H2 Physics 9749 – 2021 A Level Exam

Paper 1

1	**Essential Question(s):** • What is the relationship between weight and mass? • What are the values of 1 cN and 1 dN in N? **Solution:** mass of a smartphone = 200 g weight = mg = 0.2 x 10 = 2 N = 200 x 10^{-2} N = 200 cN **Answer: C**
2	**Essential Question(s):** • What is the definition of the tesla? **Solution:** From F = BIL, B = F / I L 1 T = 1 N / 1 A x 1 m = 1 kg m s^{-2} / A m = 1 kg s^{-2} A^{-1} **Answer: A**
3	**Essential Question(s):** • What are the forces acting on the ball? **Solution:** forces are: weight acting downwards drag force acting to the left (opposite to velocity) Resultant force = vector sum of drag force and weight **Answer: B**
4	**Essential Question(s):** • What can you conclude about the velocity of the bodies undergo an elastic collision? **Solution:** for elastic collision, relative velocity of approach = relative velocity of separation Take vectors to the right as positive. v – 0 = 0.67v – final velocity of x final velocity of x = -0.33 v speed = 0.33 v **Answer: B**
5	**Essential Question(s):** • What is the Newton's third law of motion?

	Solution: W = force on brick by earth reaction of W = force on Earth by brick S = force on brick by floor reaction of S = force on floor by brick **Answer: A**
6	**Essential Question(s):** • How is the apparent loss in weight related to upthrust? **Solution:** apparent loss in weight = upthrust = $V\rho g$ $100(9.81) - 100(9.81) \times 0.75 = V(1000)(9.81)$ $V = 25 \times 10^{-6}$ m^3 (This is the volume of fluid displaced) volume of ball = 2V = $2 \times 25 \times 10^{-6} = 50 \times 10^{-6}$ m^3 = 50 cm^3 **Answer: B**
7	**Essential Question(s):** • How do we determine the elastic energy stored from extension-force graph? **Solution:** Elastic energy stored = area under force-extension graph = area bounded by the graph and VERTICAL axis in this case Initial elastic energy stored = $\frac{1}{2} X_0 W_o$ Final elastic energy stored = $\frac{1}{2} X_1 W_1$ Extra elastic energy stored = $\frac{1}{2} (X_1 W_1 - X_0 W_o)$ **Answer: D**
8	**Essential Question(s):** • What is the work done against a resistive force **Solution:** Constant speed → no energy is consumed to convert into KE Level road → no energy is consumed to convert into GPE WD against resistive force = resistive force x distance = 400 x 1000 = 400000 J Efficiency = energy output / energy input energy input = energy output / efficiency = 400000/ 0.16 = 250000 J amount of fuel used = $2500000 / 48 \times 10^6 = 0.052$ kg = 52 g **Answer: A**

9	**Essential Question(s):** • What is the relation between tangential speed and angular velocity of a circular motion? **Solution:** angular speed ω = v / r = Be / m since r = mv / Be ω will increase when B is increased while e and m are unchanged **Answer: A**
10	**Essential Question(s):** • What is the relation between gravitational field strength and potential difference **Solution:** change in in potential per unit change in height = *6 / 10* *let ΔV be the change in potential for a change in height of 2.5 m* change in in potential per unit change in height = *ΔV / 2.5* Since gravitational field is constant uniform, change in potential per unit change in height is constant *6/10 = ΔV / 2.5* *ΔV = 1.5* *work done to bring 2 kg of mass up 2.5 m* *= m ΔV = 2 x 1.5 = 3.0 J* **Answer: B**
11	**Essential Question(s):** • What is the period of a geostationary satellite? **Solution:** v = rω= r (2π/T) = (36000000+6400000) (2π/ 24x60x60) = 3100 m s^{-1} **Answer: D**
12	**Essential Question(s):** • What is the relation between rms speed and any other properties of a gas? **Solution:** $$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle = \frac{1}{3}\frac{(Total\ mass)}{V}\langle c^2\rangle = \frac{1}{3}\frac{(no.of\ moles\ x\ molar\ mass)}{V}\langle c^2\rangle$$ $$1.0\ x\ 10^5 = \frac{1}{3}\left(\frac{5000\ x\ 0.029}{10\ x\ 3.0\ x\ 4.0}\right)\langle c^2\rangle$$ $$r.m.s.speed = \sqrt{\langle c^2\rangle} = 498 = 500\ m\ s^{-1}$$ **Answer: C**
13	**Essential Question(s):** o What is meant by specific latent heat and specific heat capacity? **Solution:**

	Q = heat to raise temp to 100 + heat to convert water to steam = $mc\Delta\theta + mL$ = 5 x 4190 x (100-30) + 5 x 2260 = 1.28×10^7 J **Answer: D**
14	**Essential Question(s):** • What is the internal energy of an ideal gas? **Solution:** Given Q = 0 and W = 0, thus $\Delta U = 0$. So no change in internal energy; internal energy remains at the initial value of 3.0 kJ. Recall also that internal energy is equal to the sum of the KE and PE associated with the microscopic **molecules** of the gas, and independent of the bulk changes in KE and PE of the system as a whole. **Answer: B**
15	**Essential Question(s):** • How to relate PE to KE of a SHM **Solution:** At t = 0, and t = 2 s, PE is max, KE is zero, v = 0 At t = 1 s, PE = 0, KE is max, v is max **Answer: C**
16	**Essential Question(s):** • How is determine phase difference from path difference? **Solution:** $$\frac{\Delta\varphi}{2\pi} = \frac{\Delta x}{\lambda} = \frac{\Delta x}{\left(c/f\right)}$$ $$\frac{\Delta\varphi}{2\pi} = \frac{1.5 \times 10^{-6}}{3.00 \times 10^{8}/5.0 \times 10^{14}}$$ $$\Delta\varphi = 1.0\,\pi\,rad$$ **Answer: D**
17	**Essential Question(s):** • How does the direction of polarization and intensity change with angle of between polarization axle of polarizing filter and the direction of polarization of incident light? **Solution:** At 45° After first polarizing filter Intensity = $I_o \cos^2 45$ = $I_o \cos^2 45$ = $I_o/2$ direction of polarisation: 45 degree to vertical After second polarizing filter Intensity = $(I_o / 2) \cos^2 45$ = $I_o/4$ when direction of polarisation: vertical At 90° After first polarizing filter

	Intensity = $I_o \cos^2 90 = 0$ direction of polarisation: NA After second polarizing filter Intensity = 0 direction of polarisation: NA At 135^o After first polarizing filter Intensity = $I_o \cos^2(135 - 90) = I_o \cos^2 45 = I_o /2$ direction of polarisation: 45 degree to vertical After second polarizing filter Intensity = $(I_o / 2) \cos^2 45 = I_o /4$ when direction of polarisation: vertical At any angle θ less than 90 After first polarizing filter Intensity = $I_o \cos^2(\theta) = I_o \cos^2\theta$ direction of polarisation: θ degree to vertical After second polarizing filter Intensity = $(I_o \cos^2\theta) \cos^2(90-\theta)$ Intensity = $(I_o \cos^2\theta) (\sin^2\theta) = I_o (1 - \cos 2\theta)/2$ direction of polarisation: $(90 - \theta)$ degree to vertical **Answer: B**
18	**Essential Question(s):** • What is the Rayleigh's criteria for resolving two point sources through a circular aperture? **Solution:** Rayleigh's criteria $\theta_{min} \approx \lambda/b = 620 \times 10^{-9} / 0.50 = 1240 \times 10^{-9}$ rad Distance between two stars, $D \approx L/\theta$ To <u>just</u> resolve the two stars, $\theta = \theta_{min}$ $D \approx L/\theta_{min}$ $= 5.7 \times 10^{18} \times 1240 \times 10^{-9}$ $= 7.1 \times 10^{10}$m **Answer: D**
19	**Essential Question(s):** • How to determine the direction of electric force on a charged particle placed in an electric field? **Solution:** Definition of electric field strength **Answer: D**
20	**Essential Question(s):** • What is the Coulomb's law on the force between two charged particles?

