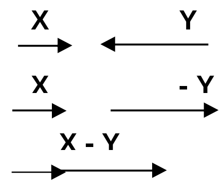
H2Physics 9749– 2022 A Level Exam

Paper 1

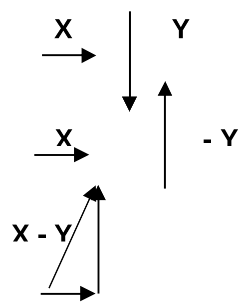
1 **Essential Question(s):**

- How to use a vector diagram to find vector subtraction?

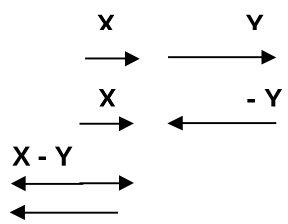
Solution:
X – Y = X + (-Y)
When angle = 0, Y is opposite to X, |X – Y| = |X| + |Y| maximum



When angle = 90, Y is perpendicular to X, | X – Y| = $\sqrt{(|X|^2 + |Y|^2)}$ less than |X| + |Y|



When angle = 180, Y is along X, | X – Y| = |Y| - |X| minimum



Answer: A

Examiner's comments:
Option B was frequently chosen, indicating that candidates were subtracting magnitudes and not thinking about the orientation of the vector.

2 **Essential Question(s):**

- How to find the range of a projectile motion?

Solution:
Let θ be the angle and u be the initial velocity

Horizontal motion
$s_x = u_x t$ a = 0
100 = u cos θ x 2
ucos θ = 50 ………(1)

Vertical motion
$s_y = u_y t + ½ a t^2$ a = g
0 = u sin θ x 2 + ½ (-g) 2^2
u sin θ = g ………………..(2)

	(2)/(1) : tan θ = g / 50 = 9.81/50 θ = 11 Answer: C **Examiner's comments:**
3	**Essential Question(s):** • What are the two mathematical relations that are the consequent of an elastic collision? **Solution:** Let v be the velocity of Q after collision along the initial velocity of P relative velocity of approach = relative velocity of separation (2 – 0) = v – (-0.5) v = 1.5 m s^{-1} Conservation of momentum m_p (2) = - m_p(0.5) + m_q (1.5) m_p / m_q = 1.5/2.5 = 3/5 Answer: B **Examiner's comments:**
4	**Essential Question(s):** • What are the conditions for a body to be in equilibrium? **Solution:** Weight = mg Upthrust = Vρg = ½ (4/3 πr^3)ρ g = ½ (4/3 x π x $(0.5)^3$)(1030) g = 269.7g Body in equilibrium Weight + tension = upthrust tension = upthrust - weight = 269.7g – 200g = 69.7 x 9.81= 684 N (Answer: B **Examiner's comments:**
5	**Essential Question(s):** • What are the conditions for a body to be in equilibrium? **Solution:** Let the tension in string be T and the weight of the mass be W. Vertical resultant force = 0 Tcos 36 = Weight = W ………(1) Horizontal resultant force = 0

	$T\sin 36$ = tension in spring = $ke = 25 \times 0.060 = 1.5$ N…….(2) (2)/ (1): $\tan 36 = 1.5 / W$ $W = 1.5 / \tan 36 = 2.064 = 2.1$ N Answer: D **Examiner's comments:**
6	**Essential Question(s):** • What is the gravitational field strength on earth surface given the radius and density of the Earth? • **Solution:** Gravitational field strength $g = GM/r^2$ $= G\ M/r^2$ $= G\ \rho(4/3\ \pi\ r^3) / r^2$ $= G\ \rho(4/3\ \pi\ r$ $\rho = g / G\ (4/3\ \pi\ r)$ $= 9.81 / \{6.67 \times 10^{-11} \times 4/3\ \pi \times 6.7 \times 10^6)$ $= G\ \rho(4/3\ \pi\ r^3) / r^2$ $= 5512$ kg m^{-3} Answer: C **Examiner's comments:**
7	**Essential Question(s):** **Solution:** Height after 2 oscillations $h = 0.60\ e^{-0.10n} = = 0.60\ e^{-0.10(2)} = 0.109$ m Initial height = 0.60 m Loss in GPE = $mg\ \Delta h = 0.4 \times 9.81\ (0.60 – 0.491) = 0.43$ J Answer: B **Examiner's Comments:**
8	**Essential Question(s):** **Solution:** All points on the disc rotate with the same angular velocity. Hence it is independent of the distance from the centre. Answer: C **Examiner's Comments:** Some candidates chose option B, which means they did not think about the concept but tried to solve the question mathematically.
9	**Essential Question(s):** • What are the conditions for a geostationary satellite? **Solution:**

<table>
<tr><td></td><td>Option A is incorrect: Radius of orbit is independent of the mass of the satellite.
Option B is incorrect: Period of the satellites is 24 hours.
Option D is incorrect: The angular speed is the same at orbit and on Earth surface. Hence the linear speed (v = rω) is proportional to the distance of orbit to the centre and the distance of surface to the centre of the Earth.

Option C is a condition for geostationary satellite.

Answer: C

Examiner’s Comments:</td></tr>
<tr><td>10</td><td>Essential Questions:
Is gravitational potential a scalar or vector quantity?
Solution:
The sum of gravitational potential at P is the sum of individual potentials,
$\phi_P = -\dfrac{GM}{\frac{1}{2}d} + \left(-\dfrac{4GM}{\frac{1}{2}d}\right) = \dfrac{-10GM}{d}$

Answer: D

Examiner’s Comment(s):
This question about gravitational potential at a point confused some candidates who subtracted the potentials instead of adding them and chose option B. Gravitational potential is a scalar.</td></tr>
<tr><td>11</td><td>Essential Questions:
What is the relation between r.m.s. speed of molecules and temperature in degree Celsius?
Solution:
r.m.s.speed $\propto \sqrt{T}$

final r.m.s. speed / initial r.m.s. speed
= $\sqrt{T_{final}} / \sqrt{T_{initial}}$
= $\sqrt{160 + 273.15} / \sqrt{80 + 273.15}$
= 1.11

final r.m.s. speed = initial r.m.s. speed x 1.11 = 350 x 1.11 = 388 m s^{-1}

Answer: A

Examiner’s Comment(s):
Some candidates found this question about r.m.s. speeds challenging. A proportion of candidates thought that the r.m.s. speed was proportional to the kelvin temperature to give option B. A similar number left the temperature in degrees Celsius and then square-rooted to give option C.</td></tr>
<tr><td>12</td><td>Essential Question(s):
What is the total kinetic energy of a gas in term of its volume and pressure?
Solution:
total kinetic energy of a gas

= N (3/2kT)

= 3/2 nRT

= 3/2 PV</td></tr>
</table>

	$= 3/2\ (1.0 \times 10^5)\ (0.10)$ = 1500 J Answer: C **Examiner's comments:**
13	**Essential Question(s):** • What is the heat absorb by a body of mass m, specific heat capacity c and rise in temperature $\Delta\theta$? **Solution:** Heat absorbed = mc $\Delta\theta$ Loss in KE = ½ m v^2 KE loss by pellet is converted to thermal energy in the pellet = 50% of ½ m v^2 = 0.5 x ½ m v^2 KE loss by pellet = gain in thermal energy in the pellet 0.5 x ½ m v^2 = mc $\Delta\theta$ $\Delta\theta = v^2 /4c$ Answer: B **Examiner's comments:**
14	**Essential Question(s):** • What is the general equation that represents the velocity of a body in s.h.m.? **Solution:** $v = v_o \cos wt = x_o w \cos wt$ from graph x_o = 0.30 m period T = 5.0 s $w = 2\pi/T$ = 2 x π/ 5 = 1.26 $v = 0.3 \times 1.26 \cos 1.3\,t = 0.38 \cos 1.3t$ Answer: C **Examiner's comments:**
15	**Essential Question(s):** • What are some examples of resonance? **Solution:** Option A is incorrect. The volume control increases the signal (voltage) in the loudspeaker which increases the amplitude of vibration of the speaker cone. This is Not a resonance effect. Option B is correct. The vibrating metal strip produces a sound wave which resonate in the organ pipe. Option C is correct. The engine produces vibration on the lorry body which cause a forced oscillation of the mirror which resonate with the energy vibration. Option D is correct. The swinging of the leg produces a period force on the child which undergoes forced oscillation which oscillate at resonance when the periodic force frequency matches the frequency of the child on the swing.

	Answer: A **Examiner's comments:** This question asked which was not an example of resonance. The most common incorrect answer was option D.
16	**Essential Question(s):** • How to determine the speed of a waves from the displacement-time and displacement-distance graph? **Solution:** From the displacement-time graph, period = 1.0/5 = 0.2 s From the displacement-distance graph, wavelength = 1.6 /2 = 0.80 m Speed = wavelength x frequency = wavelength / period = 0.8/0.2 = 4.0 m s^{-1} Answer: D **Examiner's comments:**
17	**Essential Question(s):** • What is produced between the loudspeaker and the board? **Solution:** XY = distance between two adjacent antinodes = wavelength / 2 wavelength = 2 XY = 2 x 5.0 = 10.0 cm from the trace on screen, ½ cycle = 3 divisions = 3 x 0.050 = 0.150 ms hence ½ period = 0.150 ms period = 0.300 ms frequency = 1/period = 1/ 0.300 ms = 3.33 kHz Answer: B **Examiner's comments:**
18	**Essential Question(s):** • How to determine the distance between two adjacent maxima of a double source interference pattern? **Solution:** Using distance between two adjacent maxima $x = \lambda D/a$ $x \propto \lambda/a$ D is the same for all the 4 cases. Option A: $\lambda/a = 700 \times 10^{-9}/ 0.004 = 1.75 \times 10^{-4}$ Option C: $\lambda/a = 450 \times 10^{-9}/ 0.002 = 2.25 \times 10^{-4}$ Option B: $\lambda/a = 0.020 / 0.050 = 0.4$ Option D: $\lambda/a = 0.010 / 0.20 = 0.05$ Option B ratio λ/a is the largest ➔largest separation Alternatively calculate x for each option: Option A: $x = 700 \times 10^{-9} \times 15 / 0.004 = 2.6 \times 10^{-3}$ m Option C: $x = 450 \times 10^{-9} \times 15 / 0.002 = 3.4 \times 10^{-3}$ m

	Option B: x = 0.020 x 15 / 0.050 = 6.0 m Option D: x = 0.010 x 15 / 0.20 = 0.75 m Answer: B **Examiner's comments:** Candidates who did not select the key were equally likely to choose any of the incorrect options, suggesting that they did not know how to approach the question.
19	**Essential Question(s):** • What is the path taken by a proton in a uniform electric field? **Solution:** Consider motion along the initial motion of the proton: Using "$s = ut + ½ a t^2$" $y = vt + 0$ $t = y/v$ Consider motion along the initial motion of the proton: Acceleration $a = F/m = eE/m = e(V/d)/m = eV/md$ Using "$s = ut + ½ a t^2$" $x = 0 + ½ (eV/md) t^2$ $x = ½ (eV/md) (y/v)^2$ $x = ½ \ eVy^2/ md v^2$ Answer: A **Examiner's comments:**
20	**Essential Question(s):** • How does the drift velocity of charged particles varies with the cross sectional area of a nonuniform wire when a current is flowing it? **Solution:** Current $I = nAve = n (\pi r^2)ve = n (\pi d^2/4)ve$ $v = 4I / n \pi d^2$ I is constant along the wire n is also constant $v = K/d^2$ where $K = 4 I / n \pi$ Answer: A **Examiner's comments:**

21	**Essential Question(s):**
	• How to determine the output potential difference from a potential divider circuit?
	
