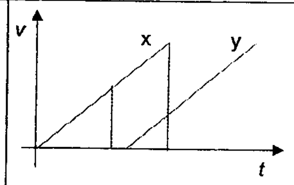
Solutions to J2 Preliminary Examination Paper 1

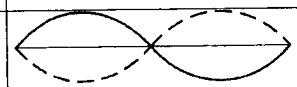
1	A
2	D
3	B
4	D
5	A
6	C
7	B
8	C
9	B
10	D

11	C
12	A
13	B
14	D
15	C
16	C
17	D
18	B
19	A
20	B

21	D
22	C
23	B
24	A
25	A
26	A
27	C
28	B
29	C
30	D

Qn	Key	guide
1.	A	Considering units of the equation, we have $s^2 = \frac{\text{kg m}^2}{\text{units of K}}$, so units of K = kg m^2 s^{-2} = (kg m s^{-2}) m = N m
2.	D	 Since air resistance is negligible, the gradient of both graphs will be the same. From the v-t graph, it can be seen that at any time, the difference in the area under graph for X and Y will be increasing hence the separation will be increasing.
3.	B	Note that the carriages and the engine have a common acceleration, say *a*. Let the mass of each carriage be *m*. Consider both carriages, Newton's 2nd law gives $T = (2m)a$, so $a = \frac{T}{2m}$ Consider the back carriage. Tension pulling the back carriage is then $ma = m\left(\frac{T}{2m}\right) = \frac{T}{2}$
4.	D	During acceleration, $W - mg = ma$, so $W = m(9.81 + 2.0)$ During deceleration, $mg - W' = ma$, so $W' = m(9.81 - 2.0)$ So $\frac{W'}{W} = \frac{9.81-2.0}{9.81+2.0} = 0.661$
5.	A	Since the same load is applied, for X, if extension is *L*, then extension for Y will be 2*L* For Z, the extension will be the greatest as the top two springs will stretch by the same amount of *L* while the lower spring will have twice the extension due to the weight being supported by only one spring
6.	C	Work done = 120 cos 37° x 5.0 = 479 = 480 W
7	B	Initially, when no force is applied to the piston, force on piston by air in container = force on piston by air in atmosphere = pressure x area = $(100\times10^3)(3.5\times10^{-3})$ = 350 N $\frac{(100\times10^3)(3.5\times10^{-3})(80\times10^{-3})}{T} = \frac{(\text{new pressure})(3.5\times10^{-3})(160\times10^{-3})}{0.5T}$ new pressure = 25 kPa new force on piston by air in container = pressure x area = $(25\times10^3)(3.5\times10^{-3})$ = 87.5 N

		For piston to remain stationary, Force on piston by air in container + F = Force on piston by air in atmosphere 87.5 + F = 350 F = 260 N (262.5)
8	C	Let X be the gas compressed isothermally (no change in temp). There is heat exchange between the gas and the surroundings. Let Y be the gas compressed and is isothermally isolated from surroundings. There is no heat exchange between gas and the surroundings. For X: Since temperature does not change due to heat exchange between gas and the surroundings, $p_1V = p_2(0.5V)$, $p_2 = 2\ p_1$ For Y: Using pV = nRT, when V decreases, pressure increases and leads to larger speed of the molecules. This leads to higher temperature of gas. A: No heat is given to both gases during compression. B: Internal energy of Y is higher due to higher temperature of gas that leads to higher average KE. C: Since mass and volumes of gases are the same, there is no change in density of gases. D: Since work done on gases depends on the pressure and the change in volume and there is no information on how pressure varies for both gases during compression, the work done on gases may not be the same.
9	B	The following options are wrong. A: There is no thermal energy supplied to the system. C: If the air becomes hot, there should be increase in internal energy. D: The statement does not lead to the effect of higher temperature of gas.
10	D	Using $v = r\omega$, $\frac{dv}{dt} = \frac{dr}{dt}\omega$ Since $\frac{dr}{dt}$ and ω are constant, it should be a straight line graph for a graph of v against t.
11	C	Use v = u + at $0 = 45 - g_x(5.2)$ $g_x = 8.65$ m s^{-2} $g_y = \Delta\Phi/\Delta x = 6.0(4.0) = 1.5$ m s^{-2} $g_y : g_x = 1.5/8.65 = 0.17$
12	A	Using $E_k = \frac{Gm_Em}{2r}$, m_A is larger than m_B and since both satellites have same kinetic energy,