	Solution: $F_1 = Q_1 Q_2 / 4\pi\varepsilon r^2 = 2$ N $F_2 = Q_3 Q_2 / 4\pi\varepsilon (2r)^2 = 2Q_1 Q_2 / 4\pi\varepsilon (2r)^2 = \{Q_1 Q_2 /(4\pi\varepsilon r)\}/2 = 2/2 = 1$ N **Answer: C**
21	**Essential Question(s):** • How to determine the resistance of a uniform wire given its length, cross-section area and resistivity? • For components in parallel, how to determine their effective resistance? **Solution:** *gradient of graph G = resistance per unit length* *Each wire* *R = resistance per unit length x L* *= GL* 4 identical wires <u>in parallel</u> $\frac{1}{R_{eff}} = \frac{1}{GL} + \frac{1}{GL} + \frac{1}{GL} + \frac{1}{GL}$ R_{eff} = ¼ (GL) **Answer: B**
22	**Essential Question(s):** 1. what is the same in a series circuit of two components? **Solution:** Current is the same sum of p.d. across the two components = 3.0 V By inspecting the graphs, when **I** = 0.1 A , V = 1.0 + 2.0 = 3.0 V **Answer: A**
23	**Essential Question(s):** • What determines the brightness of a bulb in a circuit? **Solution:** *Brightness is determined by the <u>power</u> dissipated in a bulb = $I^2 R$ or V^2 / R* Assume the resistance of the bulb is unchanged, power is increased by increasing the current in the bulb or increasing the p.d. across the bulb.. To increase the current in the bulb (or increase the p.d. across the bulb), (1) decrease the resistance of the LDR by **increasing** the intensity of light incident on it (2) increase the resistance of the thermistor by decreasing **its** temperature **Answer: C**
24	**Essential Question(s):** • How to apply Fleming's left hand rule? **Solution:**

By right hand grip rule, magnetic field inside the coil due to current I_1 acts into the paper
By Fleming's left hand rule, the *force on I_2 is upwards along the page*

Answer: A

25 **Essential Question(s):**

- Define magnetic flux

Solution:
magnetic flux $\phi = BA$
unit of $\phi = [B][A] = Tm^2$

Answer: D

26 **Essential Question(s):**

- State Faraday's law

Solution:

$$instantaneous, |E| = \left|\frac{d\Phi}{dt}\right|$$

$$average, \quad \langle E\rangle = \left|\frac{\Phi_f - \Phi_i}{\Delta t}\right| = \left|\frac{0 - NBA}{\Delta t}\right| = \left|\frac{0-(3000)(1.8)(\pi\frac{0.020^2}{4})}{0.060}\right| = 28\,V$$

Answer: A

27 **Essential Question(s):**

- What is an ideal transformer?

Solution:
For an ideal transformer,
input power = output power
$I_pV_p = I_SV_S$
$I_S = I_pV_p / V_S$
$= I_p / (V_S / V_p)$
$= I_p$ / gradient of V_s vs V_p graph
= 0.32 x 17 / 2.0 = 0.038 A

Answer: B

28 **Essential Question(s):**

- What is the relationship between the wavelength of the photon emitted during a transition from a higher energy state to a lower energy state?

Solution:

from n = 2 to n = 1
energy of an emitted photon
$E = E_2 - E_1 = hf = hc / \lambda_1 = hc / (440\ nm)$ …..(1) since $f = c / \lambda$

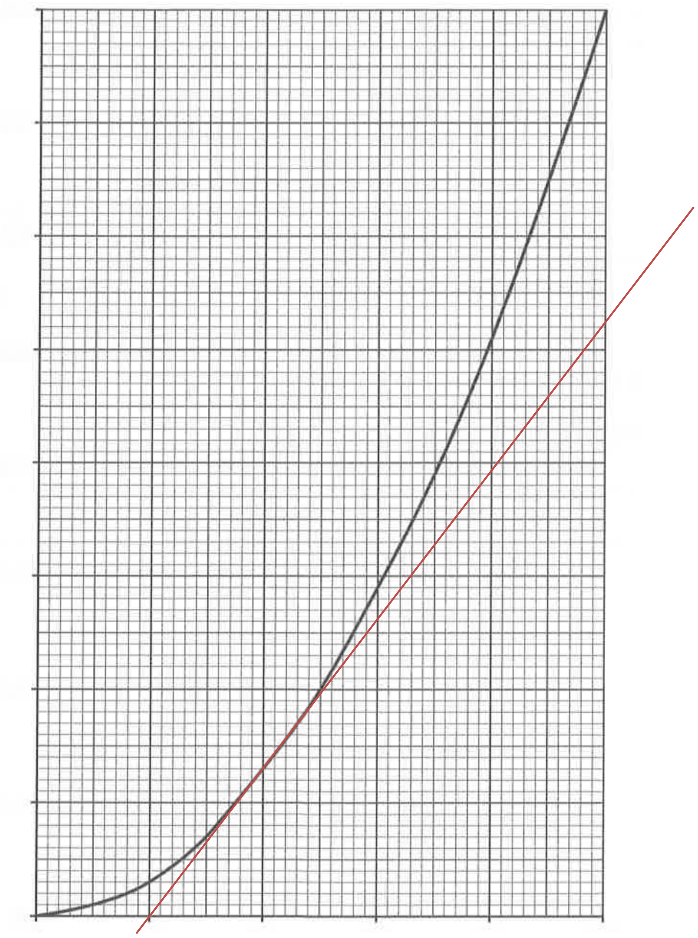
590 nm must correspond a smaller energy difference as compare to from n = 2 to n = 1
Hence the transition is from n =3 to n = 2
energy of an emitted photon
$E = E_3 - E_2 = hf = hc / \lambda_2 = hc / (590\ nm)$ ….(2)

third transition is from n = 3 to n = 1
energy of an emitted photon

	$E = E_3 - E_1 = hc / \lambda_3$ *From (1) and (2)* $E = (E_3 - E_2) + E_2 - E_1$ $= hc / (590\ nm) + hc / (440\ nm)$ $hc / \lambda_3 = hc / (590\ nm) + hc / (440\ nm)$ $1/ \lambda_3 = 1 / (590\ nm) + 1/ (440\ nm)$ $\lambda_3 = 250\ nm$ **Answer: B**
29	**Essential Question(s):** • What factors affect the intensity of light in in quantum theory of physics **Solution:** intensity = number of photons per unit time x energy of one photon / cross section area of beam = number of photons per unit time per unit area x energy of one photon If the beam has the same frequency the energy of one photon is the same, option A is not correct Hence answer is D **Answer: D**
30	**Essential Question(s):** • How to determine the energy released in a nuclear reaction, given the mass of the products and the reactants? **Solution:** energy released = (mass of reactants – mass of products) c^2 $= (136.90709 - 136.90583 - 5.49 \times 10^{-4})(3.00 \times 10^8)^2$ $= 1.1 \times 10^{-13}$ J **Answer: B**

Paper 2

1	**a**		**Essential Question(s):** • What affects motion? → Net force • What are the forces acting on the block? Hence what is the magnitude and direction of the net force, if any? **Solution:** The block's <u>speed increases at a constant rate</u>.
1	**b**	**(i)**	**Essential Question(s):** • How to draw the tangent to a curve line accurately? • How is the tangent of the graph related to speed? **Solution:** Draw a tangent that is long enough, i.e. spanning more than half the graph grid. speed at t = 0.20 s

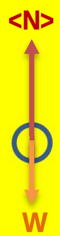
			= magnitude of the gradient of the tangent to the curve at t = 0.20s = (0.51 – 0) / (0.5 – 0.1) = 1.28 = 1.3 m s^{-1} 
1	**b**	**ii**	**Essential Question(s):** • How to use equations of motion to solve problems for a body in constant acceleration? **Solution:** Take direction downslope to be positive direction. using v = u + at 1.28 = 0 + a (0.20) a = 6.4 m s^{-2}
2	**a**		**Essential Question(s):** • How to relate KE to momentum? **Solution:** $KE = ½ m v^2$ $= m^2v^2 / 2m$ $= (mv)^2 / 2m$ $= p^2/2m$ *when ball makes contact with surface, p = 3.2 N s* $KE = p^2/2m$ $= 3.2^2/2(0.62)$ *= 8.26 = 8.3 J*
2	**b**		**Essential Question(s):** • What is the force required? → Normal contact force, N exerted by the ground on the ball.

<table>
<tr>
<td></td>
<td></td>
<td></td>
<td>

- How to determine force from the given information (i.e. p-t graph)? → Apply Newton's 2nd law in the form: $F_{net} = dp / dt$
- How is F_{net} related to N?

Solution:
By Newton's 2nd law of motion,
Average net force = average rate of change of momentum
= |change in momentum| / time taken
= | (-1.8 – 3.2) | / (0.66 – 0.51)
= 33.333 N

Considering the free-body diagram of the ball,



$<F_{net}> = <N> - W$
$33.333 = <N> - (0.62)(9.81)$
$<N> = 39.4 = 39$ N

Examiners' Comments:
The majority of candidates calculated the force required to change the momentum of the ball on contact with the surface. In some responses, an error was made by not taking the direction change into account.

</td>
</tr>
<tr>
<td>2</td>
<td>c</td>
<td></td>
<td>

Essential Question(s):

- What is the percentage of KE lost after each bounce?
- What is the percentage of KE retained by the ball after each bounce?