	Solution:
	Let R be the resistance of P and voltmeter
	Let R' be the resistance of Q
	Let $R_{//}$ be the resistance of P and voltmeter in parallel connection
	
	$R_{//} = (1/R + 1/R)^{-1} = R/2$
	
	Using potential divider formula
	P.d. across the P and voltmeter in parallel connection
	$V = (R/2)/(R/2 + R') \times 9$

	➔ $6 = (R/2)/(R/2 + R') \times 9$ $6 \times (R/2 + R') = 9 (R/2)$ $R = 4 R'$ $R/R' = 4$ Answer: D **Examiner's comments:** Those candidates who got this question wrong mostly put option C, indicating that they had not taken the resistance of the voltmeter into account.
22	**Essential Question(s):** • What is the potential gradient along a wire carrying a current? **Solution:** Potential gradient = 14.3 V m^{-1} p.d. across 84 cm of wire = $0.84 \times 14.3 = 12.01$ V p.d. across 65 cm of wire = $0.65 \times 14.3 = 9.295$ V e.m.f. of the cell = p.d. across 65 cm of wire (since galvanometer shows no current) = 9.295 = 9.3 V **Answer:** B **Examiner's comments:**
23	**Essential Question(s):** • What do you know about the forces between two parallel current carrying conductor? **Solution:** The two forces between two parallel current carrying conductor form an action and reaction pair of force, they must be equal and opposite. The two forces are attractive when the current are in the same direction The two forces are repulsive when the current are opposite in direction Option C satisfies the above. Answer: C **Examiner's comments:** Most candidates realised that the force could only be inwards when the two currents were flowing in the same direction, but some chose option B, where the forces on the wires due to each other were different.
24	**Essential Question(s):** • What is the relation between magnetic force and angle between current and magnetic field? **Solution:** Magnetic force $F = BIL \sin \theta$ where θ is the angle between current and magnetic field In this context, the angle between current and magnetic field = $90 - \theta$ Hence $F = BIL \sin (90 - \theta)$

	When $\theta = 0$, $F = BIL \sin (90 - 0) = BIL$ maximum When $\theta = 90$, $F = BIL \sin (90 - 90) = 0$ minimum F is a sinusoidal function of angle θ. F does not vary linearly with θ. Option B is incorrect. Answer: D **Examiner's comments:**
25	**Essential Question(s):** • What is the relation between magnetic flux through a coil and the angle between plane of the coil? **Solution:** magnetic flux through a coil $\phi = BA \cos \theta$ where θ is the angle between the normal of the coil and magnetic field In this context, $\theta = 90 - 60 = 30^o$ $\phi = BA \cos \theta$ $= 65 \times 10^{-6} \times 12 \times 10^{-4} \times \cos 30$ $= 6.8 \times 10^{-8}$ Wb Answer: B **Examiner's comments:**
26	**Essential Question(s):** • How to find the r.m.s. current of a square waveform current? **Solution:** Peak current = I_o Peak current = I_o Check: r.m.s. current = $\sqrt{\langle I^2 \rangle} = \sqrt{I_o^2} = I_o$ Answer: A **Examiner's comments:** Some candidates chose option B, showing that they knew the formula but did not know how an r.m.s value was calculated.
27	**Essential Question(s):** • How does the e.m.f. of an a.c. generator varies with the speed of rotation? **Solution:** e.m.f. of a generator $E = NBAw \sin wt$ Peak e.m.f. of a.c. generator $E_o = NBAw$ Since N, B and A remain constant, E_o is <u>proportional</u> to rotational speed w. **Thus,** when w is halved, E_o is halved. ➔ peak current I_o is halved ($I_o = E_o/R$, R is unchanged)

Mean power dissipated**,**

$<P> = I_{rms}^2 R = ½ I_o^2 R$

➔ <P> is proportional to I_o^2.

➔ when I_o is halved, <P> is one-quartered.

From the graph**,** peak current I_o = 2 A

New I_o = ½ x 2 A = 1 A

$<P> = I_{rms}^2 R = ½ I_o^2 R = ½ (\mathbf{1})^2 (20) = 10$ W

Answer: B

Examiner's comments:

Many chose option D, the mean power dissipated before the speed of the generator is halved.

28 **Essential Question(s):**

- What is the de Broglie wavelength?

Solution:

Kinetic energy E = ½ m v^2

Momentum p= mv

E = ½ m v^2 = ½ m^2 v^2 / m = ½ p^2 / m

p^2 = 2 m E / m

p = √2 m E

de Broglie wavelength λ = h/p= h / √2 m E

New de Broglie wavelength λ' = h / √ (2 m 9E) = 1/3 λ

Answer: A

Examiner's comments:

Nearly all those who got it wrong chose option B which indicates that they did not realise that the wavelength is inversely proportional to the square root of the energy.

29 **Essential Question(s):**

- In the representation $^{A}_{Z}X$ of an element, what is the number of neutrons and the number of protons?

Solution:

$^{212}_{83}Bi$ has 83 protons and 212-83 = 129 neutrons

Mass defect = 83Mp + 129Mn - M

Answer: C

Examiner's comments:

30 **Essential Question(s):**

- How to calculate energy released from the masses of the reactants and products**?**

Solution:

energy released

= (masses of the reactants – mass of products) c^2

= (238.1249u – 234.1165u – 4.0026u) c^2

= (0.0058u) c^2?

= (0.0058x 1.66 x 10^{-27}) (3 x 10^8)^2

	$= 8.665 \times 10^{-13}$ J **Answer:** C **Examiner's Comments:**

Paper 2
Section A

				Marks
1	a		**Essential Question(s):** • How to find the absolute uncertainty of the period of a pendulum found from the time taken for 20 oscillations? **Solution:** $T = t/10 = 7.2/10 = 0.72$ s From $T = 2\pi\sqrt{m/k}$ $k = 4\pi^2 m / T^2 = 4\pi^2 \times 0.120 / 0.72^2 = 9.14$ N m^{-1} $\Delta k / k = \Delta m/ m + 2\Delta T/T$ $T = t/10 \rightarrow \Delta T = \Delta t / 10 = 0.2/10 = 0.02$ s From $k = 4\pi^2 m / T^2$ $\Delta k / k = \Delta m/ m + 2\Delta T/T$ $= 0.01 + 2 \times 0.02 / 0.72 = 0.06555$ $\Delta k = k \times 0.06555 = 9.14 \times 0.06555 = 0.6$ (1sf) $k = (9.1 \pm 0.6)$ N m^{-1} **Examiner's Comments:** Many candidates performed well. There were a number of candidates that obtained an incorrect value for the period or did not square the period in the determination of k. A small number calculated 1% of the given mass of 120 g instead of using the 1% for the quantity m. The majority determined twice the percentage uncertainty in T when calculating the percentage uncertainty in k. A small number set up the uncertainty expression incorrectly and subtracted the uncertainty in m from the uncertainty in T. There were a significant number who gave more than one decimal place for the uncertainty in k or gave more decimal places for k than the uncertainty allowed.	
1	b	i	**Essential Question(s):** • **How is maximum acceleration related to period?** **Solution:**	

Method 1:
From Fig. 1.2, $x_o = 0.16$ m and $v_o = 1.4$ m s^{-1}

Maximum speed, $v_o = \omega x_o$
$1.4 = \omega (0.16)$
$\omega = 8.75$ rad s^{-1}

Maximum acceleration, $a_o = \omega^2 x_o$
$= (8.75^2)(0.16)$
$= 12.25 = 12$ m s^{-2}

Method 2:
Using T in (a), $\omega = 2\pi / T = 2\pi / 0.72 = 8.7266$ rad s^{-1}

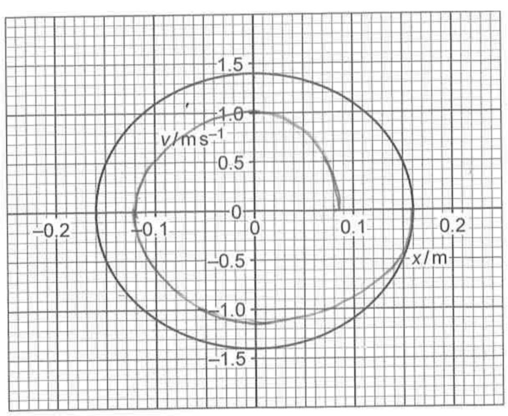
Maximum acceleration, $a_o = \omega^2 x_o$
$= (8.7266^2)(0.16)$
$= 12.18 = 12$ m s^{-2}

Examiner's Comments:
The majority of candidates started with the relevant equations for the acceleration and the period or ω and went on to determine the maximum acceleration. Some candidates attempted to apply the equations of uniformly accelerated motion to the situation. Several candidates misread points from the graph. In particular, some read the maximum velocity as 1.5 m s^{-1}. Some also read the maximum value of x as 1.6 m instead of 0.16 m.

1 b ii

Essential Question(s):
- What will happen to the maximum speed and amplitude for a lightly damped oscillation?

