Neap

Trial Examination 2023

VCE Physics Unit 3

Written Examination

Suggested Solutions

SECTION A – MULTIPLE-CHOICE QUESTIONS

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

Question 1 B

The electric field strength, given by $E = \frac{\Delta V}{d}$, is constant throughout the region between the plates and so the potential varies linearly with the position along the path parallel to the electric field. Thus:

$$E = \frac{6.0 - -12.0}{0.50}$$
$$= 36 \text{ V m}^{-1}$$

Midway:

$$36 = \frac{V - -12}{0.25}$$
$$V = 9 - 12$$
$$= -3.0 \text{ V}$$

Question 2 D

The gain in kinetic energy is equal to the electrical work done by the field. The potential varies linearly with distance and the plates have a potential difference of 18 V.

$$q\Delta V = 1.6 \times 10^{-19} \times 18$$
$$= 2.88 \times 10^{-18} \text{ J}$$

Question 3 D

The centripetal force is equal to the magnetic field force.

$$\frac{mv^2}{r} = Bvq$$
$$r = \frac{mv}{Bq}$$
$$= 0.18 \text{ mm}$$

After the conditions are altered, v becomes $2v$ and B becomes $\frac{1}{2}B$. Substituting into the equation gives:

$$r = \frac{m2v}{\frac{1}{2}Bq}$$
$$= \frac{4mv}{Bq}$$
$$= 4 \times 0.18$$
$$= 0.72 \text{ mm}$$

Question 4 B

In an ideal transformer, the input and output power are equal, so their ratio is 1 : 1.

The transformer relationships are:

$$\frac{I_1}{I_2} = \frac{1}{100} = \frac{N_2}{N_1} = \frac{V_2}{V_1}$$

Thus, the ratio of primary turns to secondary turns is 100 : 1.

Question 5 A

The Lorentz factor is equal to γ.

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

$$\begin{aligned}\frac{v}{c} &= \frac{2.0\times10^8}{3.0\times10^8}\\ &= 0.6666\end{aligned}$$

$$\begin{aligned}\gamma &= \sqrt{\frac{1}{1-(0.6666)^2}}\\ &= 1.34\end{aligned}$$

Question 6 D

$$\begin{aligned}\text{mass-energy} &= \gamma \times \text{rest mass-energy}\\ &= 3.00 \times 0.512\\ &= 1.53 \text{ MeV}\end{aligned}$$

Question 7 C

C is correct. As light is produced by the lamp, electrical power has been produced. Hence, the apparatus is a generator. As the two slip rings preserve EMF polarity, the generator must be producing AC electricity.

A is incorrect. This graph identifies the apparatus as a motor.

B is incorrect. This graph identifies the apparatus as a motor and shows DC electricity.

D is incorrect. This graph shows DC electricity.

Question 8 C

The only force acting on the 2 kg mass is gravity. Gravity is acting on the entire system, which has a total mass of 3 kg. Therefore, the acceleration of the 2 kg mass is:

$$\begin{aligned} F_{\text{net}} &= ma \\ 2 \times 9.8 &= 3a \\ a &= \frac{19.6}{3} \\ &= 6.53 \text{ m s}^{-2} \end{aligned}$$

With this acceleration, the net force acting on the 2 kg mass is:

$$\begin{aligned} F_{\text{net}} &= 2 \times 6.53 \\ &= 13.1 \text{ N} \end{aligned}$$

Question 9 D

$$\begin{aligned} \text{work done by spring} &= \text{increase in kinetic energy} \\ &= \frac{1}{2}mv^2 - \frac{1}{2}mu^2 \\ &= \frac{1}{2} \times 0.50 \times (2.0)^2 \\ &= 1.0 \text{ J} \end{aligned}$$

$$\begin{aligned} \text{work done by spring} &= \frac{1}{2}k(\Delta x)^2 \\ &= \frac{1}{2} \times k \times (0.02)^2 \\ &= k\,2.0 \times 10^{-4} \end{aligned}$$