Solution:
percentage decrease in KE for first bounce
= $(KE_i – KE_f / KE_i)$ x 100%
= $(p_i^2/2m - p_f^2/2m)/(p_i^2/2m)$ x 100%
= $(p_i^2 - p_f^2)/(p_i^2)$ x 100%
= $(1 – (p_f/p_i)^2)$ x 100%
= $(1 – (1.8/3.2)^2)$ x 100%
= 68.36 %

percentage of KE **retained** after first bounce
= 100 – 68.36
= 31.64 % > 5%

percentage of KE **retained** after 2nd bounce
= (0.3164 x 0.3164) x 100 %
= 0.1001 x 100 %
= 10.01 % > 5%

percentage of KE **retained** after 3rd bounce
= (0.3164 x 0.3164 x 0.3164) x 100 %
= 0.03167 x 100 %
= 3.2 % which is less than 5%

Hence number of bounces <u>before</u> KE reduces to less than 5% = <u>3</u>

</td>
</tr>
</table>

			Examiners' Comments: *The majority of candidates were able to calculate the amount of energy that was 5.0% of the original energy. A significant number calculated the energy lost on each bounce instead of the energy retained, which led to the incorrect number of bounces. Determining the number of bounces proved to be challenging for a large number of candidates. Some candidates did not count the first bounce, or rounded the number of bounces down, hence reaching two bounces as an answer.*
3	**a**		**Essential Question(s):** • How to apply principle of moments to solve problems **Solution:** taking moments about Q total clockwise moment = total anticlockwise moment $(F \sin 43°)(\,^2/_3\ PQ\,) = (mg)(\,½\ PQ \cos 58°\,)$ $(F \sin 43°)(^2/_3) = (2.3 \times 9.81)(½ \cos 58°\,)$ $F = 13.149 = 13$ N **Examiners' Comments:** *There were a significant number of correct answers. The main difficulties seen were in resolving forces F and W to obtain the component that was perpendicular to the line PQ or to determine the perpendicular distance of the line of action of the forces from Q.*
3	**b**	**ii**	**Essential Question(s):** • What analysis can you make by consider balance of forces vertically and horizontally? **Solution:** <u>For equilibrium</u>, there should be <u>no net force</u> on the sign. Since <u>only 3 forces act (F, weight and force at Q)</u>, and since <u>weight acts vertically</u>, the <u>force at Q must provide a horizontal force to the left</u> that is <u>equal in magnitude and opposite in direction to the rightward component of F</u>.
4	**a**		**Essential question:** • What is the Newton's law of gravitation? • Define gravitational field strength **Solution:** By Newton's law of gravitation, Gravitational force F on a <u>point</u> mass m at distance r from <u>point</u> mass M $F = GMm/r^2$ Gravitational field strength g at distance r from point mass M is defined as the gravitational force per unit mass on a point mass at that location. So, g at distance r away from $M = F / m$ $= (GMm/r^2)/(m) = GM/r^2$ **Examiner's Comments:** *There were many well-presented derivations of the required expression for g. Some responses did not give Newton's law of gravitation or the definition of g.*
4	**b**		**Essential question:** • What provides the centripetal force on a satellite in orbit? **Solution:** from (a) $g = GM/r^2$

			gravitational force provides the centripetal force on a satellite in orbit $GMm/r^2 = mrw^2$ $r^3 = GM / w^2$ $r = (GM / w^2)^{1/3}$ $= (GM / (2\pi/T)^2)^{1/3}$ $= (6.67 \times 10^{-11} \times 6.0 \times 10^{24} / (2\pi / 110 \times 60)^2)^{1/3}$ $= 7.615 \times 10^6$ m from (a) $g = GM/r^2$ $g = (6.67 \times 10^{-11} \times 6.0 \times 10^{24})/ (7.615 \times 10^6)^2$ $= 6.9$ N kg^{-1}
4	**c**		**Essential questions:** For this question, key words are "near the surface", "grav field strength", "acc of free fall". In the data sheet, "acc of free fall" is defined as 9.81 m s^{-2} near the surface. Next, you have to recall the formal definition of "grav field strength" --> grav force per unit mass acting on a small test mass placed at that point And in this question you are asked to link "grav field strength" to "acc of free fall" "near the earth surface" --> link between Force & Acc is given by N2L! • What is the definition of g? → gravitational <u>force</u> per unit mass acting on a small test mass at that point • What is meant by 'acceleration of free fall'? → <u>acceleration</u> due to gravitation force, and **in the data sheet, this is defined as 9.81 m s^{-2} near the Earth's surface** • How to relate g to acceleration of free fall? → <u>relate force to acceleration</u>, i.e. <u>apply Newton's 2nd law of motion</u>. • What force acts on a body undergoing free fall? → only gravitational force! So there are 2 mains steps: 1] Recall **definition of g (= gravitational <u>force</u> per unit mass acting on a small test mass at that point = F_G/m**). Then to **link g to acceleration: By N2L, F_{net} = ma**. For a mass **above** earth's surface (i.e. not in contact with the surface), **F_{net} is provided by the grav force F_G, so $F_{net} = F_G$**. Then from N2L and definition of g, we get **ma = mg** --> **a = g**. Next, we need to prove that it is 9.81 m s^{-2} in value…. 2] Explain that for **small changes** in height (h) **close to Earth's surface** where **h <<<< Radius of Earth**, the grav field strength g at any distance within h is **approximately constant/uniform & equal to** the **g at the <u>surface</u> of Earth**. i.e. $g_{surface} = \frac{GM_{Earth}}{R_{Earth}^{\ 2}} = 9.81 \text{ N kg}^{-1}$ where M_{Earth} and R_{Earth} is used. --> Proof is on 2 pages of your Gravitation Notes (refer to the proof). Therefore **combining 1 and 2, a = g = 9.81 N kg^{-1} = 9.81 m s^{-2} near the Earth's surface.** <u>Final Answer:</u>

For **small changes** in height (h) **close to Earth's surface** where **h is much smaller than the radius of Earth**, the gravitational field strength g at any distance within h is **approximately constant and equal to** the g at the **surface**.

For a mass in **free fall** (i.e. not in contact with Earth's surface), the **only force acting is the gravitational pull of Earth on the mass.** Thus,
net force on the mass = gravitational force acting on the mass

By Newton's second law of motion,
net force = mass x acceleration

Hence
gravitational force acting on the mass = mass x acceleration due to free fall

acceleration due to free fall, a = gravitational force acting on the mass / mass
= definition of gravitational field strength, g

$a = g = \dfrac{GM_{Earth}}{{R_{Earth}}^2} = 9.81\ \text{N kg}^{-1} = 9.81\ \text{m s}^{-2}$ close to the Earth's surface.

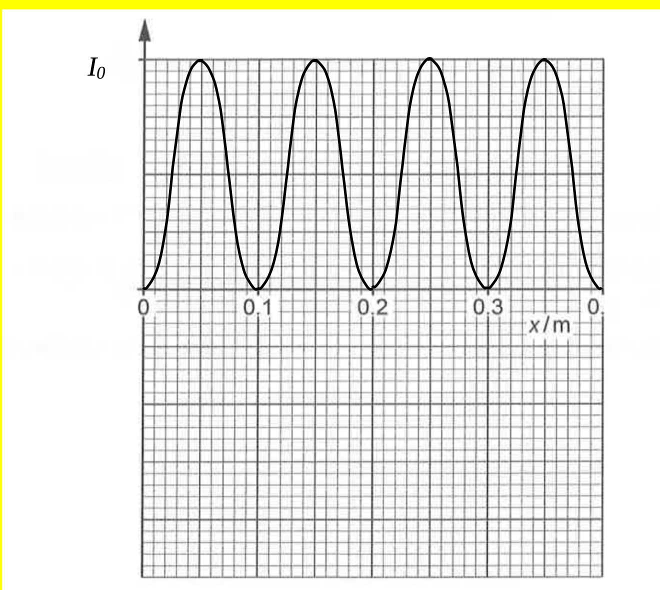
Examiner's Comments:
Stronger responses made the link between the definition of g and the meaning of 'acceleration of free fall'.

5 **a**

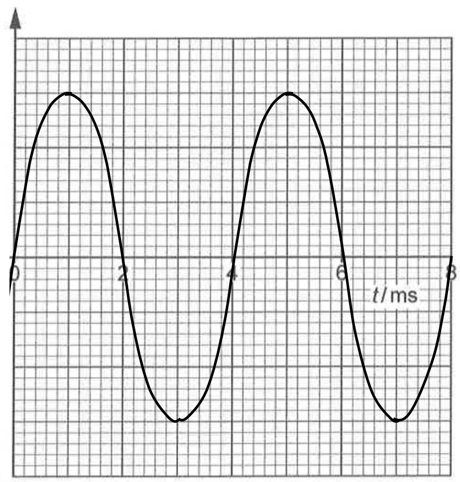
Essential question:
- What is a stationary wave? What is the characteristic of a stationary wave?
- What is the variation in intensity along a stationary wave?

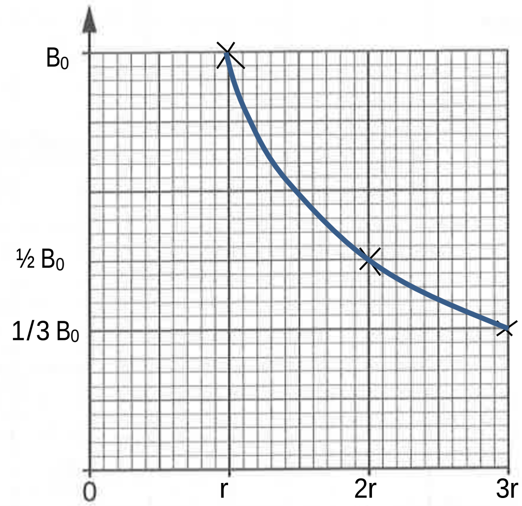
Solution:
wavelength = speed / frequency = 340/1700 = 0.20 m
distance between two adjacent nodes = ½ wavelength = 0.10 m
distance between a node and an adjacent antinode = ¼ wavelength = 0.05 m

Intensity varies from zero to the maximum at one-quarter of a wavelength and fall back again to zero at half the wavelength.



