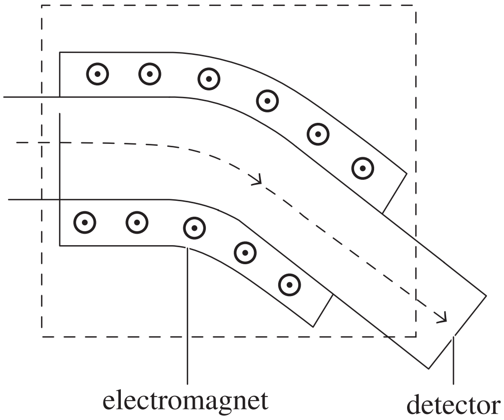
2 marks

1 mark for correct direction, including N and S labels.

1 mark for correct shape.

Question 2 (8 marks)

a.



1 mark

Note: The magnetic field must be drawn coming out of the page.

b.

$$E = \frac{V}{d}$$

$$= \frac{2700}{0.15}$$

$$= 18\,000 \text{ V m}^{-1}$$ 1 mark

$$qvB = qE$$

$$v = \frac{E}{B}$$

$$= \frac{18\,000}{0.25}$$ 1 mark

$$= 72\,000 \text{ m s}^{-1}$$ 1 mark

c. **i.** $Bqv = \dfrac{mv^2}{r}$

$$m = \frac{rqB}{v}$$ 1 mark

$$= \frac{44.82 \times 1.6 \times 10^{-19} \times 0.25}{72\ 000}$$

$$= 2.5 \times 10^{-23}\ \text{kg}\ \ \text{(to two significant figures)}$$ 1 mark

*Note: Consequential on answer to **Question 2b.***

ii. larger 1 mark

iii. Particles of different masses will be deflected at different radii and will, therefore, hit the detector at different points. The mass of each particle can be determined by the radius of the particle's path. 1 mark

Question 3 (11 marks)

a. $G\dfrac{M}{R^2} = \dfrac{v^2}{R}$

$$v = \sqrt{G\frac{M}{R}}$$ 1 mark

$$= \sqrt{6.67 \times 10^{-11} \times \frac{5.98 \times 10^{24}}{6.37 \times 10^6 + 400 \times 10^3}}$$ 1 mark

$$= 7675.72\ \text{m s}^{-1}$$

$$\approx 7.68\ \text{km s}^{-1}\ \ \text{(to three significant figures)}$$ 1 mark

b. **i.** According to the law of conversation of momentum, the total momentum of a system before and after a collision is the same (conserved). 1 mark

Since the International Space Station (ISS) and the Dragon capsule are travelling at the same orbital speed and in the same direction before the docking, the velocity of the combined mass must be the same after the docking. 1 mark

ii. kinetic energy before the collision:

$$E_k = \frac{1}{2}m_1v^2 + \frac{1}{2}m_2v^2$$
$$= \frac{1}{2}v^2(m_1 + m_2)$$
$$= \frac{1}{2} \times (7.68 \times 10^3)^2 \times (4.2 \times 10^5 + 4.2 \times 10^3)$$
$$= 1.25 \times 10^{13} \text{ J}$$

1 mark

kinetic energy after the collision:

$$E_k = \frac{1}{2}v^2(m_1 + m_2)$$
$$= \frac{1}{2} \times (7.68 \times 10^3)^2 \times (4.2 \times 10^5 + 4.2 \times 10^3)$$
$$= 1.25 \times 10^{13} \text{ J}$$

1 mark

The kinetic energies before and after the collision are equal; therefore, the collision is elastic. 1 mark

Note: Accept responses that state that the speeds of the two objects are unchanged and the combined mass is equal to the sum of the individual masses, which means that the kinetic energies before and after the collision are equal and the collision is elastic.

c.
$$T = \sqrt{\frac{4\pi^2 r^3}{GM}}$$
$$= \sqrt{\frac{4\pi^2 \times (400 \times 10^3 + 6.37 \times 10^6)^3}{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}}$$