Solution:
Taking down as positive,
initial displacement = + 0.16 m



amplitude at the ends of oscillation will progressively decrease.
maximum velocity at equilibrium point will progressively decrease.

displacement during the 1st ¼ cycle is positive (displacement is down)
velocity during the 1st ¼ cycle should be negative (moving up)

Examiner's Comments:
The majority of candidates drew a spiral that showed the gradual reduction in the displacement x and velocity v due to the damping. There were a significant number that started from maximum velocity rather than maximum displacement, as described in the question. A significant minority of candidates drew circles or ellipses within the original diagram, hence

			representing an oscillation of smaller amplitude rather than a damped oscillation.	

2	**a**	**i**	**Essential Question(s):** **Solution:** A vector quantity is a quantity which has both magnitude and direction. **Examiner's Comments:** This question was answered correctly by the majority of candidates.	
2	**a**	**ii**	e.g. velocity, displacement, acceleration, force, momentum	
2	**b**	**i**	**Essential Question(s):** • How to find the component of a vector? **Solution:** Component of W down the slope = Wsin35 = 16sin35 =9.177 N = 9.2 N **Examiners' Comments:** The majority of answers were correct. Some candidates attempted to calculate the component of the weight using 16 / sin 35° or 16 cos 35° instead of 16 sin 35°.	
2	**b**	**ii**	**Essential Question(s):** • What is the net force on a body moving at constant speed along a straight line? **Solution:** In b(i), the net force = 0 since body moving at constant speed along a straight line, the frictional force is equal and opposite to the component of W down the slope➔ frictional force = 9.177 N up the slope In b(i), frictional force = 9.177 N is now down the slope the net force = 0 since body moving at constant speed along a straight line P = component of W down the slope + frictional force down the slope = 9.177 + 9.177 = 18.35 = 18 N **Examiners' Comments:** This was only answered correctly by better performing candidates. A large number of candidates gave the force P due to only the component of the weight down the slope and ignored the effect of friction.	

2	c	i	**Essential Question(s):** • How do you deduce impulse from a velocity-time graph? **Solution:** Impulse = change in momentum = mass x change in velocity Impulse on X = 0.22 x (3.5 – 2.6) = 0.198 N s **Examiners' Comments:** The majority of candidates correctly calculated the impulse. A small number calculated the rate of change of momentum rather than the change in momentum, and a few misread the graph.	
2	c	ii	**Essential Question(s):** • Compare the impulse on X to the impulse on Y. **Solution:** impulse on X is equal and opposite to the impulse on Y let direction of motion of X and Y be positive Impulse on X = + 0.198 N s For Y impulse on Y = - 0.198 N s m (final velocity – initial velocity) = -0.198 0.40 (final velocity – 3.3) = -0.198 Final velocity = + 2.805 = 2.8 m s^{-1} Speed = 2.8 m s^{-1} **Examiners' Comments:** The majority of candidates realised that the two objects were travelling in the same direction and related the total momentum of the two masses before the collision to the total momentum after the collision. A few had the objects travelling in opposite directions before or after the collision.	
2	c	iii	**Essential Question(s):** • How to find distance travelled from a velocity-time graph? **Solution:** displacement travelled = area under velocity-time graph = ½ (0.2((2.6+3.5) = 0.61 m Distance = 0.61 m **Examiners' Comments:** The majority of candidates used the equation distance = average speed ÷ time or the equivalent area under the line (to the x-axis). Many took the area of the triangular section rather than the area all the way down to the x-axis.	

3	a		**Essential Question(s):** • What is the path on a body which experiences a constant force? **Solution:** The path in both cases is a parabolic path. The force on a mass in a gravitational field or the force on a charged particles in an electric field is always constant throughout the motion, pointing in the same direction even when the path of the object changes its velocity direction. As the force is only perpendicular to the original motion, the velocity component that is parallel to the force increases at a constant rate while the velocity component perpendicular to the force remains constant, resulting in a parabolic path. **Examiners' Comments:** There were very few correct answers. Many candidates thought that the force on the object remained perpendicular to the motion instead of perpendicular to its original motion, and therefore said incorrectly that the motion was circular. Many talked about the forces acting on the object but did not relate these to the path the object would follow. A few candidates discussed magnetic fields despite there being no mention of magnetic fields in the question	
3	b	i	**Essential Question(s):** **Solution:** Gravitational force is attractive while the electric force is repulsive, hence the force is represented by oppositive signs. **Examiners' Comments:** Many candidates stated that electric forces could be attractive or repulsive; a few did not say which one applied in this case. Many others simply stated that gravitational forces are negative and the electric force was positive, which only describes the graphs but does not explain the opposite signs of the two forces.	
3	b	ii	**Essential Question(s):** • Compare the electric force and gravitational force on two protons separated by the same distance. **Solution:** Let the separation be x. Gravitational force $= Gm^2/r^2 = 6.67 \times 10^{-11} \times (1.67 \times 10^{-27})^2 / x^2 = 1.86 \times 10^{-64} / x^2$ Electric force $= (1/4\pi\varepsilon)Q^2/r^2 = (1/4\pi\varepsilon) \times (1.6 \times 10^{-19})^2 / x^2 = 2.30 \times 10^{-28} / x^2$ Gravitational force $= Gm^2/r^2 = 6.67 \times 10^{-11} \times (1.67 \times 10^{-27})^2 / x^2 = 1.86 \times 10^{-64} / x^2$ Electric force / Gravitational force	

			$= (2.30 \times 10^{-28}/ x^2) / (1.86 \times 10^{-64}/ x^2) = 10^{36}$ For a particular value of x, the electric force is 10^{36} times the gravitational force, Suppose the horizontal axes are drawn to the same scale, the vertical axis for both graphs are not to the same scale. **Examiners' Comments:** A significant number of candidates stated the electric force was greater than the gravitational force. Many candidates concentrated on either the comparative magnitudes of the charges and the masses, or the comparative magnitudes of the constants G and 1/(4πϵ0). Several candidates said that the gravitational force was larger because the force was between the Earth and the proton. Very few stated a correct comparison between the forces.	
3	**c**	**i**	**Essential Question(s):** • Do you have to consider the direction of the electric fields when addition them? **Solution:** Between P and R Both the electric fields due to P and R are to the right, hence the net electric field cannot be zero. **Examiners' Comments:** The majority stated or implied that the electric field strength was a vector. A significant number went on to say that as the charges were of opposite signs their respective fields would cancel between P and R.	
3	**c**	**ii**	**Essential Question(s):** • Does the sign associated with an electric potential represent directions? **Solution:** Between P and R The electric potential due to P is positive while that due to R is negative. Since the potential at a point is the algebraic sum of the potential due to P and R, the potential can be zero. **Examiner's Comments:** The majority stated that potential was a scalar or implied that it was a scalar. The explanations were often not made clear. The answers did not state whether it was the charge or the potential that was positive or negative and therefore the potentials could add to give a potential of zero. g	
3	**c**	**iii**	**Essential Question(s):** • Along the straight line passing through P and R, identical the region where there is no electric field. **Solution:** Consider the section of the straight line to the right of R and consider a point X on this section of the straight line. Compare the electric field due to R and P.	

			X is near to R than P but R has a smaller charge as compared to P, since E = $(1/4\pi\varepsilon)Q/r^2$, hence the electric field at X due to R can be equal in magnitude as compared to that due to P In addition, the electric fields are opposite in direction. Hence the electric field at X can be zero and the resultant force can be zero. Let the distance from X to P be x, the distance from X to R = (x – 6) cm Electric field at X due to R = E = $(1/4\pi\varepsilon)(0.45\text{nC}) /(x - 6\text{cm})^2$ Electric field at X due to P = E = $(1/4\pi\varepsilon)(6.5\text{nC}) /x^2$ the electric fields are equal in magnitude $(1/4\pi\varepsilon)(0.45\text{nC}) /(x - 6\text{cm})^2 = (1/4\pi\varepsilon)(6.5\text{nC}) /x^2$ $(x - 6\text{cm})^2 /x^2 = 0.45 /6.5$ x = 8.142 = 8.1 cm **Examiners' Comments:** The majority of candidates found this question challenging. Some realised that the constants in the equation for the electrostatic force could be cancelled and only the charge and relevant distances were required. Many arranged their equations with distances x and (6.0 – x) so that they located the point between the charges rather than to the right of R. There was also confusion as to the correct placing of the minus sign for charge R. Many candidates used the formula for electric potential rather than for electric field strength. A few candidates correctly found the distance from R as 2.1 cm, but forgot to add 6.0 cm to give the distance from P.	
4	**a**		**Essential Question(s):** **Solution:** • Gas molecules are in constant random motion • When the molecules collide with the wall of the vessel, they rebound and reverse in direction. Their momentum is reversed. • There is a change in the momentum in the direction of opposite to the wall and they experience a force by the wall. • By Newton's 3rd law of motion, they exert a force on the wall. • The force on the wall produces a pressure on the wall. **Examiner's Comments:** Stronger responses gave a clear explanation of how the molecules of the gas exerted a force on the walls of the vessel. A significant number described the gas colliding with the walls rather than the molecules of the gas. A small number stated that the collisions increased the kinetic energy of the molecules.	
4	**b**	**i**	**Essential Question(s):** • What is the assumption of the kinetic theory of gases that is related to the average spacing of the molecules? **Solution:** The volume of the vessel is very large as compared the total volume of the molecules. **Examiner's Comments:** The majority of answers described the lack of intermolecular forces as due to the relatively large separation or the volume of the molecules of the gas being very much smaller than the volume of the gas. Some candidates stated that	