Examiner's Comments:
Strong responses displayed a <u>clear sin² graph</u> with the <u>correct intensity variation and the correct distance between nodes and antinodes</u>. A significant number of candidates did not realise that the intensity <u>could not have negative values</u> and therefore drew a sine graph. <u>Some incorrect responses gave the graph a sharp point at the nodes</u>.

5	b		**Essential question:** • What is the variation of the pressure with time at a point where a progressive sound wave passes? **Solution:** *Pressure varies sinusoidally with a period equal to the period of the waves.* *period = 1/ frequency = 1/250 = 0.004 s = 4 ms*
			 **Examiner's Comments:** *The majority of candidates produced a cosine or sine graph with the correct time period.*
5	c		**Essential question:** • What is the variation of the magnetic flux density at the centre of a flat coil with radius of the coil? **Solution:** *At the center of a flat circular coil,* $B = \mu_o NI / 2(radius)$ *B is inversely proportional to radius when* I *is constant and* μ_o *is a universal constant* Given: when radius = r, B = B_o Thus, when radius = 2r, B = 1/2 B_o when radius = 3r, B = 1/3 B_o

			
			Examiner's Comments: *Strong responses displayed the correct shape graph with detail at 2r and 3r. The instruction to cover a range from r to 3r had not been observed in many responses.*
6	**(a)**	**(i)**	**Essential question:** • How to apply voltage law and current law in a series and parallel circuit? **Solution:** *p.d. across lamp = IR = 0.30 x 5.0 = 1.5 V* *p.d. across R = p.d. across lamp = 1.5 V* p.d. across 3.0 ohm resistor = 6.0 – 1.5 = 4.5 V Current in 3 ohm resistor = 4.5 / 3 = 1.5 A Current in R = 1.5 – 0.3 = 1.2 A R = p.d. across R / current in R = 1.5 / 1.2 = 1.25 = 1.3 Ω **Examiner's Comments:** *Strong responses <u>displayed a clear step-by-step approach</u> to determining the different electrical quantities needed. In some responses, circuit equations were not recalled or were misapplied. Sometimes the total resistance of the parallel part of the circuit was mistakenly thought to be the resistance of R.*
		(ii)	**Essential question:** • How to determine the power and energy? **Solution:** Current delivered by battery, I_{total} = 1.5 A Power supplied by a battery = I_{total} E = 1.5 x 6 = 9.0 W To deliver 120 J of energy, time taken = 120 / 9.0 = 13.33 s Power transferred in lamp = $I_{lamp}^2 R_{lamp} = 0.30^2$ x 5.0 = 0.45 W Energy transferred in lamp = Pt

			$= 0.45 \times 13.33$ $= 6.0$ J **Examiner's Comments:** *Stronger candidates were able to apply the equations for power and energy in this electrical circuit. A significant number attempted to use a ratio between the energy transferred to the two resistors in parallel to that transferred by the supply. Only a small number went on to determine the energy transferred to the lamp correctly.*
		(iii)	**Essential question:** • What is the change in the resistance of a lamp before and after it is turned on? **Solution:** when the lamp is just turned on, its resistance is the lowest since its temperature is the lowest the circuit resistance is the lowest the current supplied by power supply is the highest. Hence the current in the lamp is the greatest. **Examiner's Comments:** *Candidates found it challenging to answer this question. Only the stronger responses clearly explained the subsequent decrease in current.*
	(b)		**Essential question:** • How is the current in a wire dependent on the number density of charge carriers, cross sectional area and the drift velocity? **Solution:** $I = nAve$ current in X, $I_x = n_x A_x v_x e$ current in Y, $I_y = n_y A_y v_y e$ X and Y are in series so the current is the same. $n_x A_x v_x e = n_y A_y v_y e$ $n_y / n_x = A_x v_x / A_y v_y$ $= (A_x / A_y)(v_x / v_y)$ $= (\pi r_x^2 / \pi r_y^2)(v_x / v_y)$ $= (½)^2 (3)$ $= 0.75$ **Examiner's Comments:** *This was well answered by a large number of candidates. The most common errors were incorrect algebra or confusion between the properties of wires X and Y. A few candidates determined the reciprocal of the ratio.*
7	**(a)**		**Essential question:** • State and explain the conclusions of the Rutherford alpha scattering experiment **Solution:** charge distribution:

<table>
<tr><td></td><td></td><td></td><td>
<table>
<tr><td>Evidence :
A small fraction (about 1 in 10^4) of the α-particles were deviated through angles greater than 90° and a very tiny proportion were deviated by 180°.</td><td>Since α-particles are positively charged and are repelled by this core, but only a small fraction were deflected by it, this core is positively charged and is very small compared to the size of the atom.
Protons are contained inside the small core (called nucleus) whereas electrons orbit the nucleus and not found in the nucleus.</td></tr>
</table>

mass distribution:
<table>
<tr><td>Evidence :
Most α-particles passed straight through the foil with little or no deviation.</td><td>Majority of the volume of an atom is empty space and the positively-charge core (the nucleus) occupies a very small volume of the atom.
Since the nucleus contains protons and neutrons whereas electrons orbit the nucleus and not found in the nucleus, and since each proton and neutron has about 1800 times greater mass than each electron, most of the mass of the atom is contained inside the nucleus.</td></tr>
</table>
</td></tr>
<tr><td></td><td>b</td><td></td><td>Essential Question(s):
How to apply conservation of energy to a scenario when two charged particles collide approach each other?
Solution:

Let the distance of closest approach be x.

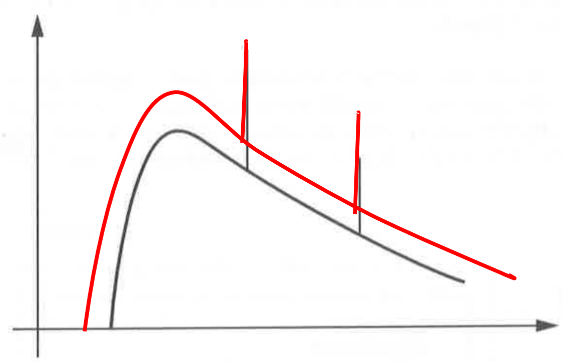
By conservation of energy, as an α-particle approaches a gold nucleus,
gain in EPE = loss in KE
$Q_1Q_2/4\pi\varepsilon x - 0$ = initial KE – 0
$(+2e)(+79e)/\ 4\pi\varepsilon x = (5.59 \times 10^6 \times 1.60 \times 10^{-19}) - 0$
$x = 4.07 \times 10^{-14}\ m$</td></tr>
<tr><td></td><td>c</td><td></td><td>Essential Question(s):
How to determine energy released from the binding energy of the reactants and the products?
Solution:
mass number of Po = 222 – 4 – 218
BE of Po = BE per nucleon of Po x 218

BE of Rn = BE per nucleon of Rn x 222 = 7.69 MeV x 222

BE of alpha particle = BE per nucleon of alpha particle x 4 = 7.08 MeV x 4

energy released = Total BE of products – Total BE of reactants
6.62 MeV = [(7.08 MeV x 4) + (BE per nucleon of Po x 218)] – (7.69 MeV x 222)

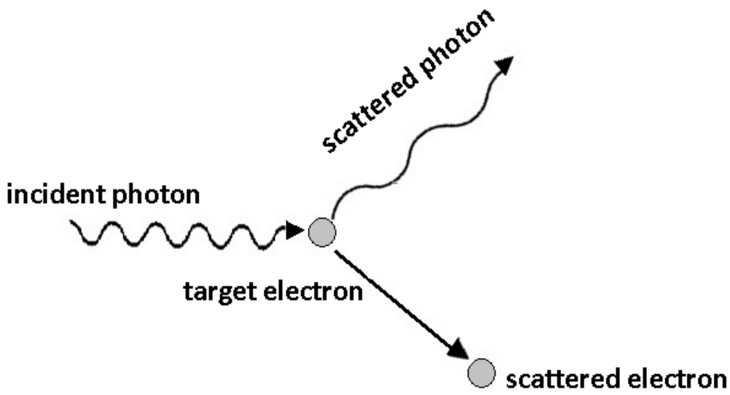
BE per nucleon of Po = 7.73 MeV</td></tr>
<tr><td>8</td><td>a</td><td></td><td>Essential Question(s):
What does evacuated mean?
Solution:</td></tr>
</table>

			As electrons have very small mass compared to air molecules, any presence of air molecules in the tube would scatter the electrons causing them to lose kinetic energy and some electrons may not be able to reach the target.
8	b		**Essential Question(s):** • How does the accelerating voltage affect the x-ray spectrum? • How does the electron current affect the x-ray spectrum? • Which feature(s) of the x-ray spectrum change and which do not change? **Solution:** the minimum wavelength λ_{min} = hc/ eV At higher V, the minimum wavelength decreases. Also, at higher V, the maximum KE of the electrons reaching the target metal increases causing the incident electrons to undergo a greater number of deflections by the target metal atoms before being brought to rest (i.e. more photons produced via the Bremsstrahlung process), and, with higher KE the incident electrons are more likely to knock out an inner shell electron from the target atom (i.e. more photons forming the peaks are produced). Overall intensity of both the broad continuous spectrum and peaks increases. The increase in the current of electron beam means more electrons collide with the target metal per unit time, hence more photons produced, causing the intensity of the spectrum to be greater. However, the wavelengths at which the peaks occur are unchanged as these are determined by the electron energy level differences of the target metal atoms and these are unique to the type of target material. 
8	c	i	**Essential Question(s):** • What are the energy transformations occurring in the tube? **Solution:** total charge in the beam during an x-ray exposure, Q = It energy acquired by the electrons during the exposure, W = QV = ItV Thermal energy released = 99% of W = 99/100 x ItV = 99/100 x (0.12)(1.1)(65 x 10^3) = 8494.2 = 8500 J OR Loss in EPE = Gain in KE = Energy loss on impact with target, E_T