Equating the two expressions gives:

$$\begin{aligned} k\,2.0 \times 10^{-4} &= 1.0 \\ k &= \frac{1.0}{2.0 \times 10^{-4}} \\ &= 5000 \text{ N m}^{-1} \end{aligned}$$

Question 10 A

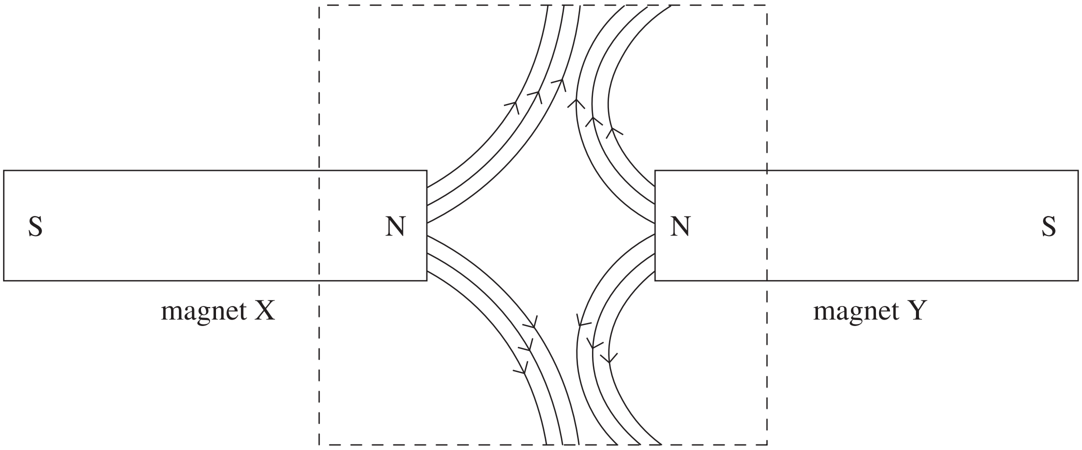
A is correct. The cart decelerates at a constant rate. Given that a is constant and $u = 2.0$ m s^{-1}, the equation $v^2 = u^2 + 2as$ becomes $v^2 = 4 - 2as$. Graph **A** has a curved profile that matches this equation.

B and **D** are incorrect. These graphs show a linear relationship between speed and position.

C is incorrect. This graph has a curved profile that does not match the equation.

SECTION B

Question 1 (2 marks)



2 marks

1 mark for at least 12 curved magnetic field lines (6 from each north pole) that do not cross or touch each other.

1 mark for correct shape and direction of the magnetic field lines.

Note: The left and right sets of curved lines should not be symmetrical; the left set should encroach on the right half of the space inside the dashed border as the magnetic field strength of magnet X is stronger than that of magnet Y.

Question 2 (6 marks)

a. Take to the right as positive.

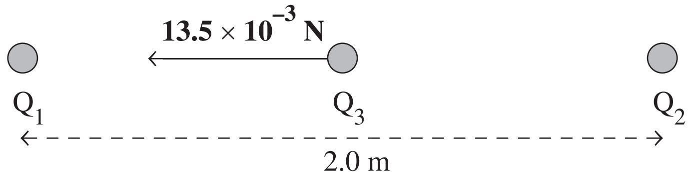
$$F_{\text{net}} = F_{Q_1 \text{ on } Q_3} + F_{Q_2 \text{ on } Q_3}$$

$$\begin{aligned} F_{Q_2 \text{ on } Q_3} &= F_{\text{net}} - F_{Q_1 \text{ on } Q_3} \\ &= -4.5\times10^{-3} - 9.0\times10^{-3} \\ &= -13.5\times10^{-3} \text{ N} \\ &= 13.5\times10^{-3} \text{ N to the left} \end{aligned}$$

2 marks

1 mark for correct value.
1 mark for correct direction.

b.