			the size of the molecules was negligible, or that the molecules were spaced far apart, but did not give the relevant comparison point.	
4	**b**	**ii**	**Essential question(s):** • Given the volume of the vessel and the number of articles in the vessel, how to find the average spacing of the particles? **Solution:** Let x be the average distance between the particles x^3 = volume of the vessel/ number of particles in the vessel x = $^3\sqrt{}$volume of the vessel/ number of particles in the vessel Using $pV= NkT$ $V/N = kT/p = 1.38 \times 10^{-23} \times 298 / 180$ Average distance $x = \sqrt[3]{(1.38 \times 10^{-23} \times 298 / 180)} = 2.8 \times 10^{-8}$ m **Examiner's Comments:** The majority of candidates correctly calculated the number of molecules in the gas. A minority were able to calculate an estimate of the separation of the molecules from this number. The most common error was to end the calculation with the volume occupied per molecule, rather than the separation of the molecules.	
4	**b**	**iii**	**Essential question(s):** **Solution:** Given diameter of a gas particle = 1×10^{-10} average distance x between particle / diameter of a gas particle $= 2.8 \times 10^{-8} / 1 \times 10^{-10}$ = 300 average distance x between particle = 300 times diameter of a gas particle hence the assumption is valid. **Examiner's Comments:** Very few candidates were able to relate their answer to (b)(ii) to the assumption in (b)(i) as their answer for the separation was incorrectly many orders of magnitude less than the diameter of the molecule.	
5	**a**		**Essential Question(s):** • **Solution:** **1.** Consider the phase of vibration. In a stationary wave, all points between two adjacent displacement nodes vibrate in phase, and, points across a displacement node vibrate in antiphase. Whereas in a progressive wave, all points within one wavelength are vibrating in different phases, and, points that are integer number of wavelengths apart vibrate in phase. **2.** Consider the amplitude of vibration. In a stationary wave, the amplitude of vibration changes from maximum at the displacement antinodes to zero at the displacement nodes, whereas in a progressive wave, all the particles have the same amplitude of vibration. **Examiner's Comments:** The majority of candidates were able to give one feature to distinguish between stationary and progressive waves. A significant number gave the requirements for forming a stationary wave. Some described stationary waves as being composed of two waves and progressive as only one. A few	

			candidates suggested that only transverse waves could form standing waves. Some candidates gave answers relevant to the comparison of longitudinal and transverse waves rather than stationary and progressive waves.	
5	**b**		**Essential Question(s):** • What is the conditions for a stationary waves to be formed? **Solution:** The waves from the microwaves transmitter is reflected from the metal plate. The incident waves and the reflected waves are of the same nature and they overlap, and hence undergo interference. Since the two waves have the same speed, frequency, almost the same amplitude (since most energy is reflected back), and travel in opposite directions along the same line, a stationary wave is formed. **Examiner's Comments:** The majority of candidates stated that the microwaves were reflected off the metal plate. The explanation of which waves formed the stationary wave was not always clear. A small number of responses gave general answers about how standing waves are formed rather than relating to the situation described.	
5	**c**	**i**	**Essential Question(s):** • What is the effect if a stationary waves is formed from two waves which have a slightly different amplitude interfere? **Solution:** At a minimum, the incident and reflected waves <u>meet in antiphase and undergo destructive interference</u>. The resultant amplitude at this point is the <u>difference</u> between the amplitudes of the two waves ($A = A_1 - A_2$). The amplitude of the reflected wave is <u>always</u> smaller than that of the incident waves due to energy loss during reflection and also due a longer distance travelled. Hence the resultant amplitude is non-zero. Intensity is proportional the square of the amplitude. Hence the intensity can never be zero. **Examiner's Comments:** The majority of candidates were able to explain that the amplitude or intensity decreased with distance from the source following the inverse square law. A significant number were unable to explain why the intensity is never zero.	
5	**c**	**ii**	**Essential Question(s):** • What is the distance between two adjacent maximum intensities in a stationary microwaves? **Solution:** distance between two adjacent maximum intensities = ½ wavelength From the graph, distance between two adjacent maximum intensities = (6.2 – 1.0) / 2 = 2.6 cm ½ wavelength = 2.6 cm Wavelength = 5.2 cm **Examiner's Comments:** A significant number of candidates did not realise that each maximum on the display shown represented an antinode, so the wavelength of the standing wave is 5.2 cm not 2.6 cm. A few measured the distance between a maximum and a minimum on the displayed waveform.	

	c	ii	**Essential Question(s):** **Solution:** Frequency = speed / wavelength = $3.00 \times 10^8 / 0.052$ = 5.769×10^9 Hz = 5.8×10^9 Hz **Examiner's Comments:** The majority of candidates answered this question correctly. A small number did not use the speed of light for the velocity of the microwaves and used the speed of sound instead.	

6	a		**Essential question(s):** **Solution:** The half-life of a radioactive nuclide is the expected average <u>time taken</u> for <u>half the nuclei</u> in a <u>sample</u> of the <u>nuclide*</u> to decay, <u>based on the average time taken in a sample with a large number of radioactive nuclei</u>. (refer to notes) **Examiners' Comments:** Some candidates answered this question correctly, but many candidates found this question challenging. Many demonstrated the wrong use of language and/or terms, e.g. concentration.	
6	b		**Essential question(s):** **Solution:** Assuming that the decay curve is a plot of count rate against time. 1. For the same graph scale used, the time for the count rate to reduce to half can be more accurately determined at the steeper part of the curve. This means that the uncertainty of the half-life is smaller. 2. There is a large absolute decrease per unit time in the number of radioactive nuclei and proportionately large absolute decrease in activity relative to random fluctuations, background radiations (if background count rate has not been accounted for) and uncertainties in measurements. This reduces percentage uncertainty in the calculations. **Examiners' Comments:** There were many responses that suggested only that the determination would be easier or did not relate the steep part of the graph to the activity. Others stated that fluctuations in readings were fewer when the activity was higher. A small number of candidates thought that the half-life changed and was shorter where the graph was steep or that the gradient was the half-life.	
6	c		**Essential question(s):** • **Solution:**	

			In such a decay process, the total momentum is constant because there is no external resultant force acting on the system of particles. Initially the nucleus is at rest and it possesses zero momentum. After decay, without the emission of a third particle, the sum of the momenta of the recoil nucleus and the beta particle cannot be zero because the beta particle is not opposite to that of the recoil nucleus. And this violates the law of the conservation of momentum. Hence a third particle must be emitted and it must possess a momentum such that the sum of the momenta of the three particles is zero to ensure that the total momentum is conserved. **Examiners' Comments:** The majority of candidates gave incomplete answers. There was a mention of the need for the conservation of momentum without relating it to this situation.	
6	d	i	**Essential question(s):** • What are the conservation rules in a nuclear reaction? **Solution:** ${}^{90}_{38}Sr \rightarrow {}^{90}_{39}Y + {}^{0}_{-1}e +$ *antineutrino* **Examiners' Comments:** Some candidates answered this correctly. A significant number gave an incorrect balance for the atomic and mass numbers or did not give any for the beta particle.	
6	d	ii	**Essential question(s):** • How to determine half- life from the activity- number of nuclei graph? **Solution:** $A = \lambda N$ Gradient of A-N graph = λ Gradient = $(4.6 \times 10^{9} - 0) / (6 \times 10^{18} - 0) = 7.667 \times 10^{-10}\ s^{-1}$ $\lambda = 7.667 \times 10^{-10}\ s^{-1}$ half-life = $\ln 2 / \lambda = \ln 2 / 7.667 \times 10^{-10} = 9.0 \times 10^{8}$ s **Examiners' Comments:** This was well-answered by the majority of candidates. There were some responses that did not use the powers of ten given on the graph.	

6	e		**Essential question(s):** • **Solution:** Let N_o be the initial number of atoms of J After 3.5 half–life, number of atoms of J = $(½)^{3.5}\ N_o$ number of atoms of K = $N_o - (½)^{3.5}\ N_o$ the ratio number of atoms of J / number of atoms of K = $(½)^{3.5}\ N_o / (N_o - (½)^{3.5}\ N_o)$ = 0.097 **Examiners' Comments:** A large number of correct responses was seen. Candidates who performed less well were unable to obtain a value for the number of J atoms remaining after 3.5 half-lives and often gave this as N_0. These candidates then considered the decay as that of the K atoms. A small number of candidates did not know how to deal with a non-integer number of half-lives and tried to estimate how many nuclei would decay between 3 and 4 half-lives.	
7	a	i	**Essential Question(s):** • What is the meaning of kWh? **Solution:** Cost to travel 400.0 km in a typical EV = 72 kWh x \$0.23 per kWh Cost to travel 1.0 km in a typical EV=72 kWh x \$0.23 per kWh / 400= \$0.0414 Cost to travel 800.0 km in an ICE car = \$80.00 Cost to travel 1.0 km in an ICE car = \$80.00 / 800 = \$ 0.1 Cost to travel 1.0 km in a typical EV/ Cost to travel 1.0 km in an ICE car = 0.0414 / 0.1 = 0.414 = 0.41 **Examiners' Comments:** The majority of candidates gave the correct ratio.	
7	a	ii	**Essential Question(s):** • **Solution:** From table 7.1, Range = 400 km per charge Typical travel distance = 290 per week Number of times to charge per week = 290 / 400 = 0.73 Need to charge less than once per week **Examiners' Comments:** This was well answered by the majority of candidates.	

<table>
<tr>
<td>7</td><td>b</td><td>i</td>
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Essential Question(s):

- What is the change in the electric potential energy when a charge Q moves across a p.d. of V in an electric field?

Solution:

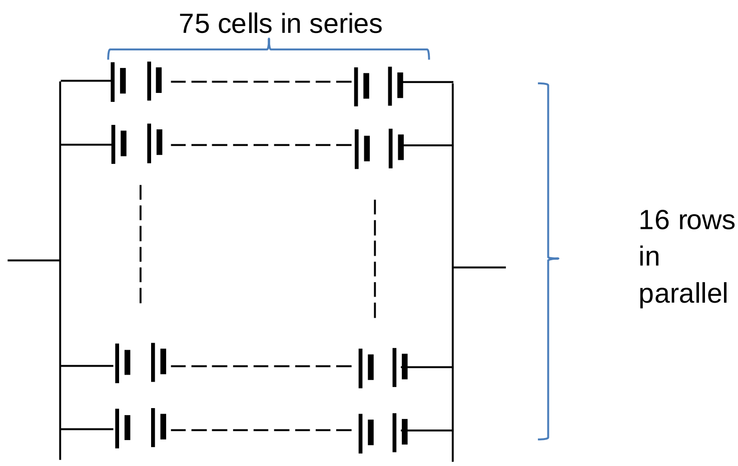
Power required = 7.2 kW
Current required = 32 A

Potential difference required = P/I = 7200 / 32 = 225 V

Each cell has a terminal p.d. of 3.0 V,
Number of cells to be connected in series to provide a p.d of 225 V
N = 225/3.0 = 75

Each cell provides a current of 2.0 A
Total current required = 32 A
Number of cells to be connected in parallel to provide a current of 32 A
N' = 32/2 = 16

Hence the arrangement of the cells consists of 16 rows of cells with each row consists of 75 cells in series



The number of cells required = 16 x 75 = 1200

Examiners' Comments:
There were many candidates who obtained the correct number of cells. Better performing candidates were able to go on and describe the arrangement of these cells. There was a significant number that did not link the maximum current and maximum voltage of a cell to the requirements of the battery.