			(Total charge Q incident on the target in 1.1 s).(accelerating p.d.) = E_T $Q.V = E_T$ $(Ne).V = E_T$ where N: no. of electrons incident during exposure time of 1.1 s Since Ne = Q = It, $It.V = E_T$ $(0.12)(1.1)(65 \times 10^3) = E_T$ $E_T = 8580$ J 99% of E_T is converted into thermal energy, so Thermal energy produced = 0.99 x 8580 = 8494.2 = 8500 J **Examiners' Comments:** *The majority of candidates correctly calculated the electrical energy given to the electrons using the data from the text. A significant number equated this to the thermal energy produced in the target instead of that stated in the text as 99% of the electrical energy. Some weaker responses confused the conversion from power to energy, finding the power and then dividing by time rather than multiplying by time in order to gain the energy.*
8	**c**	**ii**	**Essential Question(s):** • How to relate the goal (temperature rise) to the known info (answer in (c)(i) and specific heat capacity)? **Solution:** Thermal energy absorbed = mc $\Delta\theta$ where m = 12 g (see paragraph 2) $8494.2 = 0.012 \times 130 \times \Delta\theta$ $\Delta\theta = 5445$ = 5400 °C **Examiner's Comments:** *The majority of candidates obtained the rise in temperature of a stationary target. A small number made an error by subtracting 273 from their answer for the change in temperature in Kelvin in an attempt to give the change in temperature in degrees Celsius.* **Recap:** **temperature change in K = temperature change in °C.** **1 J kg^{-1} K^{-1} = 1 J kg^{-1} °C^{-1}**
8	**c**	**iii**	**Essential Question(s):** • Hint given: melting point of tungsten…How could this be related to the reason why anode is rotated? • How does the melting point of tungsten compare with the temperature rise in (c)(ii)? **Solution:** • The temperature rise of 5400 °C (from (c)(ii)) will cause the temperature of the tungsten anode to exceed its melting point (3400°C) and the target will be melted. • Cooling of the localised part of the target hit by the electron beam would be difficult. By rotating the target, different parts of the target will be exposed to the electron beam at different time and this enables the target to be cooled more easily and quickly. **Examiner's Comments:** *The majority of candidates gave an appropriate answer. A significant number gave insufficient detail by suggesting that it was to increase the distribution or spreading of the heat or merely to prevent the target from melting. Some responses gave the impression that the spinning of the target cooled it down.*

<table>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>d</td><td>(i)</td><td>

Solution:



As instructed by the question, ensure your diagram is labelled.

Examiner's Comments:
The majority of answers were correct. A number of responses did not have labels for the paths drawn. There were some answers that gave a number of electron paths or a number of photons emitted.

</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>

Essential Question(s):

- What determines the wavelength of a photon? → Energy of the photon determines its wavelength (and also its frequency).

Solution:
Some energy is transferred from the photon to the electron.
Thus energy of the scattered photon is lower than that of the incident photon.
Since energy of photon is inversely proportional to its wavelength ($E_p = hc / \lambda$), hence the scattered photon has longer wavelength.

</td></tr>
<tr><td></td><td></td><td>(iii)</td><td>

Essential Question(s):

- What do you know about the path of the photon after the Compton's effect?

Solution:
The resolution and the contrast of the x-ray image will be good when either the photons are blocked or transmitted without changing in direction before they are incident on the detector.

Due to Compton scattering, the photons will be scattered and their paths are deviated from the incident direction and this causes a reduction in the resolution and contrast.

Examiner's Comments:
This was generally not well answered. Many responses used phrases such as 'the image will be less clear' but did not explain why.

</td></tr>
<tr><td>8</td><td>e</td><td></td><td>

Solution:
From paragraph 6, in X-ray attenuation due to photoelectric effect, the attenuation is proportional to the cube of the atomic number.

$$\frac{attenuation\ of\ intensity\ of\ x-rays\ in\ bone}{attenuation\ of\ intensity\ of\ x-rays\ in\ soft\ tissue} = \left(\frac{Z_{bone}}{Z_{tissue}}\right)^3 = \left(\frac{14}{7}\right)^3 = 8$$

</td></tr>
<tr><td>8</td><td>f</td><td></td><td>

Essential Question(s):

- How does attenuation process as compared with radioactive decay?

</td></tr>
</table>

			Solution: In radioactive decay, the activity A decreases exponentially with time t $A = A_o e^{-\lambda t}$ where λ = decay constant. In X-ray attenuation in matter, the intensity I decreases exponentially thickness x $I = I_o e^{-\mu x}$ where μ = attenuation coefficient When $I = 0.5\, I_o$, $I = 0.5\, I_o = I_o e^{-\mu\, x_{1/2}}$ $0.5 = e^{-\mu\, x_{1/2}}$ ln 0.5 = $-\mu\, x_{1/2}$ $x_{1/2} = \frac{0.693}{\mu}$
8	g		**Solution:** A more sensitive detector will be able to produce images with low intensity of the X-ray radiation and reduce the harmful effects of the X-ray on the patient. **Examiner's Comments:** *The majority of responses did not give sufficient detail. Many suggested that the X-ray image was clearer or that fewer X-rays were needed.*
8	h		**Solution:** Barium has a much higher Z number (=56) than soft tissue (average Z = 7), thus x-rays passing through barium have much greater attenuation. The digestive system is made up of soft tissues which have similar Z numbers to other tissues surrounding the digestive system. Drinking barium solution introduces barium into the digestive system which enhances the contrast between the digestive system from its surrounding tissues in the x-ray image produced.
8	i		**Solution:** In a single 2D x-ray, only a single exposure to x-rays is involved. Whereas in a CT scan to produce 3D image, the x-ray source spirals down the patient's body and many images are taken. Thus in a CT scan the patient has greater exposure to x-rays and also for a longer duration. This is harmful as x-ray is a form of ionizing radiation which can cause damage to living cells and can cause health hazards such as cancer.

Paper 3
Section A

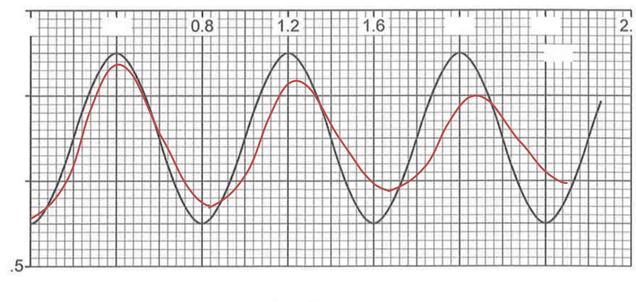
1	a	i	**Essential Question(s):** • What determines acceleration? → Net force • How to determine net force? → Draw free body diagram • On the slope, what is the net force acting on the ball? What provides for this net force? **Solution:** Draw free body diagram of the ball along the slope. Normal to the slope: no net force Parallel to the slope: net force given by downslope component of the ball's weight Net force on ball = downslope component of ball's weight = mg sinθ

			By Newton's second law of motion, mg $\sin\theta$ = ma a = g $\sin\theta$ = 9.81 sin 40° = 6.3057 = 6.3 m s^{-2} **Examiner's comments:** *This question proved challenging for candidates. The most common misconception was to think that the vertical acceleration was a component of the acceleration down the slope rather than the other way round, leading to an unrealistic answer that was greater than g.*
1	**a**	**ii**	**Essential question:** • How to relate the goal to the known information? **Solution:** using "$v^2 = u^2 + 2as$ " Take downslope direction as positive direction, $v^2 = 0^2 + 2(6.3057)(0.56)$ v = 2.6575 = 2.7 m s^{-1}
1	**b**	**i**	**Essential question:** • How to relate the goal to the known information? **Solution:** Centripetal force = mv^2 / r = 0.072 x 1.5^2 / (0.24/2) = 1.35 = 1.4 N
1	**b**	**ii**	**Essential Question(s):** • What provide the centripetal force at the top? • What type of force does 'force due to the track' refer to? → contact force (Normal contact force and/or friction); since 'smooth' track no friction acts; required force is N. **Solution:** At the top, 2 forces act on the ball: Normal contact force exerted by track (N) and ball's weight (W); both act downwards. resultant force = N + W resultant force provides centripetal force N + W = centripetal force N = centripetal force – W = 1.35 – 0.072 x 9.81 = 0.644 = <u>0.64 N</u> direction is <u>vertically downwards</u>
2	**a**		**Essential question:** • What is the definition of gravitational potential? **Solution:** Gravitational potential is <u>defined</u> to be <u>**zero at infinity**</u>.