		Using total energy $= -\frac{Gm_Em}{2r}$, satellites A and B have the same total energy, (Option A is false) Orbital radius for satellite A is larger than that of satellite B. (Option B is true) Using T^2 is proportional to r^3, satellite A has a larger period (Option C is true) Since angular velocity is inversely proportional to T, satellite A as smaller angular velocity (Option D is true)
13.	B	Total energy of mass in S.H.M: $\frac{1}{2}m\omega^2x_0^2 = \frac{1}{2}\left(\frac{8}{1000}\right)(2\pi(40))^2\left(\frac{5}{1000}\right)^2$ $= 6.32\times10^{-3}$ J
14.	D	With increased damping, amplitude will generally be lower throughout and peak will shift left.
15.	C	
16	C	 $\lambda = L$ Points between two adjacent nodes are in phase. Points in adjacent segments are anti-phase.
17	D	Using $x = \frac{\lambda D}{a}$, $x = \frac{(600\times10^{-9})(1)}{a}$ $2x = \frac{(400\times10^{-9})D}{a}$ D = 3.00 m
18	B	Current in circuit, $I = \frac{V}{R} = \frac{10}{4.0} = 2.5$ A, Potential difference across connecting wires = 12 – 10.0 – (2.5)(0.20) = 1.5 V Power loss in connecting wires = (2.5)(1.5) = 3.75 W

19	A	Using $a = \frac{F}{m}$ and $F = Eq$, $\therefore a = \frac{Eq}{m}$ proton: $a_{proton} = \frac{Eq}{m}$ alpha particle: $a_{alpha} = \frac{E(2q)}{4m} = \frac{a_{proton}}{2}$ Using v = u + at, $v_{proton} = 0 + at$ $v_{alpha} = 0 + \frac{a}{2}t$ Ratio = 0.5
20	B	Electric potential decreases along the direction of electric field strength.
21.	D	By conservation of charges, $I_1 = I_2 + I_3$ --- (1) Also for the parallel circuit, we note that $\frac{I_2}{I_3} = \frac{R_3}{R_2}$ ----- (2) Using (1) and (2) to eliminate I_2, (1) becomes $I_1 = I_3\left(\frac{R_3}{R_2}\right) + I_3$, or $I_1 = I_3\left(\frac{R_3}{R_2} + 1\right)$, giving $\frac{I_3}{I_1} = \frac{R_2}{R_2+R_3}$
22.	C	$B = \frac{\mu_0 I}{2\pi d}$ Since we want to find the distance at which the PEAK flux density would be, that would occur when the PEAK current is flowing through the circuit. $100\times10^{-6} = \frac{\mu_0\left(2000\times\sqrt{2}\right)}{2\pi d}$ $d = 5.66$ m
23.	B	Current-carrying conductors will attract when currents are in same direction, but repel when in opposite directions. Hence, PS will attract each other while PQ and PR will repel each other, since PR are further apart, the repelling force will be weaker than the force between PS and PQ,
24.	A	There is maximum cutting of the magnetic field when the coil is horizontal therefore the induced e.m.f. will be the greatest. OR Since $E = -\frac{dN\Phi}{dt}$, the graph of magnetic flux linkage and that of induced e.m.f. will be out of phase by π/2, thus when magnetic flux linkage is zero, induced e.m.f. will be maximum.

25.	A	According to Faraday's law, $E = -\frac{dN\Phi}{dt}$. Magnitude of induced e.m.f. in coil = $\frac{B\Delta A}{\Delta t} = \frac{5.00(\pi(8.0\times10^{-2})^2)}{10.0\times10^{-3}} = 10.1$ V Since resistance of coil is 4.00 Ω, current through coil = 10.1 / 4.00 = 2.51 A According to Lenz's law, direction of induced e.m.f. is to oppose the change causing it. Thus the direction of induced e.m.f. will produce a current to oppose the decreasing flux into the coil. Hence by right hand grip rule, the current will be flowing clockwise in order to produce flux going into the page.
26.	A	Using turn ratio, voltage across the secondary coil is $120 \times \frac{10}{500} = 2.4$ V So current in secondary coil is $\frac{2.4}{15} = 0.16$ A. For ideal transformer, $120 \times I_p = 0.16 \times 2.4$ so $I_p = 0.0032$ A
27.	C	Diffraction is a phenomenon exhibited by waves. Electron undergoing diffraction shows that it has wave property.
28.	B	Energy (= eV) transferred to the electron and proton is the same, since they have the same magnitude of charge, so since $E = \frac{p^2}{2m}$, their momentum is given by $p = \sqrt{2mE}$, so their associate wavelength is $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}}$. Hence $\lambda \propto \frac{1}{\sqrt{m}}$ or $\frac{\lambda_p}{\lambda_e} = \sqrt{\frac{m_e}{m_p}} = \sqrt{\frac{9.11\times10^{-31}}{1.67\times10^{-27}}} = 0.0234$
29.	C	Original count rate per minute due to source = 532 – 24 = 508 per minute After two half-lives, the count rate would have dropped to 0.5*0.5*508 = 127. Taking the background count rate into consideration, the reading will be 127 + 24 = 151.
30.	D	Since the radiation is able to pass through 1 mm of aluminium sheet, it cannot be alpha radiation which can get blocked by paper. From the topic of electromagnetism, we learnt that the radius of the circular motion of a charged particle in a magnetic field is directly proportional to the speed of the particle. $r = \frac{mv}{qB}$ From the figure, we can see that the radius on left side of sheet is smaller than that on right side, thus it is likely that the radiation slowed down upon passing through the sheet. Therefore the path must be from Y to X.