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<tr>
<td>7</td><td>b</td><td>ii</td>
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Essential Question(s):

Solution:

The car can travel a distance of 40 km per hour of charging time.

Note that from the passage the battery takes 10 hours to fully be charged and from table 7.1, the range is 400 km per fully charged battery

Examiners' Comments:
The meaning of this term was well-understood by most candidates. Some candidates thought it meant that the drift velocity of electrons in the charging circuit was 40 km h–1, or that the charge enabled the car to travel at a speed

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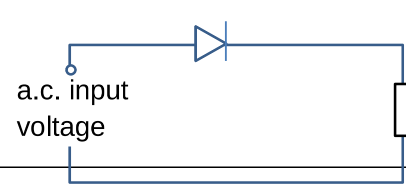
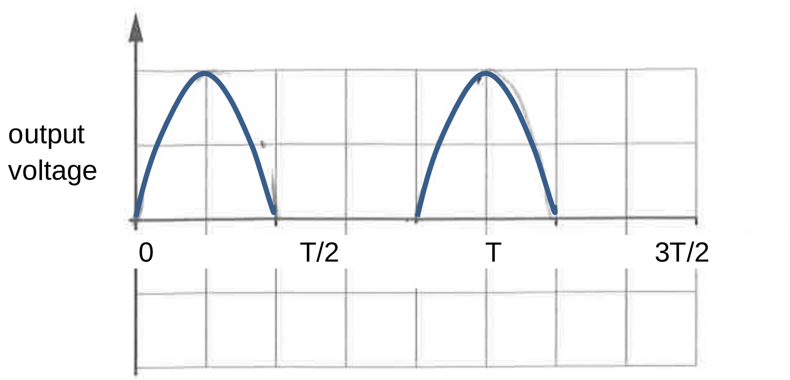
			of 40 km h^{-1}. A few thought that the car had to travel at 40 km h^{-1} whilst charging.	
7	b	iii	**Essential Question(s):** • What does specific mean? • What does Wh means? **Solution:** Specific means per unit mass Wh is the unit of energy (equivalent to 1 x 60 x 60 = 3600 J) 141 Wh kg $^{-1}$ means that the battery can provide 141 Wh of energy per kg of the mass of the battery. **Comments:** A significant number of candidates explained the specific energy in terms of the power provided by the battery. There seemed to be some confusion over the unit Wh.	
7	b	iv	**Essential Question(s):** • **Solution:** Energy = 72 kWh = 72 000 Wh Specific energy = 141 Wh kg^{-1} Energy / mass = specific energy 72000 Wh / mass = 141 Wh kg^{-1} mass = 72000 / 141 = 510 kg **Examiner's Comments:** The majority of candidates correctly calculated the mass.	
7	b	v	**Essential Question(s):** **Solution:** To lower the centre of gravity of the car. With a lower centre of gravity, the car is more stable and it is less likely to overturn when it goes round sharp bends. **Examiner's Comments:** The majority of responses explained the positioning of the battery beneath the floor was to produce a low centre of gravity for the car and hence greater stability. A minority of candidates did not realise the position of the battery was stated in the passage and thought they needed to suggest the location of the battery and to explain their own suggestion.	
7	c	i	**Essential Question(s):** • How to convert an AC to DC? **Solution:** 	

			Examiners' Comments: There were many correct circuit diagrams. A significant number of candidates gave an incorrect symbol for the diode or labelled a rectangular box as a diode. There were also many transformers drawn where the candidate converted a high a.c. voltage into a low a.c. voltage. This did not answer the question which required d.c from a.c.	
7	**c**	**ii**	**Essential Question(s):** **Solution:**  **Examiner's Comments:** The majority of candidates drew a half-wave rectified d.c. voltage. There were a significant number who drew an alternating voltage instead of the required d.c output voltage.	
7	**d**		**Essential Question(s):** **Solution:** KE of car before stopping = ½ m v^2 =½ (1685) $(25)^2$ = 52562 J Energy from regenerated energy = 52562 J Energy used to travel 400 km of distance = 72 kWh = 27 000 x 60x 60 J Energy used to travel 1 km of distance = 27 000 x 60x 60 /400 Energy from regenerated energy can travel = 52562 / (27 000 x 60x 60 /400) = 0.813 km **Examiner's comments:** Most candidates correctly calculated the kinetic energy of the EV. Many found it difficult to move on from there to find the extra range gained. Stronger responses were able to determine the energy required by the car to travel 400 km from the data in the text.	
7	**e**	**i**	**Essential Question(s):** Solution: A wireless charger operates using electromagnetic induction which works only only using a.c. voltages.	

			Examiner's comments: A significant number of candidates described the need for a changing magnetic flux linkage for a wireless charger. There were many responses that referred to reducing energy losses or to preventing a heating effect.	
7	e	ii	**Essential Question(s):** **Solution:** This is to allow the magnetic flux from the circuit on the ground to link efficiently (i.e. to maximize the linking of the magnetic field from the ground to the charging coil) to the charging coil connected to the battery. **Examiner's comments:** Better performing candidates described the need to reduce the loss of magnetic flux linkage. Some described a reduction in energy losses or a reduction in heating due to eddy currents.	
7	f	i	**Essential Question(s):** **Solution:** Maximum torque = 395 N m Torque = force x perpendicular distance between the force = *NBIL x d* = *NBIA* 395 = (1200)(B)(96)(6.1 x 10^{-3}) *B* = 0.5621 = 0.56 T **Examiner's comments:** There were many correct answers. Some candidates omitted the effect of the number of turns in the coil. A significant number used an inappropriate equation for magnetic flux density of a flat coil from the formula page. There were some responses that started with the expression F = BIL but then did not relate this force to the torque on the coil.	
7	f	ii	**Essential Question(s):** **Solution:** In every rotation, the coil experiences 4 times the maximum torque as compared to that of one pair of magnetic poles. Hence the total torque per rotation of the coil is 4 times higher than that of one pair of magnetic poles. In addition, the torque experienced by the coil is more uniform for every rotation of the coil. **Examiner's comments:** The majority of candidates described the effect of the extra magnets as a coil with a greater torque or speed. A small minority realised that the magnets were positioned in this way to produce a more consistent rotation or smoother running of the motor. There were some answers that referred to a greater induced e.m.f.	

Paper 3

1	a		**Essential Question(s):** **Solution:** The inertia of a body is the property of the body which resists the change of its state of motion (at rest or uniform velocity). A body with higher inertia requires a greater force to change its state of motion by the same amount as compared to another body of lower inertia. **Examiner's comments:** Some candidates confused inertia with mass. Some responses had a partial description such as 'resistance to change in direction of motion' but this is incomplete. Some incorrectly stated that inertia is a force or referred to a 'change of momentum'.	
1	b		**Essential Question(s):** **Solution:** Gravitational field strength on surface $g = GM/r^2$ $= (6.67 \times 10^{-11}(7.35 \times 10^{22})/(1.74 \times 10^{6})^2$ $= 1.619$ $= 1.62$ N kg^{-1} **Examiner's comments:** Nearly all candidates answered this correctly. The few incorrect responses usually had an incomplete substitution of values (leaving the gravitational constant as G rather than 6.67×10^{-11} or missing the squared term from the value for the radius).	
1	c	i	**Essential Question(s):** **Solution:** By Newton's 3rd law of motion, Downward thrust on gases by rocket = Upward thrust on rocket by gases = 10.0 kN By Newton's 2nd law of motion, Downward thrust on gases by rocket = mass flow rate of the gases x change in velocity of the gases $10 \times 10^3 = 70 \times$ (exit speed of gases – 0) exit speed of gases = 142.9 = 143 m s^{-1} **Examiner's comments:** Many candidates answered this correctly. The most common error was to use F = ma and to try to calculate a value for the acceleration of the mass of air. Quite a few candidates realised that using Newton's second law is important and often wrote $F = \Delta p / \Delta t$, but some did not progress any further. A few appeared not to realise that the change of mass is key, writing an equation such as $F = m\Delta v / \Delta t$ is not correct in this context. These candidates did not realise that the rocket and its gases are a closed system, and the planet is irrelevant in this case.	
1	c	ii	**Essential Question(s):** **Solution:** After 15.0 s Mass of rocket = 4000 – 70 x15 = 2950 kg Weight of rocket = mg = 2950 x 1.62 = 4779 N Net force on the rocket = 10000 – 4779 = 5221 N	

			Using Newton's 2nd law of motion Net force = mass x acceleration 5221 = 2950 x acceleration Acceleration = 1.770 = 1.77 m s^{-2} **Examiner's comments:** Most candidates answered this question correctly. Some candidates did not realise that the total mass of the rocket decreases as the exhaust gases continue to leave the rocket, so left the mass as 4000 kg. Whilst F = ma is appropriate, these candidates did not realise that it is the resultant force (thrust – weight) that is key. Some used the value of g as 9.81 N kg^{-1} despite having been told that it was 1.62 N kg^{-1}.	
1	**c**	**iii**	**Essential Question(s):** **Solution:** Assuming that the relative speed with respect to the rocket and the rate of mass ejected are unchanged, the thrust on the rocket is constant at 10000 N. As the rocket ascends, the gravitational field strength deceases as it is further away from the centre of the planet because the gravitational field strength is inversely proportional to the square of the distance from the centre of the planet. At 15 s, the rocket has ascended and the distance from the centre of the planet is increased. The gravitational field strength is now lower than 1.62 N kg^{-1} and hence the weight of the rocket is smaller than 4779 N. The net force (= thrust – weight) will be larger since the thrust is the same From the Newton's second law of motion, Net force = mass x acceleration, After 15 s, the mass rocket is the same as in c (ii), (=2950 kg). As compared to part c(ii), since net force is greater, the acceleration is greater than 1.77 m s^{-2} the mass of rocket is still 2950 kg. **Examiner's comments:** Some candidates found this question challenging. A significant number decided that the planet has an atmosphere which would produce resistive forces and decrease the acceleration. Some mentioned that a reduction in weight or gravitational force would give rise to a greater acceleration but did not make it clear that the reduction was due to a decrease in gravitational field strength.	
2	**a**		**Essential Question(s):** **Solution:** Resistance R = $\rho L/A$ Resistance per unit length $R/L = \rho/A = \rho/\pi r^2$ $1.73 = \rho/(\pi \times (0.00102/2)^2)$ $\rho = 1.414 \times 10^{-6}$ $= 1.414 \times 10^{-6}\ \Omega$ m **Examiner's comments:** Nearly all candidates answered this question correctly. A few made errors in the calculation of area. Some did not include an appropriate power of ten on the answer line and some rounded their answer to two significant figures.	
2	**b**	**i**	**Essential Question(s):** • What is the energy transfer when the wire is heated up?	