1 mark

$$= 5541.78 \text{ s}$$

1 mark

$$= 92.4 \text{ min}$$

1 mark

Question 4 (12 marks)

a. **i.**
$$\frac{V_2}{V_1} = \frac{275}{11}$$
$$= 25$$

1 mark

$$I_1 = 700 \times 25$$
$$= 1.75 \times 10^4 \text{ A}$$

1 mark

ii.
$$P_{\text{loss}} = I^2R$$
$$= 700^2 \times 145 \times 0.1 \times 2$$

1 mark

$$= 1.42 \times 10^7 \text{ W}$$

1 mark

iii. $P_{\text{station}} = VI$

$= 11\,000 \times 1.75 \times 10^4$ 1 mark

$= 1.93 \times 10^8 \text{ W}$ 1 mark

$$\text{percentage loss} = \frac{\text{power loss}}{\text{power generated}}$$

$$= \frac{1.42 \times 10^7}{1.93 \times 10^8}$$

$= 7.4\%$ 1 mark

iv. *Any one of:*

- High voltages can be dangerous, depending on the height of the transmission lines above ground.
- The transmission lines might be damaged by the high voltages.

1 mark

b. $$\frac{V_2}{V_1} = \frac{N_2}{N_1}$$

$N_2 = 500 \times \frac{275}{11}$ 1 mark

$= 12\,500 \text{ turns}$ 1 mark

c. $V_{\text{peak}} = V_{\text{RMS}} \times \sqrt{2}$

$= 475 \times \sqrt{2}$ 1 mark

$= 672 \text{ kV}$ 1 mark

Question 5 (10 marks)

a. $\Phi = BA$

$= 0.50 \times (0.10)^2$

$= 5.0 \times 10^{-3} \text{ Wb}$ 1 mark

b. **i.** less than initial magnetic flux 1 mark

The maximum magnetic flux is reached when the coil is perpendicular to the magnetic field. When the coil is rotated, the flux decreases. 1 mark

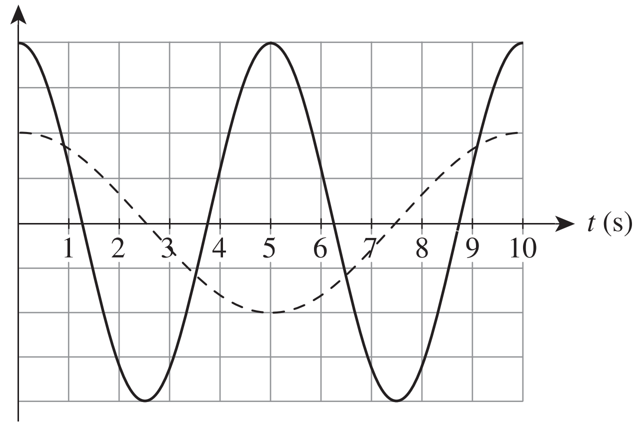
ii. $$\varepsilon = -N \frac{\Delta\Phi}{\Delta t}$$

$= 1 \times \frac{5.0 \times 10^{-3}}{5}$ 1 mark

$= 1.0 \times 10^{-3} \text{ V}$ 1 mark

c. The plane of the coil started parallel to the magnetic field. The graph shows the initial EMF (at $t = 0$) as a maximum. EMF is produced by a change in the magnetic flux ($\Delta\Phi$). The magnetic flux is at a maximum when the loop is parallel to the field. 1 mark

d. EMF (V)



2 marks

1 mark for showing that the amplitude doubles.

1 mark for showing that the period halves and two cycles occur.

Note: The dashed line represents the existing graph line in the question.

e. Rotating the coil twice as fast doubles the amplitude of the EMF; according to Lenz's Law, EMF is inversely proportional to time. 1 mark

The period also halves because the coil experiences maximum and minimum magnetic flux twice in the 10-second period. 1 mark

Question 6 (6 marks)

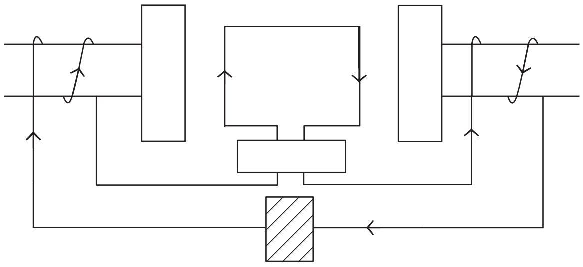
a. The split-ring commutator changes the direction of the current through the coil every half-cycle because direct currents (DC) flow in one direction. 1 mark

This allows the coil to rotate in the same direction by changing the direction of the force applied, according to the right-hand palm rule or the left-hand rule. 1 mark

b. The alternating current (AC) that flows through the armature coils must change direction. 1 mark

If the direction of the magnetic field does not change, the coil will rotate in the opposite direction when it is perpendicular to the field, according to the right-hand palm rule or the left-hand rule. By changing the direction of the magnetic field, the direction of the force on the top length of the coil will change to down. 1 mark

c.