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1 (a) error that does not have a fixed magnitude or direction — B1

or

error that scattered around the true value.

or equivalent statement

(b) (i) $13\cos 35^o = 10.6$ or 11 m s^{-1} — B1

(ii) $v_{max} = 13 \times 1.1 \cos 34^o = 11.9$ m s^{-1} — B1
or
$v_{min} = 13 \times 0.9 \cos 36^o = 9.47$ m s^{-1}

uncertainty = $11.9 - 10.6 \approx \pm 1$ m s^{-1} — B1
or $10.6 - 9.47$ or $\frac{11.9-9.47}{2}$

(11 ± 1) m s^{-1} — B1
uncertainty given to 1 sf and value given to the same precision as uncertainty

2 (a) No net force — B1
No net torque/moment about any point — B1

(b) (i) Downwards weight from centre of block
Force by ball at upper left hand corner of block, follows direction of velocity of ball.
Upwards normal reaction force at A (equal length to weight) — B1 for both

Frictional force acting at A to the left — B1

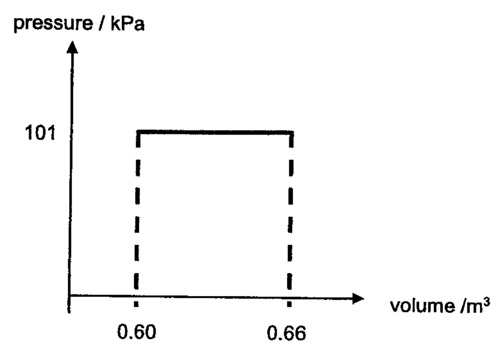
(ii) Taking pivot about A, clockwise moments by force from ball = anticlockwise moments by weight. — C1

9.0 × F = 300/1000 × 9.81 × 5.0 — M1
F = 1.64 N — A1

3 (a) (i) When the gas is heated, the molecules gains kinetic energy (or speed), leading to a larger change in momentum per collision with the container per unit time. This leads to a larger force on the walls of container and piston. — B1

This leads to an increase in pressure in the container. To keep the pressure constant, the piston moves up that leads to an increase in volume of gas until the rate of change of momentum of gas molecules with the walls of the container decreases to the original level. — B1

(ii) — B2



$$\frac{0.60}{28+273.15} = \frac{V_2}{57+273.15}$$
$V_2 = 0.66$ m^3

1 mark for correct graph
1 mark for correct showing correct values on both axes

(iii) Energy from heater = (24)(15)(60) = 21600 J

Using $\Delta U = Q + W$,

Q = – 7000 + 21600 = 14600 J — B1
W = 101000(0.66 – 0.60) = 6060 J — C1

ΔU = 14600 – 6060 = 8540 J — A1

Accept slight variation in values if using raw values from (ii)
Max of 1 mark if students using alternative methods

(b) (i) Using $pV = \frac{1}{3}Nm\langle c^2\rangle$ and $pV = NkT$,

$\frac{2}{3}N\left(\frac{1}{2}m\langle c^2\rangle\right) = NkT$ — B1

$E = \frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$

(ii) Using $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$, $k = \frac{R}{N_A}$ and $M = N_A m$

$c_{rms} = \sqrt{\langle c^2\rangle} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3(8.31)(57+273.15)}{4.0\times10^{-3}}} = 1.43\times10^3$ m s^{-1} — C1 A1

4 (a) A **progressive** wave is a wave in which **energy is carried from one point to another** by means of vibrations or oscillations within the wave. Particles within the wave are <u>not transported</u> along the wave. B1

(b) (i) λ = 0.40 m since distance between P and Q is 1.5 wavelength. C1

$v = f\lambda = 0.40 \times 850 = 340$ m s^{-1} A1

(ii) Intensity of sound at man $I = \frac{P}{A} = \frac{1500}{4\pi(80.0)^2}$ C1

$= 0.01865$ W m^{-2} C1

Power intercepted by man = $I \times A = 0.01865 \times 2.1 \times 10^{-3}$ A1
$= 3.9 \times 10^{-5}$ W

5 (a) Destructive interference is when <u>two waves arrive at the same point anti-phase</u> (phase difference of π / 3π etc rad) they superpose to produce a <u>resultant wave with minimum (or zero) amplitude or a minimum is produced.</u> B1 B1

(b) (i) $\lambda = \frac{v}{f}$

$\lambda = \frac{v}{f} = \frac{330}{1780} = 0.185m$ A1

(ii) $S_1D = \sqrt{12^2 + 4^2} = 12.649$ m

Path difference
$= 12.649 - 12$
$= \frac{0.649}{0.18539}\lambda$ C1 A1
$= 3.5\lambda$

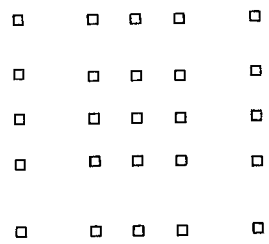
(iii) The path difference of 3.5λ would lead to a phase difference of π rad. Since sound from both speakers have a phase difference of π rad, this would mean that there is no net phase difference at D. B1

Constructive interference of sound waves will take place and loud sound will be heard at D. B1