			Also, due to the **attractive** nature of gravitational force, to move a point mass **from infinity towards** another mass **without a change in kinetic energy**, an **external agent** would need to **exert a force** that acts **opposite direction to** the **change in displacement** of the mass being moved, thus **work done *per unit mass* by the external agent is negative**. Thus gravitational potential at any point other than at infinity is negative. • ***Relate back to definition of gravitational potential: Gravitational potential at a point is the work done per unit mass by an external agent in bringing a point mass from infinity to that point (without a change in kinetic energy).*** • ***potential' is a 'per unit mass' quantity, hence reference is made to work done 'per unit mass' in the explanation.*** **Examiners' Comments:** *In some responses, there was a tendency to refer to energy and fields rather than potential and forces. In some responses, there was confusion with the scalar nature of gravitational potential and the use of external forces to move objects. Some responses referred to work done being in the opposite direction to the movement or similar. This makes no sense since work done is a scalar and has no direction.*
2	**b**		**Solution:** gravitational potential at the surface of planet = -GM/r $= - 6.67 \times 10^{-11} \times 6.2 \times 10^{23} / (6.8 \times 10^{3} \times 1000 \div 2)$ $= - 1.216 \times 10^{7}$ $= - 1.2 \times 10^{7}$ J kg^{-1} **Examiners' Comments:** *Most candidates performed well. Occasional mistakes such as power of ten errors or confusion of diameter with radius were seen in some responses.*
2	**c**		**Essential Question(s):** • How to apply the law of conservation energy for the rock? • What is the criterion for the rock to escape the gravitational pull of the planet? **Solution:** For the rock to ***just** escape* to space, By the conservation of energy, loss in KE = gain in GPE initial KE at surface – final KE at infinity = final GPE at infinity – initial GPE at surface initial KE – 0 = 0 – (2.8)(-1.216×10^{7}) = 3.405×10^{7} J Hence the initial KE must be more than = 3.405×10^{7} J Given initial speed of rock = 3.8×10^{3} m s^{-1}, Initial KE of rock = ½ (2.8) $(3.8 \times 10^{3})^{2} = 2.022 \times 10^{7}$ J which is less than 3.405×10^{7} J The rock will not be able to be escape to space and it will return to the planet **Examiners' Comments:** *The most common mistake was to compare the kinetic energy with the gravitational potential rather than the potential energy.*
3	**a**		**Essential Question(s):** • What is the definition of internal energy? • What are the assumptions of an ideal gas? **Solution:**

			The **internal energy of a** ***system*** in general is **sum of** the **random kinetic and potential energies** of the **individual atoms or molecules of the system.** An ***ideal gas*** has **no intermolecular forces**, **therefore potential energy between the molecules is zero**. Hence, **internal energy of an *ideal gas* equals to the total kinetic energy of the molecules only.** **Examiners' Comments:** *Candidates found this question challenging. Some responses omitted the idea of a 'sum'. A significant number talked about potential energy as being non-zero.*
3	**b**	**i**	**Essential Question(s):** • How to apply ideal gas equation? **Solution:** Using "PV = nRT" Before $1.0. x10^5 \times 3.2 \times 10^{-3} = nR(12 + 273.15)$ ….(1) After $1.0. x10^5 \times 3.6 \times 10^{-3} = nR(T_f)$ ……………(2) (2) / (1): $3.6 / 3.2 = T_f / 285.15$ $T_f = 320.8$ K $= 320.8 - 273.15$ °C $= 47.65$ °C $= 48$ °C
3	**b**	**ii**	**Essential Question(s):** • How to calculate the work done during expansion of a gas? **Solution:** work done against the atmosphere $= P_{atm} \Delta V$ $= 1.0. x10^5 \times (3.6 \times 10^{-3} – 3.2 \times 10^{-3})$ assume P_{atm} = pressure of gas = 40.0 J = 40 J
3	**c**	**i**	**Essential Question(s):** • How do apply 1st law of thermodynamic in a thermodynamic process? **Solution:** increase in internal energy = heat supplied to gas + work done ON gas = 101 + (- 40.0) = 61.0 = 61 J
3	**c**	**ii**	**Essential Question(s):** • How to calculate the average KE of a molecule of a gas **Solution:** Using " PV = NkT" Number of molecules in the gas N = PV / kT $= (1.0. x10^5)(3.2 \times 10^{-3}) / (1.38 \times 10^{23})(12 + 273.15)$ $= 8.132 \times 10^{22}$ Average increase in KE of a molecule of an ideal gas = total KE of molecules / N Since internal energy of an ideal gas = KE of the molecules in the gas, hence total increase in KE = increase in internal energy

			Therefore increase in average KE of a molecule of an ideal gas = increase in internal energy a molecule of an ideal gas = 61 / 8.132 x 10^{22} = 7.5 x 10^{-22} J <u>Extension:</u> If the ideal gas were a MONOatomic gas then the increase in internal energy $= \frac{3}{2} k\ \Delta T$ $= \frac{3}{2}\ (1.38\ x\ 10^{-23})(48 - 12)$ = 7.5 x 10^{-22} J Hence the gas in question is a monoatomic gas. **<u>Note: Since the question did not specify that the ideal gas is monoatomic, you cannot simply assume and apply $\frac{3}{2} k\ \Delta T$ directly!</u>**
4	**a**	**i**	**Solution:** amplitude x_o = peak to peak distance / 2 = (-0.25 – (-1.25))/2 = 0.50 cm **Examiners' Comments:** *When reading from a graph, the value given should be to the appropriate number of decimal places. The most common mistake was to give the amplitude to one decimal place instead of two.*
	a	**ii**	**Solution:** period = (1.2 – 0.4) = 0.8 s angular frequency ω = 2π / T = 2 x 3.1415 / 0.8 = 7.854 = 7.9 rad s^{-1}
	a	**iii**	**Solution:** $v_o = \omega\ x_o$ = 7.854 x 0.50 = 3.927 = 3.9 cm s^{-1}
	b		**Essential Question(s):** • What are the effects of light damping on the oscillations? **Solution:** Amplitude decreases exponentially with t. Period longer than no damping case; but period remains constant with t.



Examiners' Comments:
Although candidates tended to understand what was required of them, the sketches produced were often unclear. The majority of candidates realised that the amplitude of the oscillations would decrease. However, many responses had the period increasing. Some responses did not show the amplitude decreasing continuously. A significant number of graphs were drawn in the space under the question although the paper gave a specific instruction for them to be sketched on Fig. 4.2.

5 a

Essential Question(s):

Solution:
It is the **<u>spreading</u>** of a wave into the <u>geometrical shadow regions</u> when they pass <u>**through** an **opening** or **around** an **obstacle**</u>.

Examiners' Comments:
Many responses displayed confusion on the difference between gaps and obstacles and/or the language used with each. Some responses contained phrases such as 'the bending of a wave through an obstacle'. This has the wave passing through an obstacle, rather than through a gap or around an obstacle.

- ***Cannot replace 'spreading' with 'bending'.***
- ***Phrase logically e.g. 'through an obstacle' makes no sense; should be 'around an obstacle'.***

b i

Essential Question(s):
- What equation governs single-slit diffraction?

Solution:
For single-slit diffraction, $b \sin\theta = m\lambda$
for first minimum, $m = 1$
$b \sin\theta = \lambda$
$\sin\theta = \lambda / b = 590 \times 10^{-9} / 0.100 \times 10^{-3} = 0.059$
$\theta = 0.3380^{o}$

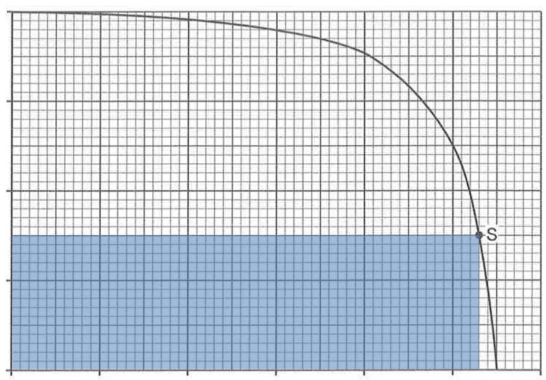
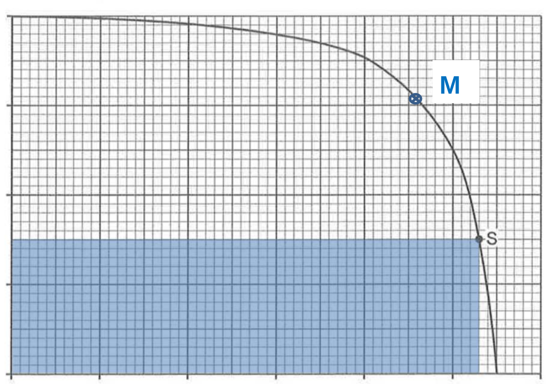
let y = distance from centre of pattern to the first minimum along the screen
$\tan\theta = y / D$
$y = D \tan\theta = 2.60 \times \tan 0.3380^{o} = 0.01534$ m

width of central fringe = $2y = 2 \times 0.01534 = 0.03068 = 0.0307$ m

Examiners' Comments:
Candidates performed well on this question. The most common misconception was not realizing that the width of the central maximum subtends an angle that is twice the diffraction angle for the first minimum. Some responses started out by using the wrong equation, usually the double-slit equation or the diffraction grating equation.