1 mark

c. If the force of Q_1 on Q_3 is to the right and the net force is to the left, then the force of Q_2 on Q_3 is to the left. Given that Q_3 is positive and Q_2 is to the right of Q_3, then Q_2 must also be positive.

$$F_{Q_2 \text{ on } Q_3} = \frac{kQ_2Q_3}{d^2}$$

$$13.5\times10^{-3}\text{ N} = \frac{9.0\times10^{9}\times1.0\times10^{-6}\times Q_2}{1.0^2}$$ 1 mark

$$Q_2 = \frac{13.5\times10^{-3}}{9.0\times10^{3}}$$

$$= 1.5\times10^{-6}\text{ C}$$ 1 mark

sign: positive (+) 1 mark

Note: Consequential on answer to ***Question 1a.***

Question 3 (10 marks)

a. $$I = \frac{V}{R}$$

$$= \frac{12.0}{2.0}$$

$$= 6.0\text{ A}$$ 1 mark

$$F = nIlB$$

$$= 50\times0.50\times6.0\times0.15$$

$$= 22.5\text{ N}$$ 1 mark

direction: D 1 mark

(*Using the right-hand palm rule, the thumb (positive current flows in the opposite direction to electron movement) is out of page. The fingers (B-field) are to the right. The force acts out of the palm of the hand; therefore, downwards.)*

b. The force on side JK is equal and opposite to the force on side LM; thus, the net force acting on the coil is zero. 1 mark
However, as the forces act along different lines of transmission, they both provide torques (rotational effects) that are clockwise (same direction). 1 mark

c. The removal of the magnets reduces the value of B in the equation $F = nIlB$, 1 mark
which reduces the rotation effect and slows the coil until it stops rotating. 1 mark

d. Removing the split ring commutator prevents the current passing through the coil from changing the direction of flow relative to the coil. 1 mark

This prevents the forces on sides JK and LM from alternating. 1 mark

As a result, the coil is not able to continuously rotate, and instead oscillates and slows until it reaches rest with its area in the vertical plane orientation. 1 mark

Question 4 (13 marks)

a. magnetic flux = magnetic field × cross-sectional area being threaded

$= 0.20 \times 0.05 \times 0.05$ 1 mark

$= 5.0 \times 10^{-4}$ Wb 1 mark

b. $\text{EMF} = N\left|\dfrac{\Delta\phi}{\Delta t}\right|$

$= 10\left|\dfrac{(5.0\times10^{-4})-0}{0.20}\right|$ 1 mark

$= 2.5\times10^{-2}$ V 1 mark

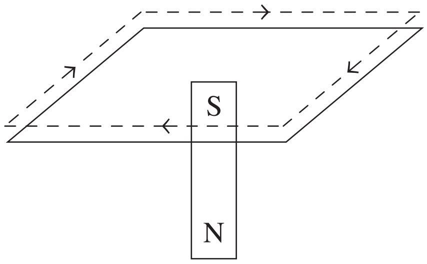
Note: Consequential on answer to ***Question 4a.***

c. The external magnetic flux is in the downward direction through the loop. As the magnet falls away, this external flux diminishes. 1 mark

The loop compensates for this by providing its own magnetic flux downwards. 1 mark

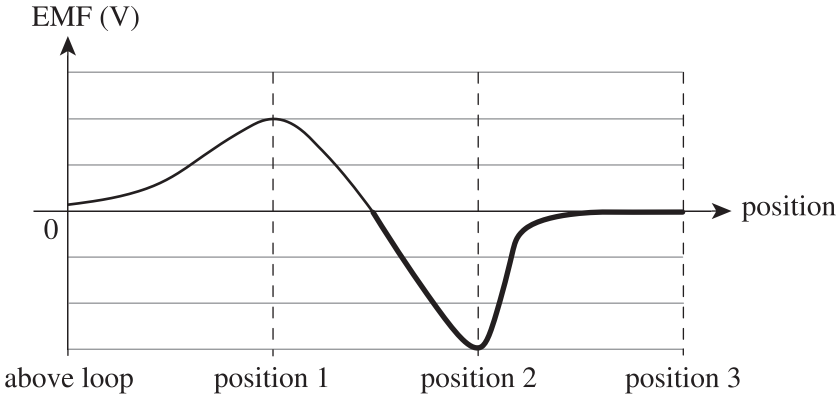
This induced flux in the loop must have an associated current to produce it. 1 mark