2 marks

1 mark for correctly indicating the direction of the current through the armature coils.
1 mark for correctly indicating the direction of the current through the electromagnet coils.
Note: Accept arrows for the electromagnet coils that are placed on the electromagnet or in the external wiring.

Question 7 (8 marks)

a. $k = \text{gradient}$

$= \frac{10}{0.1}$

$= 100 \text{ N m}^{-1}$ 1 mark

b. $U_s = \frac{1}{2}kx^2$

$= \frac{1}{2} \times 100 \times 0.05^2$

$= 0.125 \text{ J}$ 1 mark

$E_k = U_s$

$\frac{1}{2}mv^2 = 0.125$

$v = \sqrt{\frac{2 \times 0.125}{0.01}}$

$= 5 \text{ m s}^{-1}$ 1 mark

c. $u = 5.0 \times \sin(40)$

$= 3.214 \text{ m s}^{-1}$ 1 mark

$v^2 = u^2 + 2as$

$0 = 3.214^2 - 2 \times 9.8 \times s$

$s = 0.53 \text{ m}$

Accounting for the height of the cannon, the maximum height of the marble is:

$h = 0.53 + 0.15 \times \sin(40)$

$= 0.63 \text{ m}$ 1 mark

*Note: Consequential on answer to **Question 7b**.*

d. maximum spring compression = 10 cm

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

$$v = \sqrt{\frac{100 \times 0.1^2}{0.01}}$$

$$= 10 \text{ m s}^{-1}$$ 1 mark

$$R = \frac{v^2 \sin(2\theta)}{g}$$

$$= \frac{10^2 \sin(2 \times 40)}{9.8}$$ 1 mark

$$= 10.05 \text{ m}$$ 1 mark

OR

$$u_{\text{vertical}} = 10 \times \sin(40)$$

$$= 6.43 \text{ m s}^{-1}$$ 1 mark

$$v = u + at$$

$$0 = 6.43 - 9.8t_{\text{top}}$$

$$t_{\text{flight}} = 0.66 \times 2$$

$$= 1.31 \text{ s}$$ 1 mark

$$u_{\text{horizontal}} = 10 \times \cos(40)$$

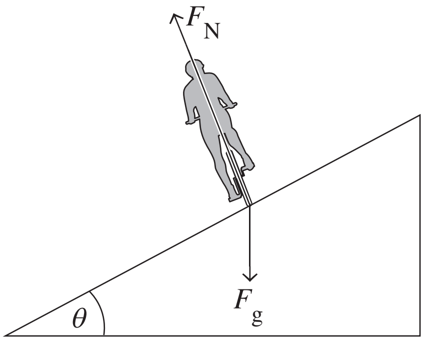
$$= 7.66 \text{ m s}^{-1}$$

$$x = 7.66 \times 1.31$$

$$= 10.05 \text{ m}$$ 1 mark

Question 8 (5 marks)

a.

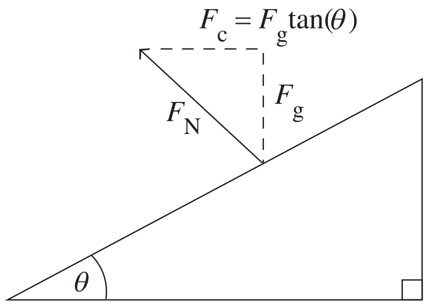


1 mark

1 mark for labelling the two forces.

Note: The arrows must originate from the point where the wheel touches the surface.

b. **i.** The horizontal component of the normal force provides the centripetal force.



$$v = \frac{70}{3.6}$$
$$= 19.4 \text{ m s}^{-1}$$ 1 mark

$$\frac{mv^2}{r} = mg\tan(\theta)$$
$$\theta = \tan^{-1}\left(\frac{19.4^2}{10 \times 9.8}\right)$$
$$= 75.4°$$ 1 mark

At 70 km h^{-1}, a banking angle of 75.4° is required to prevent the cyclist from coming off the banked section of the track. This is greater than the existing bank of the track. 1 mark