(c) (i) d sinθ = nλ
Since sin θ cannot be greater than 1
For max order, sin θ < 1
n λ / d <1
n < 2.7 C1

Since n must be an integer, and cannot exceed 2.7, the max order =**2** A1

(ii)



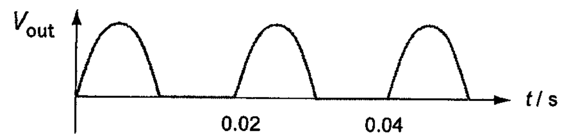
1 mark for correct shape grid of spots 5x5 B1
1 mark for 2[nd] order dots are further apart than 1[st] order dots B1

(iii) The new light source has shorter wavelength. Using d sinθ = nλ, the diffracted angle for each wave will be smaller.

Hence, <u>more bright spots</u> can be seen on the screen and the <u>closer spacing between spots</u>. B1

6 (a) (i) $100\pi = 2\pi f$, so frequency $f = 50$ Hz. So period T = 1/50 = 0.020 s — B1

(ii)



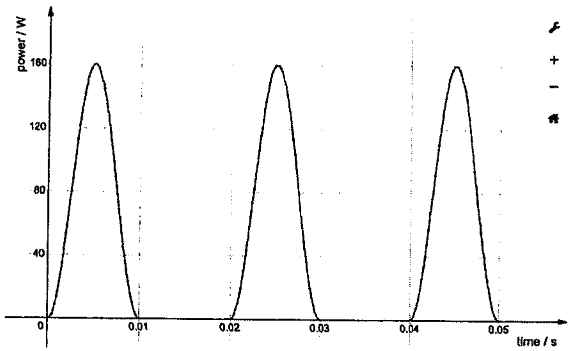
1 mark for shape — B1
1 mark for labelling of period — B1

(b) (i) mean power = $\frac{V_{rms}^2}{640} = 40$ — B1

For half-rectified voltage, mean square voltage = $\frac{V_0^2}{4}$ — C1

Hence $\frac{V_0^2}{4} = 640 \times 40$, giving $V_0 = 320$ V — A1

(ii)



B1

1 mark for shape
1 mark for labelling of peak power at 160 W — B1

7 (a) (i) photons and electrons undergo a one-to-one interaction. — B1

(ii) photons could have interacted with electrons below surface; energy is used to take electron to the surface. — B1

or

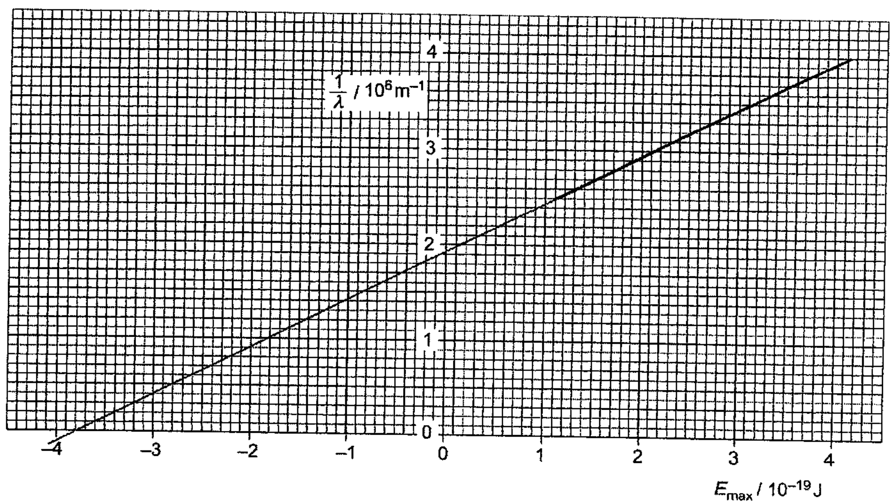
some electrons are more tightly bound to nuclei than others

(iii) 1. $\phi = -E_{max}$ when $\frac{1}{\lambda} = 0$ (use of the x-intercept) — B1
Allow range $(3.8 \pm 0.2) \times 10^{-19}$ J

(allow use of substitution)

2. Use of gradient = $\frac{1}{hc}$ — C1
Allow range of gradient $(4.8 - 5.2) \times 10^{24}$ — B1
Allow range of h $(6.4 - 6.9) \times 10^{-34}$ J s

alternative
(allow use of substitution of points) — C1
Allow range of h $(6.4 - 6.9) \times 10^{-34}$ J s — A1



(iv) increase intensity only increases the rate / number per unit time of the emitted electrons — B1
E_{max} depends on frequency of photons and work function of metal only. — B1

Hence, no change.

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(b) (i) energy difference $\Delta E = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{663\times10^{-19}} = 3.0\times10^{-19}$ M1

So energy levels associated with the transition is between $n = 2$ and $n = 3$ B1

Since dark line is observed, $n = 2$ to $n = 3$ A1

(ii) $21.8 \times 1 = 21.8$

$5.4 \times 2^2 = 21.6$

$2.4 \times 3^2 = 21.6$

1 mark for working to find constant B2

1 mark for comparing the any pair of values

8 (a) (i) Similarity: B1

Both nuclear reactions produce energy

or

Both produces products that are more stable/higher binding energy per nucleon.