			• What is the energy transfer during constant temperature (steady equilibrium) state? **Solution:** Δu q w Time 0 - 59 s + - + Time 60-100 s 0 - + **Examiner's comments:** Many candidates found applying the first law of thermodynamics to an electrical system challenging. Most candidates realised that as temperature increases the internal energy increases and when the temperature is constant there is no change in internal energy. However, many did not realise that the work done on the system is that supplied by the electrical system and that thermal energy is released by the wire both as its temperature rises and when it is at constant temperature.	
2	**b**	**ii**	**Essential Question(s):** • What is the work done on the wire in terms of electrical energy transfer in the wire? **Solution:** w = work done on the system (wire) = work done by the electric field on the mobile electrons in the wire = qV = ItV = 12 x 40 x 230 = 1.10 x 10^5 J Since temperature is constant, there is no change in the internal energy Δu = 0 Hence q = Δu - w = 0 - 1.10 x 10^5 J = - 1.10 x 10^5 J **Examiner's comments:** Most candidates recognised that ΔU would be zero and the majority calculated a correct value for q and w although often with incorrect signs.	
3	**a**	**i**	**Essential Question(s):** **Solution:** $\omega = 2\pi f$ = 2π x (1200/60) = 125.7 = 126 rad s^{-1} **Examiner's comments:** Nearly all candidates answered this question correctly. Whilst most could recall $\omega = 2\pi / T$, some candidates were unable to calculate the period, leading to an incorrect value for the angular speed.	
3	**a**	**ii**	**Essential Question(s):** • What is required to maintain circular motion? **Solution:** Draw the free body diagram of the Towel at the Bottom of the circular motion.	

The **upward resultant force of** the normal contact force exerted by the drum (F) and the towel's weight (mg) provide the centripetal force (F_c) required:
$F - mg = F_c$

$F - mg = mr\omega^2$
$F - (1.20)(9.81) = (1.20)(0.230)(125.664)^2$
$F = 4370.2 = 4370$ N

Examiner's comments:
A majority of candidates answered this question correctly. The most common error was to omit the weight of the towel from the calculation, although some subtracted the weight rather than adding it. Whilst the effect of the weight is relatively small, it is still significant.

3 a iii

Key words:

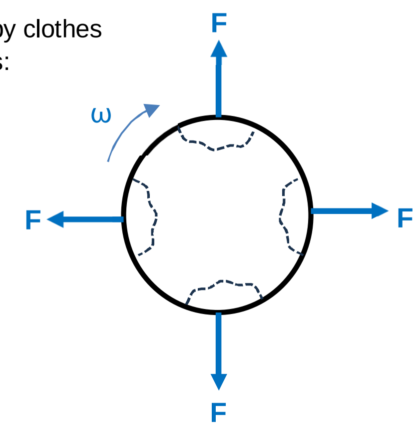
- With reference to vibrations
- and to your answer in (a)(ii)
- why ….very large masses placed at their base

Essential Question(s):

- Why will the machine vibrate?
- What is the significance of the answer in (a)(i) in relation to vibrations of the machine?

Solution:
By Newton's 3rd law, F in (a)(ii) is also th magnitude of the force exerted by the clothes on the drum. Since weight of the clothes is much smaller in magnitude than F, the centripetal force required F_c is approximately equal to F throughout the drum's spin. As the clothes spins with the drum, the direction of F varies as shown on the diagram below, and since magnitude of F calculated in (a)(ii) is quite large, it can cause the machine to vibrate and topple over.

Variation of force by clothes on drum as it spins:



During drying process, the drum spins at a very high frequency.
The large mass increases the total mass of the whole washing machine. The washing machine is undergoing forced vibration due to the vibration of the drum containing the clothes. The large mass reduces the natural frequency of vibration of the washing machine ($f = 1/2\pi \sqrt{k/m}$).
This ensures that the drum is spinning at a frequency much greater compared to the natural frequency of the washing machine and the amplitude of vibration of the washing machine is greatly reduced.

The mass is placed at the bottom to lower the centre of gravity of the washing machine so that the centre of gravity if nearer to the base. This will prevent the machine from toppling over when it vibrates.

Examiner's comments:

			Candidates found this question challenging. Most realised that the force would be large, but many wrote vague comments about vibrations. The majority stated that the large masses gave a lower centre of gravity which made the machine more stable without making any appropriate reference to vibrations.	
3	b		**Essential Question(s):** • When will an object leave the circular path? **Solution:** At the holes, there is no normal contact force exerted by the drum on the water molecules to provide for the centripetal force required to keep the water molecules in circular motion. Thus the water molecules move to a larger radius of curvature and leaves via the holes almost tangentially to the circular path. **Examiner's comments:** Only the stronger candidates answered this question correctly. There were frequent references to centrifugal force indicating a misunderstanding of circular motion. A number commented that due to Newton's third law the water experienced a contact force from the drum and the drum experienced a reaction force from the water, but then added the incorrect conclusion that at the holes the contact force disappeared, but the reaction force remained and forced the water out of the holes. There were many candidates who thought that the force on the towel squeezed the water out of the holes. The weight of the water was often mentioned, but given the size of the centripetal force acting, this was not relevant to the situation.	
4	a		**Essential Question(s):** **Solution:** There is a point at x = 0.68 m where the potential gradient is zero, showing that there is a point where electric field strength equals zero between A and B. This can only happen when A and B are of same sign. The charge on A (and B) is positive because the potential is positive for all values of x. OR The potential at P is the algebraic sum of the potentials due to A and B. A and B have the same sign because the potential at P decreases as x increases and then increases when P approaches the surface of B. If they have the opposite signs, as x increases, the potential at P will decrease continuously as P approaches the surface of B. The charge on A (and B) is positive because the potential is positive for all values of x. **Examiner's comments:** The majority of candidates answered correctly. Stronger responses recognised either that there is a point where the potential gradient is zero or that the potential is always positive. Some candidates appeared to understand that the change in gradient was important but did not manage to convey how this would lead to a conclusion that the charges were of the same sign. An explanation such as 'electric potential becomes more positive when P moves towards either sphere' is not correct as the potential becomes less positive as P moves towards B up to 0.68 m. Saying that the spheres had the same charge, rather than the same sign, was also a common error.	
4	b		**Essential Question(s):**	

Solution:
Electric field strength $E = -\,dV/dx$

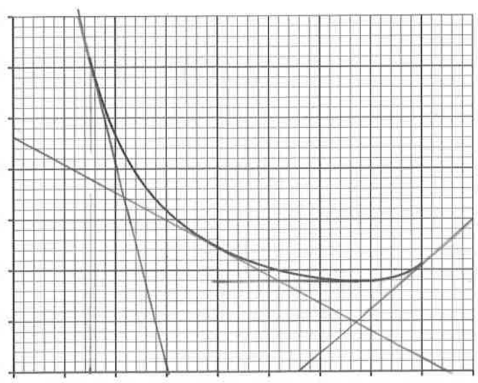
At x = 0.15 m,
dV/dx = gradient of V-x graph = (600 – 0)/(0.15 – 0.30) = - 4000 V m^{-1}
E = 4000 V m^{-1}

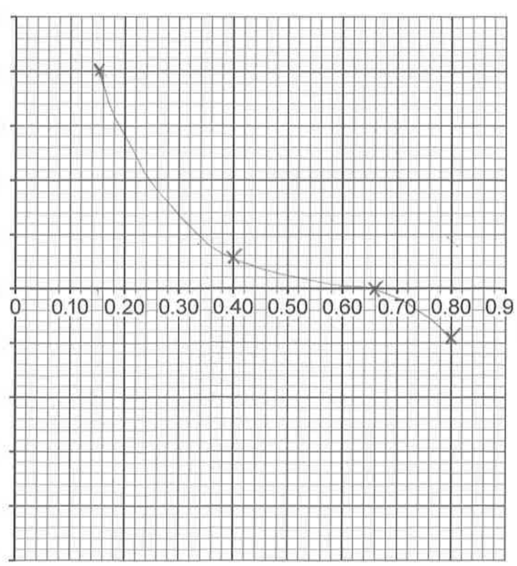
At x = 0.40 m,
dV/dx = gradient of V-x graph = (450 – 0)/(0-0.85) = - 530 V m^{-1}
E = 530 V m^{-1}

At x = 0.66 m,
dV/dx = gradient of V-x graph = 0 V m^{-1}
E = 0 V m^{-1}

At x = 0.80 m,
dV/dx = gradient of V-x graph = (0 - 300)/(0.56-0.90) = 880 V m^{-1}
E = -880 V m^{-1}

At x = 0.40 m,
dV/dx = gradient of V-x graph = (450 – 0)/(0-0.85) = - 530 V m^{-1}
E = 530 V m^{-1}