5 b ii

Essential Question(s):
- How to calculate fringe separation of the double slit pattern?

			Solution: fringe separation $= \lambda D / a$ $= 590 \times 10^{-9} \times 2.60 / 1.40 \times 10^{-3}$ $= 1.096 \times 10^{-3}$ m number of separations of the double slit fringes within the diffraction central bright fringe $= 0.03068 / 1.096 \times 10^{-3}$ $= 28.01$ number of <u>complete</u> bright fringes <u>within</u> the diffraction central bright fringe = 28
6	**a**	**i**	**Essential Question(s):** • How do you determine P from a I-V graph? What equation relates P, I and V? **Solution:** P = IV On an I-V graph, P is the <u>product of the coordinates (I, V)</u> at a given point, which is <u>represented by the area of the rectangle shown below</u>.  **Examiners' Comments:** *Most candidates performed well here. They ensured that the shading on the graph was carefully completed so that it was clear exactly which area represented the power dissipated in the resistor.*
		ii	**Solution:** To give rise to maximum power, the shaded area is the largest. M is determined by working out the power P = IV at different values of V and identifying the maximum value with approximation. 
6	**b**	**i**	**Solution:** when I = 100 mA, from graph V = 500 mV R =V/I = 500 mV / 100 mA $= 5.0\ \Omega$

6	b	ii	**Solution:** power dissipated in R = IV = 100 mA x 500 mV = 0.050 W
	b	iii	**Solution:** Use E = V + Ir Where V = 500 mV when I = 100 mA To find E: When I = 0 → Ir = 0, therefore E = V = 550 mV (horizontal intercept of graph) 500 mV = = 550 mV – 100mA x r r = 0.50 Ω Extension: While the horizontal intercept gives the value of E, the vertical intercept gives the value of the short-circuit current, because V = 0 occurs when R = 0.
7	a		**Solution:** similarity: The potential at a point is inversely proportional to the distance from the point charge / point mass to that point. difference: Electric potential can be positive or negative; whereas gravitational potential is always negative (except at infinity). **Examiners' Comments:** *Many candidates simply defined potential, either electric or gravitational.*
7	b	i	**Essential Question(s):** • What can be deduced from the features of the V-x graph? ➔ It is formed by the addition of the V-x graph due to the two point charges. Hence it may be inferred that the point charge on the left is positive charge and the point charge on the right is negative charge. ➔ Also, E = -dV/dx. Since there is no point between the two point charges where the gradient = 0, the two point charges must be of opposite signs. **Solution:** The potential nearer to A is positive and that nearer to B is negative. This implies that the two charges have opposite signs. OR There is a point between A and B (at x = 9 cm) where the resultant potential equals to zero. This implies that the two charges have opposite signs. OR Since the negative of the potential gradient is equal to the electric field strength, and since there is no point between A and B where gradient equals zero, it implies that the resultant field strength is non-zero everywhere between A and B and must mean that the two charges have opposite signs.
7	b	ii	**Essential Question(s):** • What can you conclude when the potential is zero? **Solution:** At x = 9.0 cm, resultant potential due to A and B = 0

$V_{\text{due to A}} + V_{\text{due to B}} = 0$

$$\frac{Q_A}{4\pi\varepsilon_o(9.0\ cm)} + \frac{(-Q_B)}{4\pi\varepsilon_o(12\ cm - 9.0 cm)} = 0$$

$$\frac{Q_A}{Q_B} = \frac{9.0}{3.0} = 3.0$$

Examiners' Comments:

The majority of candidates realised that the potentials were of the same magnitude at x = 9.0 cm, but some responses did not state this. The question asked candidates to explain their working, which some did not do. Some candidates attempted to find the two charges by using two points on the line and simultaneous equations, which is a valid but extremely difficult approach and was seldom correctly executed. These candidates usually attempted the same method in (b)(iii) and it was generally incorrect there too.

7 b iii

Essential Question(s):

- How to determine the electric field strength at a point from a potential – distance graph?

Solution:

electric field strength = - dV / dx

dV /dx = gradient of the graph

Draw a tangent at x = 7.0 cm.

Ensure tangent is long enough

Get 2 coordinates separated far apart on the tangent to calculate the gradient.

electric field strength

= - (0 – 180) / (8.9 – 0)

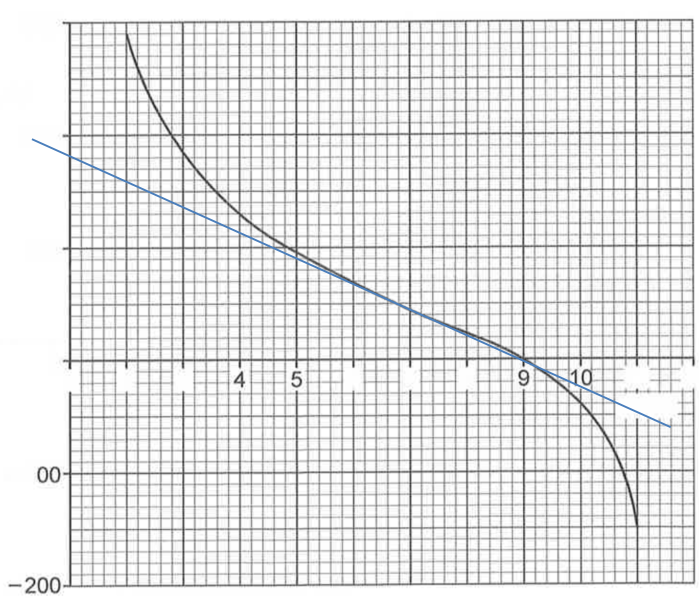
= 20 V cm^{-1}

= 2022 V m^{-1}

= 2022 N C^{-1} (1 N C^{-1} = 1 V m^{-1})

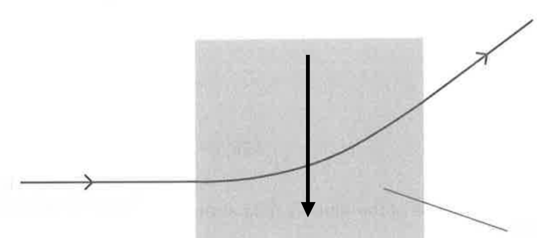
= 2000 N C^{-1}

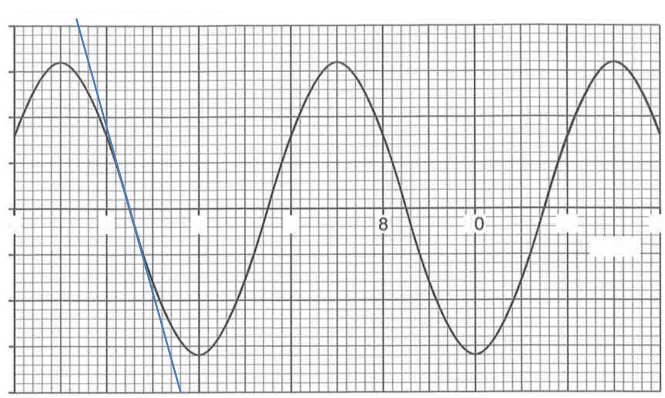
magnitude of electric field = 2000 N C^{-1}



Examiners' Comments:

Most candidates realised that the field strength is the (negative) potential gradient. Responses often displayed tangents that had not been drawn accurately.

8	a		**Solution:** Magnetic flux density is defined as the **magnetic** force **per** unit current **per** unit length on a **long straight** current-carrying conductor placed at **right angle** to the **uniform** magnetic field. **Examiners' Comments:** This definition was well-known. Some candidates referred to unit current rather than *per* unit current.
8	b	i	**Essential Question(s):** **Solution:** The proton is a **charged** particle. When it moves perpendicular to the uniform magnetic field, it experiences a **magnetic force** that is **always** acting **perpendicular** to its velocity v, which **continuously changes the direction of v but not the magnitude of v**. The **constant speed** in turn keeps the **magnitude of** the magnetic force hence centripetal force constant. Hence the proton moves in a circular path with **constant** radius.
8	b	ii	**Solution:** Magnetic force provides for the centripetal force on the proton $Bqv = mv^2/r$ $B = mv/ qr$ $= 1.67 \times 10^{-27} \times 6.2 \times 10^5 / 1.6 \times 10^{-19} \times 0.076$ $= 0.08515$ $= 0.085$ T
8	c	i	**Essential Question(s):** • What is the condition for the proton to be undeflected by the 2 fields? ➔ Concept of Velocity Selector **Solution:** Magnetic force must be equal in magnitude and opposite in direction to the electric force Magnetic force deflects the proton up the page, so the electric force must act down the page. Since proton is positively charge, the electric field acts down the page so that the electric force is acting down the page. 
8	c	ii	**Essential Question(s):** • What is the condition for the proton to be undeflected by the 2 fields? **Solution:** For the magnetic force to be equal in magnitude to the electric force, $Bqv = qE$ $E = Bv$ $= 0.08515 \times 6.2 \times 10^5$