Difference: B1

Nuclear fusion combines two lighter nuclei into a heavier nuclei while nuclear fission splits a heavier nuclei into two lighter nuclei of similar sizes.

Nuclear fission produces radioactive waste while nuclear fusion does not.

(ii) The process is able to use the energy produced to keep itself going without any external help/guidance. B1

(iii) It does not produce any radioactive waste/ produces very little short-lived radioactive wastes. B1

It produces more energy per unit mass compared to nuclear fission.

Nuclear fusion reactors will not melt down compared to nuclear fission reactors.

The raw ingredients required for fusion is more readily available compared than that for fission.

(b) (i) High amount of kinetic energy required for the positively charged nuclei to B1

overcome the Coulombic/electrostatic repulsion B1

(ii) To increase the probability of collision between the nuclei B1

(c) (i) $4\,m_H - (m_{He} + 2\,m_e)$

$= 4(1.007825) - (4.002604 + 2(0.000549))u$ M1

$= 4.58(1) \times 10^{-29}$ kg. A1

(ii) $E = \Delta mc^2$

$= (4.581 \times 10^{-29})(3.00 \times 10^8)^2$

$= 4.123 \times 10^{-12}$ J (/ 1.60×10^{-19})

$= 25.8$ MeV A1

(iii) Percentage loss in mass

$= (4 \times 1.007825 - (4.002604 + 2(0.000549)) / (4 \times 1.007825)$

$= 0.006846$

$= 0.6846\%$ A1

(iv) Loss in mass $M = M_{core} \times 0.006846 = 0.10 \times M_{Sun} \times 0.006846$ C1

$3.8\times10^{26} = \frac{(0.10\times M_{Sun}\times0.006846)(3.00\times10^8)^2}{t}$ C1

$t = 3.243\times10^{17}$ s A1

$= 10.3$ billion years

(d) (i)
- Inverted asymmetrical U-shaped curve with right side lower in height. B1
- Max B.E per nucleon is between 8.0 to 9.5 MeV B1
- Corresponding nucleon number is between 55 - 65 B1

(ii) Iron has a very high binding energy per nucleon. M1

When iron is fused, the products are less stable/lower BE per nucleon and there is no net energy released in the reaction. A1

(iii) They are produced via explosions which provide energies for these elements to be fused together. B1

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1 (a) Distance travelled before hitting the ground = Area under graph from 0 to 0.6 s. M1

= ½ (4 + 10) * 0.60 = 4.2 m A1

(b) Distance that the ball bounce upwards M1
= ½ (1.0 * 10.0) = 5.0 m

Height above original = 0.8 m A1

(c) Acceleration = 10/1.0 = 10 m s^{-2} A1

(d) Time taken to travel upwards = time taken to travel downwards
Next time the ball will reach ground = 2.6 s A1

2 (a) (i) conservation of linear momentum gives C1

$$10m + 2(5m) = mv + 4.5(5m)$$

$v = -2.5$ m s^{-1} A1

(ii) kinetic energy before collisioin $\frac{1}{2}m10^2 + \frac{1}{2}(5m)2^2 = 60m$ B1

kinetic energy after collision $\frac{1}{2}m(-2.5)^2 + \frac{1}{2}(5m)4.5^2 = 53.75m$ B1

percentage loss = $\frac{60-53.75}{60} \times 100\% = 10\%$ B1

(b) conservation of momentum gives B1
$10m + 2(5m) = mv_1 + (5m)v_2$ -------(1)

for elastic collsion, relative speed of approach = relative speed of separation. So $10 - 2 = v_2 - v_1$-------- (2) B1

Or conservation of kinetic energy gives
$\frac{1}{2}m2^2 + \frac{1}{2}(5m)2.0^2 = \frac{1}{2}mv_1^2 + \frac{1}{2}(5m)v_2^2$ -------(2)
solving simultaneous (1) and (2) M1
$v_1 = -3.3$ m s^{-1}, $v_2 = +4.7$ m s^{-1} A1

3 (a) loss in gravitational potential energy = gain in kinetic energy + gain in elastic potential energy B1

(b) (i) $4.0 \times 9.81 \times 0.090 = \frac{1}{2} \times 200 \times 0.09^2 + E_k$ B1
$E_k = 2.7$ J B1

(ii) Since both blocks have same acceleration and hence same velocity, M1
$E_k \propto m$
So taking ratio, $\frac{E_{k,Q}}{E_k} = \frac{4}{6}$

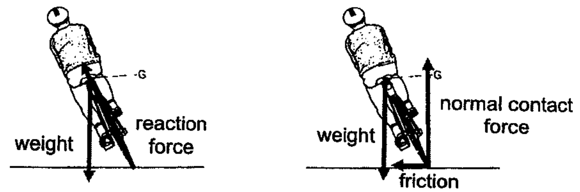
or other appropriate method
$E_k = 1.8$ J A1