d. Using the right-hand rule, the induced flux is downwards (fingers pointing downwards), so the thumb points tangentially to the left on the loop when viewed from the front. Thus, when the diagram is viewed from the front, the current travels around the loop as shown below.



1 mark

e.



3 marks

1 mark for showing that the depth of the trough at position 2 must be greater than the height of the peak at position 1 because the magnet accelerates through the loop. The trough must also be negative due to the inversion of the induced flux as the magnet passes through the loop.

1 mark for showing that the EMF must return to zero after position 2.

1 mark for showing that the EMF returns to zero more quickly than the EMF increases from zero to maximum when approaching position 1 because the magnet accelerates away from the loop.

f. *Any one of:*

- Increasing the number of turns will increase the amount of flux through the coil. 1 mark
  Increasing the amount of flux increases the maximum EMF. 1 mark
- Increasing the strength of the magnetic field will increase the total flux. 1 mark
  Increasing the total flux increases the maximum EMF. 1 mark
- Increasing the area of the square loop will increase the total flux. 1 mark
  Increasing the total flux increases the maximum EMF. 1 mark

Note: Do not accept responses that refer to the reduction of time; the time cannot be altered as the magnet falls under gravity.

Question 5 (11 marks)

a. $I_{\text{station}} = \dfrac{P_{\text{gen}}}{V_{\text{station}}}$

$= \dfrac{400\times10^6}{20.0\times10^3}$ 1 mark

$= 2.0\times10^4$ A RMS 1 mark

$I_{\text{station peak}} = 2.0\times10^4\times\sqrt{2}$ 1 mark

$= 2.83\times10^4$ A

b. $I_{\text{line}} = I_{\text{station}}\times\dfrac{N_{\text{primary}}}{N_{\text{secondary}}}$ 1 mark

$= 2.0\times10^4\times\dfrac{1}{15}$

$= 1.3\times10^3$ A 1 mark

Note: Consequential on answer to ***Question 5a.***

c. $P_{\text{loss}} = I^2_{\text{line}}\times R_{\text{line}}$

$12.8\times10^6 = \left(1.3\times10^3\right)^2\times R_{\text{line}}$ 1 mark

$= 1.8\times10^6\times R_{\text{line}}$

$R_{\text{line}} = \dfrac{12.8\times10^6}{1.8\times10^6}$ 1 mark

$= 7.2\ \Omega$ 1 mark

Note: Consequential on answer to ***Question 5a.***

d. The reduction of power loss in the long-distance line will increase the power and voltage output at the city substation. 1 mark

This can occur by reducing the long-distance line current, since $P_{\text{loss}} = I^2_{\text{line}}\times R_{\text{line}}$. 1 mark

The line current can be reduced by having a greater secondary to primary turns ratio than 15 : 1, since $I_{\text{line}} = I_{\text{station}}\times\dfrac{N_{\text{secondary}}}{V_{\text{primary}}}$. 1 mark

Question 6 (4 marks)

a. Horizontally, the ball travels at constant speed.

$$v_{\text{horizontal}} = \frac{d_{\text{horizontal}}}{t}$$

$$t = \frac{6.75}{10.91 \times \cos(45)}$$ 1 mark

$$= 0.875 \text{ s}$$ 1 mark

Note: Deduct 1 mark if not correct to three significant figures.

b. For the tennis ball to enter the plane of the netball ring, the tennis ball must be at a vertical height of 3.00 m at a time of 0.875 seconds.