			= 52790 = 53000 N C^{-1}
8	**d**	**i**	**Essential Question(s):** • What is root mean square value of a sinusoidally varying quantity? **Solution:** for sinusoidal variation of a quantity, R.M.S. value = peak value / √2 Peak value of magnetic flux density = 6.4 mT R.M.S. value of magnetic flux density = 6.4 mT / √2 = 4.525 = 4.5 mT
8	**d**	**ii**	**Essential Question(s):** • How to determine the induced e.m.f. from the magnetic flux density vs time graph? **Solution:** magnetic flux linkage Φ in S = NBA Induced e.m.f. in S = - dΦ/dt = -d (NBA) /dt =- NA dB/dt =- NA x gradient of the B-t graph Induced e.m.f. = 0 when dB / dt = 0. This occurs when t = 1.0 ms, 4.0 ms, 7.0 ms, 10 ms, 13 ms (give any two values)
8	**e**		**Essential Question(s):** • How to determine the induced e.m.f. from the magnetic flux density vs time graph? **Solution:** Maximum induced e.m.f. in S = - NA x **maximum** gradient of the B-t graph **maximum** gradient of the B-t graph = [8 – (-8)] mT/ (1.4 – 3.6)ms = 7.27273 T s^{-1}  gradient of the Maximum induced e.m.f. in S = - NA x maximum gradient of the B-t graph

= - 270 x (πx 0.012^2) x 7.27273
= 0.8883 V
= 0.89 V

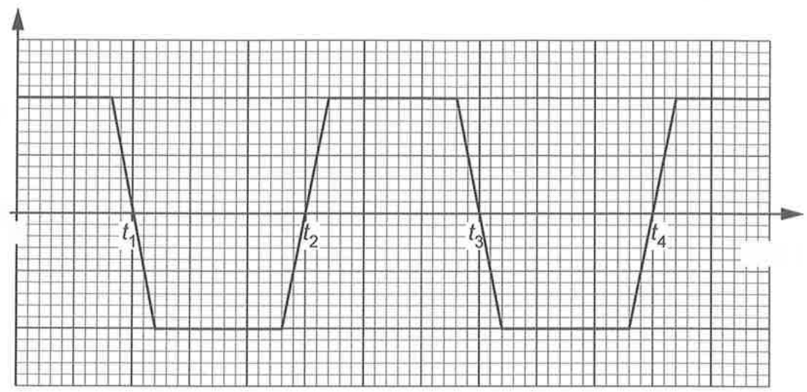
Examiners' Comments:

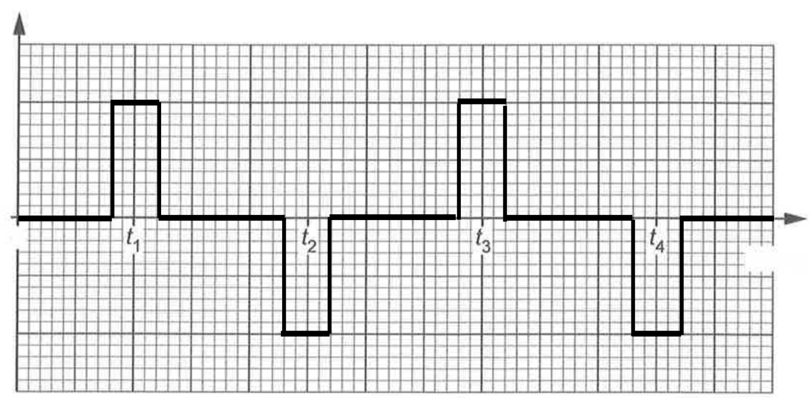
8 **f**

Essential Question(s):

- How to determine the induced e.m.f. from the magnetic flux vs time graph?

Solution:





tic

flux linkage Φ in S = Nϕ

Induced e.m.f. in S
= - d (Nϕ) / dt
= - N (dϕ / dt)
= - N x gradient of the ϕ-t graph

gradient of the ϕ-t -t graph at t = t_1 and t = t_3 is a negative constant

Induced e.m.f. in S
= - N x gradient of the ϕ-t graph
= a positive constant

gradient of the ϕ-t -t graph at t = t_2 , t = t_4 is a positive constant equal in numerical value to that at t = t_1 , t = t_3

Induced e.m.f. in S

			= - N x gradient of the ϕ-t graph = a negative constant equal in numerical value to that at $t = t_1$, $t = t_3$ When ϕ is constant gradient of the ϕ-t graph = 0, induce e.m.f. in S = 0 **Examiners' Comments:** *This was generally well answered, with candidates realising that the e.m.f. was only induced when the flux was changing. The most common mistake was not realising that the e.m.f. is positive when the change in flux is negative.*
9	**a**	**i**	**Solution:** Experiment observations: 1. No electron is emitted if the frequency of the radiation is below a certain threshold frequency even with very intense radiation. 2. Increasing the intensity of the radiation has no effect on the *maximum* kinetic energy of the electrons emitted. Instead, the maximum kinetic energy of the emitted electrons increases with the frequency of the radiation for the same metal surface. 3. Electron emission is instantaneous even if very faint light is used as long as the frequency of the radiation is greater than or equal to the threshold frequency.
9	**a**	**ii**	**Essential Question(s):** **Solution:** Experiment observations: • A line emission spectrum shows that only certain values of wavelengths (or frequencies) of photons are emitted when gas atoms de-excite. • Photons emitted have **energies** equal to the **differences** between the pairs of electron energy levels involved in the de-excitation. • The fact that only certain **wavelengths** are seen implies that only photons of certain **energies** are emitted, which in turn implies that electrons inside an atom can only possess certain discrete values of energies (called the electron energy levels).
9	**b**	**i**	**Essential Question(s):** • How to relate photon energy to photon wavelength? **Solution:** $E = hf = hc/\lambda$ $= 6.63 \times 10^{-34} \times 3.00 \times 10^{8} / 340 \times 10^{-9}$ $= 5.85 \times 10^{-19}$ J $= 5.85 \times 10^{-19} / 1.60 \times 10^{-19}$ eV = 3.66 eV
9	**b**	**ii**	**Essential Question(s):** • Key word: 'visible' line spectrum **Solution:** In part (b)(i) we have for purple light $\lambda = 340 \times 10^{-9}$ m and E = 3.66 eV Purple wavelength is the shortest as compared to the other colours of the visible spectrum. Hence the visible spectrum wavelength must be equal or more than that of the purple line and the energy of transition must be less than 3.66 eV.

			However the smallest energy of transition to -13.6 eV level [= -3.4 ev – (-13.6 ev) = 10.2 eV] is more than 3.66 eV, so all the photons emitted when electrons de-excite to the -13.6 eV energy level have wavelengths shorter than that of the purple line. Hence no visible line spectrum is observed.
9	**c**	**i**	**Essential Question(s):** • What is probability of decay of a nuclide and how it is related to half life? **Solution:** The decay constant is defined as the probability of a radioactive nucleus decay in the next unit time interval. this means that the probability of decay in one day = the decay constant with a unit of day^{-1} = ln 2 / 53 = 0.01308 = 0.013 day^{-1}
9	c	ii	**Essential Question(s):** • How to relate the number of undecayed nuclei to decay constant? **Solution:** number of undecayed nuclei $N = N_o e^{-\lambda t}$ where N_o = number of undecayed nuclei at time t = 0 = initial mass of sample / mass of a nucleus = 5.7×10^{-12} kg / 7u = $5.7 \times 10^{-12} / (7 \times 1.66 \times 10^{-27})$ number of undecayed nuclei $N = N_o e^{-\lambda t}$ $= 5.7 \times 10^{-12} / (7 \times 1.66 \times 10^{-27})\ e^{(-0.01308 \times 120)}$ $= 1.02 \times 10^{14}$
9	**c**	**iii**	**Essential Question(s):** • How does the structure of a nucleus affected by a gamma decay? **Solution:** A gamma ray photon is a quantum of energy and there is no proton and neutron associated with it. The emission of a gamma ray photon will not affect the number of protons and the number of neutrons in the nucleus. Hence when a Be-7 emits a gamma photon, its proton number and neutron number is unchanged. The type of nucleus depends on the proton number and the neutron number in the nucleus. So the Be-7 nucleus remains as Be-7 nucleus after the emission of a gamma ray photon.
9	**d**		**Essential Question(s):** • How to determine the momentum of a photon with energy E? **Solution:** From de Broglie's relation, $\lambda = h / p$ Energy of a photon $E = hf = hc/\lambda = hc / (h/p) = pc$

			Momentum of a photon $p = E/c$ $= 0.48 \times 10^6 \times 1.60 \times 10^{-19} / 3.00 \times 10^8$ $= 2.56 \times 10^{-22}$ kg m s^{-1} Initial total momentum = 0 since the Be-7 nucleus is at rest initially. Final total momentum = momentum of Be-7 + momentum of photon Take direction of photon's momentum to be positive direction. Let v be the recoil speed of Be-7. By the conservation of the momentum, final total momentum = initial total momentum momentum of Be-7 + momentum of photon = 0 $(-7u.v) + (2.56 \times 10^{-22}) = 0$ $7 (1.66 \times 10^{-27}) v = 2.56 \times 10^{-22}$ $v = 22000$ m s^{-1}