(c) When blocks come to rest $E_k = 0$. Let distance required by x, then conservation of energy gives

$$4 \times 9.81 \times x = \frac{1}{2} \times 200 \times x^2$$ M1

$x = 39$ cm A1

4 (a)



B1
B1

1 mark for correct direction of arrows
1 mark for similar length of arrows in vertical direction

(b) Since frictional force provides for the centripetal force,

$f = \frac{mv^2}{R}$

$70 = \frac{(80)v^2}{55}$

$v = 6.9$ m s^{-1} C1 A1

(c) (i) For a surface which is banked, the horizontal component of the normal reaction is an <u>additional source of the centripetal force</u>. B1

Since <u>Centripetal Force = $\frac{mv^2}{r}$</u>, an increase in the centripetal force would allow the rider to turn the corner at a higher speed without slipping, provide the <u>mass of cyclist and bicycle and radius of turn remain constant.</u> B1

(ii) Considering forces acting on the rider/bicycle in the horizontal direction:

$N \sin 20° + f \cos 20° = \frac{mv^2}{r}$ ---------------------- (1) C1 for both

For the equilibrium in the vertical direction:
$N\cos 20° = mg + f\sin 20°$ ------------------(2)

Solving (1) & (2),

$\tan 20° \left(mg + f \sin 20°\right) = \frac{mv^2}{r} - f \cos 20°$ C1

→max velocity during turning v = 15.7 m s^{-1} A1

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5 (a) (i) A = 3.00 B1
ω = 2π / T = 2π / 0.785 = 8.00 B1

$x = A\cos(\omega t - B)$
$2.00 = 3.00\cos(8.00(0) - B)$
$B = 0.841$ B1

(ii) Maximum velocity = ωx_0 = (8.00)(3.00) = 24.0 A1

Maximum acceleration = $\omega^2 x_0$ = (8.00)(3.00)^2 = 192 A1

(iii) ½ mv_{max}^2 = ½ $m\omega^2 x_0^2$
= ½ (5.0 × 10^{-6})(8.00^2)(3.00^2)
=1.44 × 10^{-3} J

1 for correct maximum kinetic energy B1
1 for correct shape (2 periods with peak slightly to the left of origin) B1

(b) An oscillator with damping can vibrate at resonance with amplitude that remains constant with time. M1

This is because the energy supplied by driver is equal to energy lost due to dissipative forces. A1

6 (a) When a p.d. of 240 V is applied across it, then the power dissipated by the lamp is 100 W. B1

(b) Resistance of lamp $R = \frac{V^2}{P} = \frac{240^2}{100} = 576\ \Omega$

Current flowing through the filament ,
$I = \frac{V}{R} = \frac{280}{576} = 0.486\text{ A}$

In one second, quantity of charge flowing through it, Q = 0.500 C C1

$\frac{n}{t} = \frac{Q}{e} = \frac{0.486}{1.6\times10^{-19}} = 3.04\times10^{18}\text{ s}^{-1}$ A1

(c) The temperature (or internal energy) of the filament rises with work done by the electrons on the filament. B1

This causes more vigorous lattice vibration of the atoms resulting in greater collision frequency between electrons and atoms, causing the resistance to rise. B1

To include explanation that just involve collisions of electrons with lattice ions.

7 (a) $A = A_0 e^{-\lambda t}$
$3.7 \times 10^{11} = A_0\, e^{-\frac{\ln 2}{5.2}(2.5)}$ M1
$A_0 = 5.16 \times 10^{11}$ A1

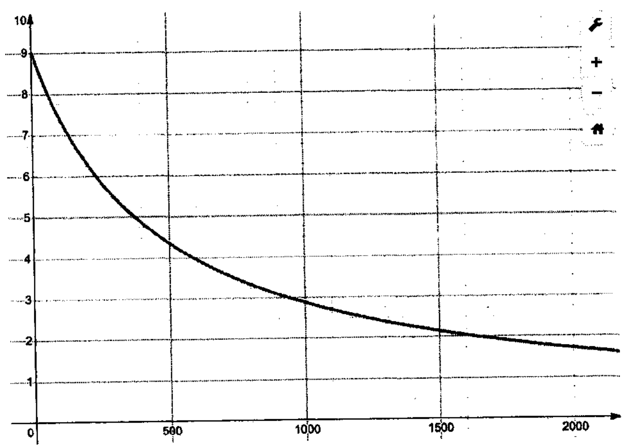
(b) $A_0 = \lambda N_0$
$N_0 = \frac{5.16 \times 10^{11}}{5.2 \times 365 \times 24 \times 60 \times 60}$ C1
$= 1.2216 \times 10^{20}$ C1

mass = $\frac{1.2216 \times 10^{20}}{6.02 \times 10^{23}} \times 60 = 0.012\ g$ A1

(c) Rate of emission of energy B1
= $(3.7 \times 10^{11} \times (0.31 + 1.17 + 1.33)(1.60 \times 10^{-19})$
= 0.166 W B1

8 (a) (i) potential divider method gives C1
$V = 9.0\left(\frac{470}{470+1650}\right)$
$V = 2.00$ V A1