Given that, vertically, $a = –9.8$ m s$^{–2}$, $u = 10.91\sin(45.0)$ and $t = 0.875$ s, it needs to be shown that, vertically, $s = 3.00$ m.

$$s_{\text{vertically}} = u_{\text{vertically}}t + \frac{1}{2}at^2$$

$$= (10.91\sin(45) \times 0.875) - \left(\frac{1}{2} \times 9.8 \times 0.875^2\right)$$ 1 mark

$$= 6.75 - 3.75$$

$$= 3.00 \text{ m}$$ 1 mark

Note: Consequential on answer to ***Question 6a.***

Question 7 (5 marks)

a. As the net motion of the rider is a horizontal circular motion, she must have a net force that is horizontal and directed towards the centre of her turning circle. 1 mark

This centripetal force is provided by the horizontal component of the road reaction on the motorbike. 1 mark

b. Vertically: $R\cos(\theta) - mg = 0$ (equation 1)

Horizontally: $R\sin(\theta) = \dfrac{mv^2}{r}$ (equation 2)

Dividing equation 2 by equation 1 gives:

$$g\tan(\theta) = \frac{v^2}{r}$$ 1 mark

$$v = \sqrt{rg\tan(\theta)}$$

$$= \sqrt{40.0 \times 9.8 \times \tan(35)}$$

$$= 16.6 \text{ m s}^{-1}$$ 1 mark

The rider cannot successfully ride around the corner at 20 m s$^{–1}$. This is greater than the required speed of 16.6 m s$^{–1}$; thus, the rider's inertia will cause her to tip over on the outer side of the turn. 1 mark

Question 8 (8 marks)

a. At the top of the loop, the normal reaction and the weight are both downwards, as is the net force or centripetal force.

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

Thus, $2mg + mg = 3mg = \frac{mv^2}{r}$.

$$v = \sqrt{3gr}$$ 1 mark

$$= \sqrt{3 \times 9.8 \times 10.0}$$

$$= 17.1 \text{ m s}^{-1}$$ 1 mark

b. $$N + mg = \frac{mv^2}{r} \quad (\text{where } N = 0)$$ 1 mark

$$v = \sqrt{rg}$$

$$= \sqrt{10.0 \times 9.8}$$ 1 mark

$$= 9.9 \text{ m s}^{-1}$$

Note: Award a maximum of 1 mark if the correct equation is used with N = 0 but an incorrect answer is obtained.

c. Using total mechanical energy conservation gives:

$$mgh_{\text{top}} + \frac{1}{2}mv^2{}_{\text{top}} = \frac{1}{2}mv^2{}_{\text{bottom}} \quad (\text{divide out } m)$$ 1 mark

$$(9.8 \times 20.0) + \left(\frac{1}{2} \times 9.9^2\right) = \frac{1}{2} \times v^2$$ 1 mark

$$196 + 49 = \frac{1}{2}v^2$$

$$v = \sqrt{2 \times 245}$$

$$= 22 \text{ m s}^{-1}$$ 1 mark

Note: Award a maximum of 1 mark if r = 10.0 m is substituted into the correct equation.

Question 9 (7 marks)

a. As the distance between the markers is stationary for spacecraft X, its astronauts measure the markers to be 1000 m apart. The astronauts of spacecraft Y measure a smaller distance because they see the markers move past them.

$$\text{distance}_{\text{astronauts in Y}} = \frac{1000}{\gamma}$$

$$= \frac{1000}{1.51} \qquad \text{1 mark}$$

$$= 662 \text{ m} \qquad \text{1 mark}$$

b. **Method 1:**

The astronauts in spacecraft Y will measure a time given by $\frac{\text{distance}}{\text{speed}}$.

$$\text{time} = \frac{\text{distance}}{\text{speed}}$$

$$= \frac{662}{0.75c}$$

$$= \frac{662}{0.75 \times 3.0 \times 10^{8}} \qquad \text{1 mark}$$

$$= 2.94 \times 10^{-6} \text{ s}$$

$$= 2.94\ \mu\text{s} \qquad \text{1 mark}$$

Note: Deduct 1 mark if the final answer is not expressed to three significant figures.
*Consequential on answer to **Question 9a.***