OR

Maximum speed cyclists can travel to stay on the track with the banking angle alone:

$$\frac{mv^2}{r} = mg\tan(\theta)$$
$$v = \sqrt{rg\tan(\theta)}$$
$$= \sqrt{10 \times 9.8 \times \tan(45)}$$
$$= 9.90 \text{ m s}^{-1}$$ 1 mark

$$9.90 \times 3.6 = 35.6 \text{ km h}^{-1}$$ 1 mark

As the cyclist is travelling at 70 km h^{-1}, the banking angle is not sufficient on its own to prevent the cyclist from coming off the track. 1 mark

ii. Cyclists can lean in towards the centre of the track to increase the angle. 1 mark

Question 9 (8 marks)

a. The tension is 0 N. 1 mark

As the train and the carriages are moving at a constant speed and not accelerating, the net force is zero. 1 mark

OR

$$
\begin{aligned}
T &= \Sigma F_{\text{A and B}} \\
&= ma \\
&= m \times 0 && \text{1 mark} \\
&= 0 \text{ N} && \text{1 mark}
\end{aligned}
$$

b.

$$
\begin{aligned}
a &= \frac{\Delta v}{\Delta t} \\
&= \frac{20}{10} \\
&= 2 \text{ m s}^{-2} && \text{1 mark}
\end{aligned}
$$

$$
\begin{aligned}
F &= ma \\
&= 3.0 \times 10^5 \times 2 \\
&= 6.0 \times 10^5 \text{ N} && \text{1 mark}
\end{aligned}
$$

c. The displacement of the train and the carriages is the area under the graph.

From $t = 0$ to $t = 5$:

$$
\begin{aligned}
A &= 5 \times 5 \\
&= 25 \text{ m} && \text{1 mark}
\end{aligned}
$$

From $t = 5$ to $t = 15$:

$$
\begin{aligned}
A &= 5 \times 10 + \frac{1}{2} \times 10 \times 20 \\
&= 150 \text{ m}
\end{aligned}
$$

total displacement = 175 m 1 mark

OR

From $t = 0$ to $t = 5$:

$$
\begin{aligned}
x &= 5 \times 5 \\
&= 25 \text{ m} && \text{1 mark}
\end{aligned}
$$

From $t = 5$ to $t = 15$:

$$
\begin{aligned}
x &= ut + \frac{1}{2}at^2 \\
&= 5 \times 10 + \frac{1}{2} \times 2 \times 10^2 \\
&= 150 \text{ m}
\end{aligned}
$$

total displacement = 175 m 1 mark

d. graph III 1 mark

Between $t = 0$ s and $t = 5$ s and when $t > 15$ s, the train and carriages are at a constant speed, so acceleration is 0. Between $t = 5$ s and $t = 15$ s, the train and carriages are accelerating uniformly, so the acceleration is constant. 1 mark

Question 10 (6 marks)

a. $v = 0 \text{ m s}^{-1}$

$a = 9.8 \text{ m s}^{-2}$

$s = 0.46 \text{ m}$ 1 mark

$v^2 = u^2 + 2as$

$0 = u^2 + 2 \times (-9.8) \times 0.46$

$u = \sqrt{9.016}$

$= 3.0 \text{ m s}^{-1}$ 1 mark

OR

$\frac{1}{2}mv^2 = mg\Delta h$

$\frac{1}{2} \times v^2 = 9.8 \times 0.46$ 1 mark

$v = 3.0 \text{ m s}^{-1}$ 1 mark

b. **i.** $\Delta p = m\Delta v$

$= 40 \times (3 - 0)$

$= 120 \text{ kg m s}^{-1}$ 1 mark

direction is up 1 mark

ii. $F\Delta t = m\Delta v$

$F = \frac{120}{0.025}$ 1 mark

$= 4800$

$= 4.8 \times 10^3 \text{ N}$ 1 mark

Question 11 (4 marks)

a. $L = \frac{L_0}{\gamma}$

$\gamma = \frac{100}{50}$

$= 2.0$ 1 mark

$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$

$1 - \frac{v^2}{c^2} = \frac{1}{4}$

$v^2 = \left(1 - \frac{1}{4}\right)c^2$

$v = \sqrt{(0.75)}c$

$v = 0.866c \text{ m s}^{-1}$ 1 mark

b. Proper time is measured by scientist A as the event of the timing of the ship requires them to be at rest relative to the ship. Thus, scientist B measures the dilated time as the spaceship is travelling relative to them.

$$t_B = \frac{d_B}{v}$$

$$= \frac{2 \times 4.37}{0.866}$$

$$= 10.09 \text{ years}$$ 1 mark

$$t_B = t_0 \gamma$$

$$t_0 = \frac{10.09}{2}$$

$$= 5.05 \text{ years}$$ 1 mark