(ii) downward sloping with decreasing gradient B1
cuts at (0,9) B1
and graph below 2 V (or the value in (a)(i)) when curve reaches $R_1 = 2000\ \Omega$
Example



Justification
$V = 9\left(\frac{470}{470+R}\right)$

(b) (i) $\frac{1}{R_\parallel} = \frac{1}{470} + \frac{1}{100\,000}$, $R_\parallel = 467.8\ \Omega$ B1
$V = 9\left(\frac{467.8}{467.9+1650}\right) = 1.988$ B1

$\frac{1.988-1.955}{1.955} \times 100\% = -0.35\%$ A1

(ii) No significant changes / very slight differences / voltmeter may not have enough precision to detect the difference. B1

comparison using numbers. B1

E.g.

internal resistance is 3 orders of magnitude smaller than resistance in circuit.

Or, take internal resistance to be maximum at 10 Ω, fraction $\approx \frac{10}{1645+640} = 0.004$.

internal resistance is small compared to resistance in circuit (1 mark maximum)

9 (a) (i) The electric field strength at a point is defined as the electric force per unit positive charge placed at that point: B1

(ii) Electron gains speed as it moves from point A of 200V to 300V. B2 for all 3

Its speed remains approximately constant when it is between the region of 300V.

Its speed decreases (to the same initial speed) as it moves from 300V to point B

(iii) Loss in kinetic energy = gain in electric potential energy

$= q\,(V_C - V_A)$

$= (-1.60 \times 10^{-19})\,(0 - 200)$ C1

$= 3.20 \times 10^{-17}$ J A1

To deduct one mark if answer does not reflect negative value which represents the loss in KE.

(iv) Distance between 300V and 100V beside B is 2.7×10^{-2} m

Magnitude of field strength

$= |\Delta V/\Delta x|$

$= (300 - 100)/(2.7\times10^{-2})$ C1

$= 7400$ V m^{-1} (7100 – 7700) A1

(v) Vertically downwards B1

(vi) $F = qE$

$=(1.60\times10^{-19})(7400)$

$=1.18\times10^{-15}$ N A1

Vertically upwards. A1

(b) (i) The gravitational force acting on the object provides the centripetal force.

$\frac{GMm}{R^2} = mR\omega^2$ B1

$\omega = \sqrt{\frac{GM}{R^3}}$

(ii) A longer arrow acts towards the Sun.
A shorter arrow acts towards the Earth B1

(iii) The centripetal force acting on the SOHO depends on both the gravitational forces due to the Sun and the Earth. Hence, the expression in (i) does not apply to the angular velocity for SOHO. B1

Due to the gravitational force acting on SOHO by the Earth, the net centripetal force acting on SOHO is lower. This will result in a lower angular velocity for SOHO that can be comparable to that of the Earth at a further distance from the Sun. B1

(iv) $\frac{GMm}{R^2} - \frac{GM_{Earth}m}{R_{Earth}^2} = mR(\frac{2\pi}{T})^2$

$\frac{GM}{R^2} - \frac{GM_{Earth}}{R_{Earth}^2} = R(\frac{2\pi}{T})^2$

where m is the mass of SOHO, M_{Earth} is the mass of the Earth and R_{Earth} is the distance from SOHO to the Earth. From the above equation, the orbital period does not depend on the mass of SOHO B1

(c) (i) Since $\frac{GM_E}{R_E^2} = 9.81$, $R_E = \sqrt{\frac{G(6.0 \times 10^{24})}{9.81}} = 6.39 \times 10^6$ m C1

$v = \sqrt{\frac{G(6.0 \times 10^{24})}{(7.0+6.39) \times 10^6}} = 5470$ m s^{-1} A1

(ii) GPE at infinity + KE at infinity
= GPE of stone on satellite + KE of stone on satellite

$0 + 0 = -\frac{G(6.0 \times 10^{24})m}{(7.0+6.39) \times 10^6} + \frac{mv^2}{2}$

v = 7731 m s^{-1} C1

Minimum projection speed = 7731 + 5470 = 1.3×10^4 m s^{-1} A1

(iii) The lowest speed of projection will be 7731 – 5470 = 2261 m s^{-1} relative to the speed of satellite and the stone should be projected in the same direction as the movement of satellite. Any other direction of projections will not lead to lower speed to escape from the Earth's gravitational field. B1

10 (a) (i) Magnetic force provides centripetal force. M1

$$Bqv = mr\omega^2 = mr\left(\frac{2\pi}{T}\right)^2$$ A1

$$T = \frac{2\pi m}{qB}$$

(ii) Into the page/plane B1

(iii) $f = \frac{qB}{2\pi m} = \frac{(2\times1.60\times10^{-19})(0.850)}{2\pi(6.88\times10^{-27})}$ M1