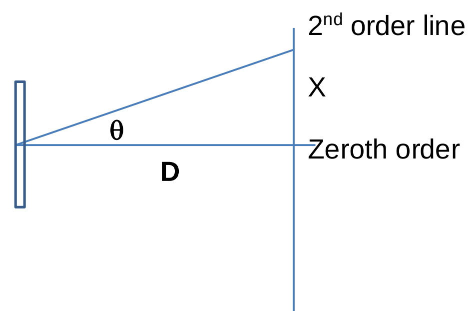


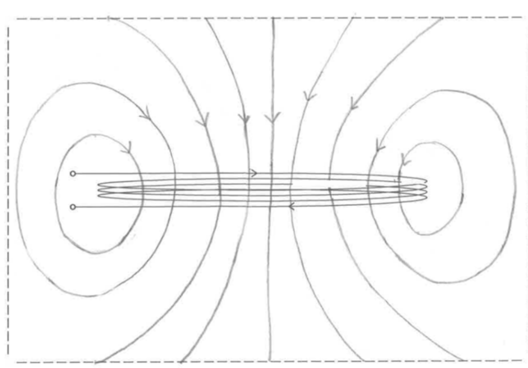


Examiner's comments:
The vast majority of candidates realised that the field strength is the negative of the gradient of the potential graph and used Fig. 4.2 to determine some relevant values. Some included straight-line sections in their curve. A minority started or

			ended the line at the wrong value of x – some showing a field inside the sphere. A number started with a negative value of E at 0.15 m and ended with a positive value at 0.80 m. A small minority drew a curve that did not cross the x-axis at all.	
4	**c**	**i**	**Essential Question(s):** **Solution:** Electric potential at the surface of sphere A $V = Q/4\pi\varepsilon_o r$ = 1.0 x 10^{-8} / 4πx 8.85 x 10^{-11} x 0.15 = 599.4 = 600 V (2 .s.f) **Examiner's comments:** This was answered correctly by most candidates.	
4	**c**	**ii**	**Essential Question(s):** **Solution:** The potential on the surface of A is the algebraic sum (resultant) of the potential due to A itself (= 600 V) and the potential due to B (which is positive). Hence the potential on the surface of A is higher than 600 V on Fig. 4.2. **Examiner's comments:** Many of the candidates answered this question correctly. Some candidates wrote that because sphere A is not a point charge, the charge would not be evenly distributed over the sphere. This was the most common incorrect answer. Some candidates only realised that the potential was different because of the presence of sphere B.	
5	**a**		**Essential Question(s):** **Solution:** Before the switch is closed, the reading on the voltmeter is zero. When the switch is closed for a short time, there is a non-zero reading on the voltmeter for a short period of time and then the reading returns to zero. When the switch is re-opened, the reading becomes non-zero again but is now of opposite sign compared to that when it was closed. After a short period of time, the reading returns to zero. **Examiner's comments:** The majority of candidates answered this completely. Most candidates realised that the voltmeter would give a reading when the switch is closed, but many missed the point that the reading would return to zero after a short time. Some realised that the voltmeter reading would be opposite when the switch is re-opened. The most common incorrect answer was to state that the reading would be positive when the switch was closed and return to zero when it was re-opened.	
5	**b**		**Essential Question(s):** **Solution:** When the switch is closed or opened, the current in the primary coil increases or decreases respectively, causing the magnetic flux density in the primary coil to increase or decrease respectively. The changing magnetic field produced by the primary current is linked via the core to the secondary coil. The secondary coil thus experiences an increasing or decreasing magnetic flux linkage respectively. By Faraday's Law, this causes an e.m.f. to be induced in the secondary coil of magnitude equal to its rate of change of magnetic flux linkage. The induced e.m.f. is detected by the voltmeter.	

			But after a short period of time, as the current in the primary coil reaches a steady constant value, rate of change of magnetic flux linkage becomes zero and thus induced e.m.f. becomes zero and so voltmeter reading returns to zero. By Lenz's Law, the direction of the induced e.m.f. in the secondary coil will be such as to oppose the change in magnetic flux linkage, hence the direction of the induced e.m.f. for the timeframe when flux linkage increases is opposite that when flux linkage decreases, causing the voltmeter reading to be of opposite signs. **Examiner's comments:** Many candidates answered this completely. There was occasionally confusion over the state of the switch – when a switch is open, the circuit is not complete and closing it completes the circuit. Quite a few candidates stated that 'the induced e.m.f. is proportional to the change (in magnetic flux linkage)' rather than the rate of change. A minority of candidates mentioned the core and of those only a few managed to describe the current in the primary coil causing a field in the core. A number wrote that a current flows from the primary coil through the core. Several wrote about the transformer rather than the core and some thought that closing and opening the switch gave an alternating current. Whilst most realised that a change in flux would induce an e.m.f., some candidates did not make it clear the relevant change was in the secondary coil. Some thought that a current in the secondary coil induced an e.m.f. A minority realised that a constant current would lead to no change in flux and hence no e.m.f. Whilst many referred to a decreasing change in flux when the switch re-opened, a minority mentioned that this would give an opposite e.m.f. to the original. A significant number included Lenz's law in their answers, not realising that there is no current in the secondary coil as the coil is connected to a voltmeter.	
6	**a**		**Essential Question(s):** **Solution:** At 20^{o}C, R = 60 Ω Assume that the voltmeter has an infinite resistance. Using potential divider formula, p.d. across the fixed resistor = 1.50 (R_{fix} / (R_{fix} + R)) 0.43 = 1.50 (R_{fix} / (R_{fix} + 60)) R_{fix} = 24.11= 24 Ω **Examiner's comments:** Most used an appropriate expression linking the resistance across the fixed resistor with relevant values, but some did not show appropriate working to arrive at 24 Ω.	
6	**b**		**Essential Question(s):** **Solution:** At 32 ^{o}C, R = 40 Ω Current in R = 1.5 / 40 = 0.0375 A Current in R_{fix} = 1.5 / 24 = 0.0625 A Current in cell = Current in R + Current in R_{fix} = 0.0375 + 0.0625 = 0.10 A Assume that the voltmeter has an infinite resistance.	

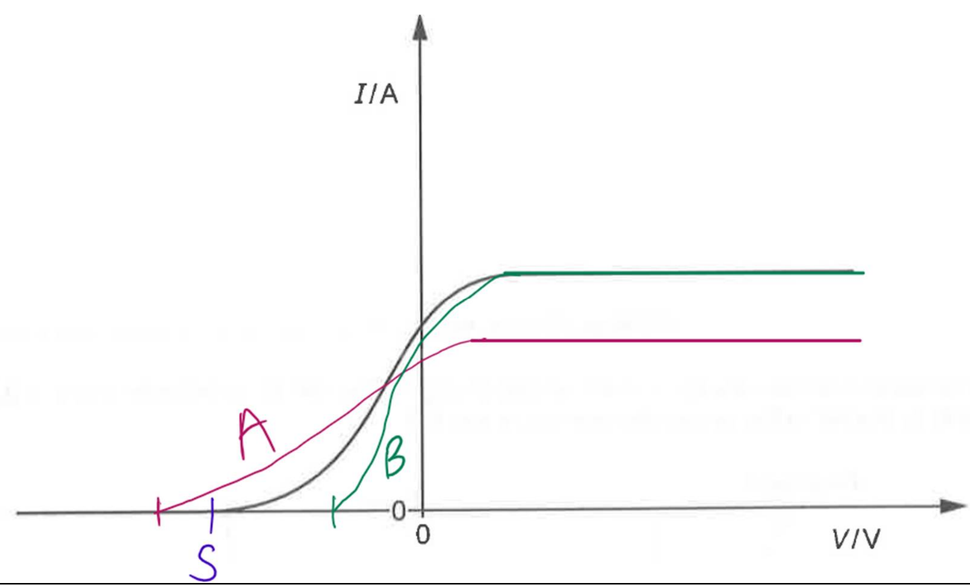
			Examiner's comments: A few misread the value of R from the graph (48 Ω rather than 40 Ω). A very small minority calculated values for resistors in series.	
7	a		**Essential Question(s):** **Solution:** Coherent waves have a constant phase difference with one another. **Examiner's comments:** The majority of candidates answered this question correctly. The most common incorrect response was 'no phase difference'. Whilst this is an example of coherence, it is not a full description. Some mentioned wavelengths, frequencies, or amplitudes without any reference to phase.	
7	b		**Essential Question(s):** **Solution:** d = 1/ N = (1/300,000) m Using d sinθ = nλ (1/300000) sinθ = 2 x 640 x 10^{-9} sin θ = 0.384 θ = 22.58 ^{o} tan θ = x / D tan 22.58 = x / 2.1 x = 0.873 = 0.87 m = 87 cm  **Examiner's comments:** The majority of candidates answered this question correctly. Nearly all recalled nλ = d sinθ although a number wrote λ = ax / D, which is not correct in this context. Most calculated the correct value of d and substituted correctly in the expression although a minority thought that d = 300 000 m. A significant number thought that sinθ ~ tanθ which is only true for small angles. Some thought the angle they had to calculate was between the first and second order.	
8	a	i	**Essential Question(s):** **Solution:** The electric field strength at a point is the electric force per unit positive charge at that point. **Examiner's comments:** The majority of candidates answered this correctly. Stronger responses stated clearly that it is the ratio of force to charge by using a phrase such as 'the force per unit positive charge'. Other errors included writing potential rather than force and writing mass rather than charge.	
8	a	ii	**Essential Question(s):** **Solution:** Electrons have very small mass compared to the air particles and would be easily deflected when they collide with the air particles. It will result in fewer electrons successfully exiting the gun. **Examiner's comments:** Many candidates answered this correctly. Few commented that this would affect the number of electrons (or the speed of the electrons) reaching the anode.	
8	a	iii	**Essential Question(s):**	

			Solution: Applying conservation of energy for <u>each</u> electron moving between the cathode and anode, Gain in the kinetic energy = Loss in electric potential energy (or Work done on each electron by the electric field) Gain in the kinetic energy = $e.\Delta V$ $2.48 \times 10^{-16} = (1.60 \times 10^{-19}).\Delta V$ $\Delta V = 1550$ V **Examiner's comments:** The majority of candidates answered this correctly. A few either rounded their value to two significant figures or made an arithmetic error in the calculation.	
8	a	iv	**Essential Question(s):** **Solution:** Electrons emitted from the cathode have a **range of <u>initial</u> kinetic energy (KE)**. Since the **<u>increase in</u> the KE** (= final KE – initial KE) **for <u>all</u> these electrons is the <u>same</u>**, there is a **range of the <u>final</u> KE** of the electrons. Since KE = ½ x mass x speed^2 and mass of electron is constant, hence there is a range of speeds. **Examiner's comments:** This question proved challenging. Many realised that the electrons emerging from the cathode would have different kinetic energies, but some attributed this to collisions between electrons leaving the cathode.	
8	b	i	**Essential Question(s):** **Solution:** $B = \mu_o N\ I / 2r$ $= 4\pi \times 10^{-7} \times 120 \times 3.5 / 2 \times 0.15$ $= 0.001759$ $= 1.8 \times 10^{-3}$ T **Examiner's comments:** Most candidates correctly calculated the magnetic flux density. A minority used the diameter rather than the radius in the denominator.	
8	b	ii	**Essential Question(s):** **Solution:**  Note: Current in coil is flowing clockwise from the top view. Use Right Hand Grip Rule to determine the direction of the field lines. **Examiner's comments:**	