Method 2:

The time according to spacecraft X is the dilated time. Thus:

$$\text{time}_{\text{astronauts in Y}} = \frac{\text{time}_{\text{astronauts in X}}}{\gamma}$$

$$= \frac{4.44}{1.51} \qquad \text{1 mark}$$

$$= 2.94 \times 10^{-6} \text{ s}$$

$$= 2.94\ \mu\text{s} \qquad \text{1 mark}$$

Note: Deduct 1 mark if the final answer is not expressed to three significant figures.

c. Both spacecrafts represent inertial frames of reference, meaning that the laws of physics are equivalent in both their frames of reference. 1 mark

As they are travelling at least at 10% of the speed of light relative to each other, relativistic effects will be significant. 1 mark

The measurements of the distance travelled and time of travel are correct from each frame of reference due to relativistic effects, though this means the astronauts will disagree about the correctness of the other astronauts' results. 1 mark

Question 10 (9 marks)

a. $g = \dfrac{GM_{\text{Earth}}}{r^2}$

r = radius of Earth + altitude

$= 6.37 \times 10^6 + 540 \times 10^3$

$= 6.91 \times 10^6$ m 1 mark

$g = \dfrac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{\left(6.91 \times 10^6\right)^2}$ 1 mark

$= 8.35 \text{ N kg}^{-1}$ 1 mark

b. **Method 1:**

$T = 2\pi\sqrt{\dfrac{r^3}{GM}}$

$= 2\pi\sqrt{\dfrac{\left(6.91 \times 10^6\right)^3}{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}}$ 2 marks

1 mark for radius.
1 mark for correct substitution into equation.

$= 5727$ s 1 mark

Note: Award a maximum of 1 mark if the correct equation is used to obtain an incorrect answer.

Method 2:

$T = 2\pi\sqrt{\dfrac{r_{\text{orbit}}}{g}}$

$= 2\pi\sqrt{\dfrac{6.91 \times 10^6}{8.33}}$ 2 marks

$= 5727$ s 1 mark

Note: Award a maximum of 1 mark if the correct equation is used to obtain an incorrect answer.

c. Jen is incorrect. The speeds of the satellites cannot vary for the same orbital radius. 1 mark

Bilal is incorrect. The speeds of the satellites are independent of their masses. 1 mark

The orbital speed of a satellite varies inversely as the square root of the orbital radius, for the same central body, $v = \sqrt{\dfrac{GM_{\text{Earth}}}{r}}$. 1 mark

Question 11 (5 marks)

a. Momentum conservation needs to be used to determine the forward speed of the car. The total momentum of the system after collision is equal to the total momentum of the system before collision.

$$(5000 \times 5.0) + (800 \times 2.0) = (5000 \times 4.2) + (800 \times v)$$

$$25\ 000 + 1600 = 21\ 000 + 800v$$ 1 mark

$$26\ 600 = 2100 + 800v$$

$$v = \frac{5600}{800}$$ 1 mark

$$= 7.0 \text{ m s}^{\ 1}$$

b. total kinetic energy before collision $= \frac{1}{2} \times 5000 \times 5.0^2 + \frac{1}{2} \times 800 \times 2.0^2$

$$= 62\ 500 + 1600$$

$$= 64\ 100 \text{ J}$$ 1 mark

total kinetic energy after collision $= \frac{1}{2} \times 5000 \times 4.2^2 + \frac{1}{2} \times 800 \times 7.0^2$

$$= 44\ 100 + 19600$$

$$= 63\ 700 \text{ J}$$ 1 mark

Since the total kinetic energy after the collision is less than that before the collision, the collision is inelastic. 1 mark

Note: The difference in kinetic energy has been transferred to heat, sound and some crumpling of the vehicles' contact points.