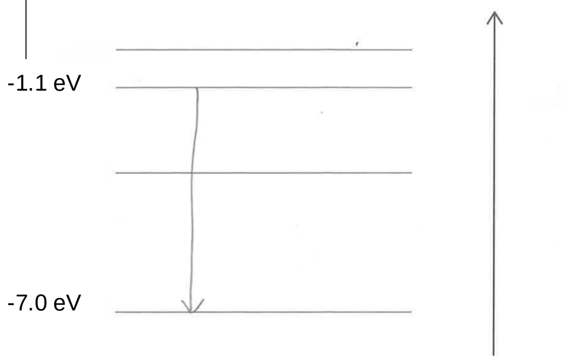
			Most candidates drew at least five lines with consistent directions of arrows. The majority drew a straight line in the centre. A small number incorrectly drew lines converging at the centre and touching. Some candidates incorrectly drew three or more parallel straight lines whilst others drew arcs of the same radius. Whilst most drew lines symmetrical about the centre, a significant number drew their lines bunched together so that they occupied less than half of the coil.	
8	**c**	**i**	**Essential Question(s):** • What is required for circular motion? → Centripetal force • What force provides for the centripetal force here? → Magnetic force • How does Magnetic force here? • Why does centripetal force result in motion along a circular path? **Solution:** Electrons are **charged** particles, and **when they move perpendicular to the uniform magnetic field**, they experience a **magnetic force (F_B) that is <u>always</u> acting perpendicular to both the magnetic field and the electron's velocity (v)**. Thus **F_B continuously changes the direction of v but not the magnitude of v, deflecting the electron along a circular path**. And **since the magnitude of v is unchanged, F_B is constant in magnitude, and hence radius of the circular path is also unchanged**. Thus the electron moves in a **circular path of constant radius**. **Examiner's comments:** Stronger responses stated that the force is always perpendicular to the velocity of the electron.	
8	**c**	**ii**	**Essential Question(s):** **Solution:** Let B_2 be the magnetic flux density created by 2 coils, i.e. $B_2 = 1.43B$. The magnetic force provides for the centripetal force. $B_2qv = mv^2/r$ $r = mv / B_2q$ $= mv / (1.43B)q$ $= (9.11 \times 10^{-31} \times 2.40 \times 10^7) / (1.43 \times 0.001759 \times 1.60 \times 10^{-19})$ $= 0.05432$ $= 0.0543$ m **Examiner's comments:** The majority of candidates correctly calculated the radius of the circle. The most common error was to miss out the magnetic field strength or to forget to multiply the magnetic field strength by 1.43.	

8	**d**		**Essential Question(s):**
			
			Solution:
			Electron now has velocity components perpendicular to the magnetic field ($v_\perp$) as well as parallel to the magnetic field ($v_{//}$).
			
			$v_\perp$ causes the electron to deflect in a circular motion in the plane perpendicular to the magnetic field.
			$v_{//}$ causes the electron to translate parallel to the magnetic field at a uniform rate.
			
			These two motions occur simultaneously and the combined effect is a helical path of constant radius and constant pitch.	

			Examiner's comments: Candidates found this descriptive answer challenging. Most mentioned components of velocity but many described them in terms of horizontal and vertical components rather than in terms of their angle to the magnetic field. Of those who did realise that the components of the velocity were important, a significant number said that there was a force acting on the electron parallel to the field which is why it moved in that direction.	
9	**a**		**Essential Question(s):** **Solution:** 1. In the particulate nature of electromagnetic radiation, energy of the radiation exists in discrete units called photons. The energy of a photon is equal to hf, where f is the frequency of the radiation. At constant frequency, the energy of the photons is fixed. The particulate nature of light also implies that each photon interacts with an electron in the metal on a one-to-one basis, meaning that no more than one photon can transfer its energy to a single electron in the metal. Hence by conservation of energy, (maximum kinetic energy of ejected electron) = (photon energy) – (work function energy). Since the work function energy and the photon energy are held constant, the maximum kinetic energy is constant regardless of the intensity of the incident radiation. A higher intensity beam of light contains more photons but the maximum kinetic energy of the emitted electrons from the metal surface depends on the energy of each individual photon and not the cumulative energy of multiple photons. This observation does not support the wave nature as classical wave theory suggests that since the intensity of a wave is the power of the wave per unit area normal to the direction of energy transfer, a higher intensity beam of light has more energy hence it will impart more kinetic energy to the photoelectrons, but this is not observed in reality. 2. Below a certain frequency, the energy of the photon is lower than the work function energy of the zinc plate and there is not enough energy to liberate an electron from the metal surface, since each electron in the metal can only absorb one photon. Photon energy is not cumulative so no electrons can be emitted below this threshold frequency. Hence there is no emission of electrons regardless of the intensity, according to the particulate nature of radiation. For photoelectric emission, Minimum photon energy = Work function energy of the metal surface $\Rightarrow$ h x (Threshold frequency) = (Work function energy) $\Rightarrow$ (Threshold frequency) = (Work function energy) / h This observation does not support the wave nature as classical wave theory suggests that regardless of the frequency and regardless of whether the intensity is high or low, an electron in the metal can accumulate sufficient energy over time to overcome the work function energy of the metal and be liberated. However, this is not observed in reality. **Examiner's comments:** Many candidates answered this completely. A number of candidates gave phrases which appeared in the question as explanations such as, 'The maximum kinetic energy of the emitted photoelectrons is independent of the intensity of the incident radiation'. Many candidates gave clear explanations of either why the observations support particulate nature or why they did not support wave nature, but few managed to cover both. Many referred to the maximum kinetic energy being dependent on the frequency of the radiation without relating the frequency to the energy of a photon. A number wrote the formula KEmax = hf – φ without explaining that the term hf is the energy of the incoming photon. Many merely commented that the energy of the photons depends on the frequency. Many	

			pointed out that according to wave nature, given enough time photoelectrons would be emitted, but did not make any reference to any intensity or any frequency. Some thought that the intensity had to be high to emit photons, according to wave nature.	
9	b		**Essential Question(s):** **Solution:** Threshold frequency **Examiner's comments:** The majority of candidates answered this correctly.	
9	c		**Essential Question(s):** **Solution:** Maximum KE = photon energy - work function energy $= hc/\lambda - \phi$ $= (6.63 \times 10^{-34} \times 3.0 \times 10^{8}) / 210 \times 10^{-9} - 4.33 \times 10^{-16}$ $= 2.543 \times 10^{-19}$ $= 2.54 \times 10^{-19}$ J **Examiner's comments:** The majority of candidates answered this correctly. There were occasional calculation errors.	
9	d		**Essential Question(s):** **Solution:** Let V_s be the stopping potential. eV_s = maximum KE V_s = maximum KE /e $= 2.543 \times 10^{-19} / 1.6 \times 10^{-19}$ = 1.590 = 1.59 V **Examiner's comments:** The majority of candidates answered this correctly.	
9	e	i	**Essential Question(s):** **Solution:** S is the point when I = 0  	

			Examiner's comments: The majority of candidates answered this correctly.	
9	**e**	**ii**	**Essential Question(s):** **Solution:** Shorter wavelength ➔ photon energy larger (photon energy = hc/λ) ➔ maximum KE is larger (Maximum KE = photon energy - work function energy) ➔ stopping potential is larger. (V_s = maximum KE /e) Intensity = number of photons incident per unit time per unit area x photon energy = number of photons incident per unit time x hc/λ / area Shorter wavelength but same intensity ➔ number of photons incident per unit time is reduced ➔ number of electrons emitted per unit time is lower ➔ saturation current is lower **Examiner's comments:** The majority of candidates correctly started the line to the left of the original, but fewer candidates realised that a higher frequency at the same intensity would mean fewer photons and hence a lower current.	
9	**e**	**iii**	**Essential Question(s):** **Solution:** same wavelength ➔ same photon energy (photon energy = h c / λ) Larger work function and same photon energy (photon energy = h c / λ) ➔ smaller maximum KE is larger (maximum KE = photon energy - work function energy) ➔ smaller maximum KE ➔ smaller stopping potential (V_s = maximum KE /e) Same wavelength and same intensity ➔ number of photons incident per unit time per unit area is unchanged (Intensity = number of photons incident per unit time x hc/λ / area) ➔ number of electrons emitted per unit time is unchanged. ➔ saturation current is unchanged. **Examiner's comments:** Most candidates realised that the line would start to the right of the original.	
9	**e**	**iv**	**Essential Question(s):** **Solution:** **For values of V equal to or more negative than the stopping potential**, the **maximum KE of the photoelectrons** is **less than the energy required to do work against the electric field produced by the retarding potential difference V**. **All** the electrons would lose **all** their KE **before reaching** the electrode. Hence **all** of the photoelectrons **reverse direction of velocity before reaching** the electrode, and therefore the current is zero. **Examiner's comments:** Many did not explain clearly that the values of V had to be greater than or equal in magnitude to the stopping potential. A significant number of candidates thought	

			that at values greater than or equal to the stopping potential there would be no emission of photoelectrons, which is incorrect physics.	
9	**f**	**i**	**Essential Question(s):** **Solution:**  Explanation Photon energy in (c) $= hc/\lambda$ $= (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / 210 \times 10^{-9}$ $= 9.471 \times 10^{-19}$ J $= 9.471 \times 10^{-19} / 1.60 \times 10^{-19}$ eV = 5.92 eV The difference in energy value between two level = 5.92 eV By inspection, transition from -1.1 eV to -7.0 eV gives energy release of 5.92 eV **Examiner's comments:** Most candidates correctly drew a line between −1.1 eV and −7.0 eV, although lines between all levels were seen and occasionally candidates drew several lines. A few candidates drew a line with an arrow pointing up – indicating absorption of a photon rather than emission.	
9	**f**	**ii**	**Essential Question(s):** **Solution:** Photon of longest wavelength ➔ lowest frequency ($f = c/\lambda$) ➔ lowest photon energy (photon energy = hf) ➔ smallest transition energy ➔ from -0.4 eV to – 1.1 eV Energy of photon emitted = (-0.4) –(-1.1) = 0.7 eV $hc/\lambda = 0.7$ eV $(6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / \lambda = 0.7 \times 1.60 \times 10^{-19}$ $\lambda = 1.78 \times 10^{-6}$ m **Examiner's comments:** The majority of candidates answered this correctly. Some candidates did not give an explanation or gave an incomplete explanation despite the instruction 'Explain your working.'	