$= 6.29\times10^{6}$ Hz A1

(iv) Gain in KE per revolution

$= 2\times450\times2\times1.60\times10^{-19}$ M1

$= 2.88\times10^{-16}$ J A1

(v) Gain in KE = ½ mv²

$3\times2.88\times10^{-16} = \frac{1}{2}(6.88\times10^{-27})(v^2)$ M1

$v = 501000$ m s^{-1} A1

(vi)
- Same time intervals when travelling with constant speed B1
- (Shorter and shorter time intervals when accelerating)
- Smaller increase in speed each acceleration B1

(vii)
- The cyclotron uses the same accelerating gap, which enables it to become compact and therefore saves cost in many ways. B1
- The accelerating particles can be taken to higher energy states within the small space available.
- Besides the small size of a cyclotron, there are other factors which reduce the cost of this device. For example the cost of the building which contains it, the cost of the foundation and the cost of radiation shielding.
- Another big advantage of a cyclotron is that it has only one electric driver. This makes it cost-efficient because of less cost equipment and less costly power.
- Cyclotrons can produce the particle beam in a continuous form.

(b) (i) $E = -Blv = -(0.080)(1.5)(3.00)$ M1

$= 0.36$T

$$I = \frac{E}{R}$$

$= \frac{0.36}{4.0} = 0.090A$ A1

(ii) *b*. Induced e.m.f. flows from lower to higher potential. B1

(iii) When the rod is moving at constant speed, due to the cutting of magnetic flux, there will be an induced current through it. The direction of the induced current will be such that there will be a magnetic force to oppose the motion causing it. B1 B1

Therefore, to keep the rod moving at constant speed, a force needs to be applied

(iv) Work done by external force = Electrical energy supplied to keep charges moving / heat dissipated by current in the resistor R / joule heating in resistor R B1

(v) $F = BIL$

$= 0.080\ (1.5)(0.090)$ M1

$=0.0108$ N A1

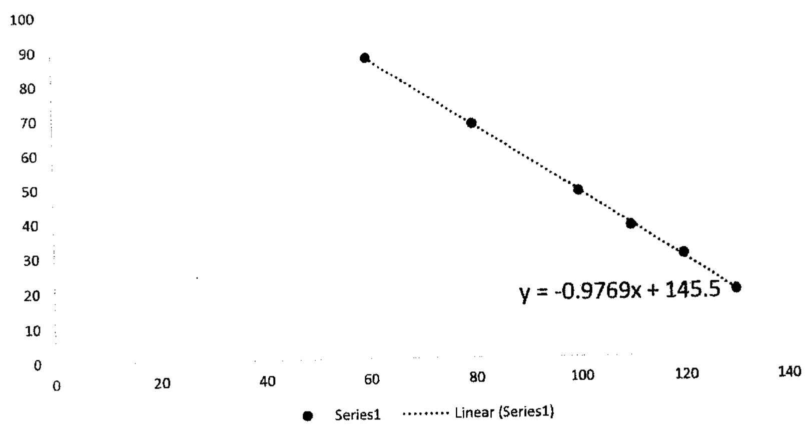
Mark Scheme

Question	Answer	Marks
1(a)(i)	current recorded to correct 1 d.p. in mA (setting of digital ammeter)	1
(ii)	$\frac{1}{I}$ recorded in the same s.f. as recorded in the corresponding I.	1
(iii)	percentage uncertainty calculated correctly using appropriate method and given to 1 or 2 s.f. E.g. I = 70.4 mA, $\frac{1}{I}$ = 14.2 A^{-1} Using $\frac{\Delta(\frac{1}{I})}{1/I} = \frac{\Delta I}{I}$, so percentage uncertainty = $\frac{\pm 2}{70.4} \times 100\% = \pm 2.8\%$ *or* $\pm 3\%$ Alternative or max $\frac{1}{I} = \frac{1}{68.4}$ = 14.6 A^{-1} taking difference with $\frac{1}{I}$ = 14.2 A^{-1} So absolute uncertainty can be estimated as ± 0.4 A^{-1}, so percentage uncertainty = $\frac{\pm 0.4}{14.2} \times 100\% = \pm 2.8\%$ *or* $\pm 3\%$	M1 A1
(b)	gradient = $\frac{R}{E}$ intercept = $\frac{r}{E}$	1
(c)(i)	correctly plotting of points with acceptable best fit line drawn	1
(ii)	correct method to calculate gradient	1
	correct method to calculate intercept	1
(iii)	$\frac{R}{r}$ obtained by $\frac{gradient}{intercept}$	1
(iv)	line parallel to original line and shifted upwards (or to the left)	1

Question	Answer	Marks
2(a)	• L = 98.5 ± 0.1 cm	1
(b)	• y_2 lesser than y_1 • y, y_2 and y_1 are all recorded to the nearest 0.1 cm • Repeated measurements	1
(c)	Tabulation • Collected 5 sets of data for m, y_1 and y_2. • Correct trend (0 marks for 4 sets and fewer)	1
	Column Heading • Each column heading must contain a **quantity and a unit**: y/cm, m/g • No split table	1
	Raw data (i.e x and I): Precision of recording • All values of y_1 and y_2 to nearest mm & • All values of m to nearest g	1
	Calculated quantity: Accuracy of calculation All values of y calculated correctly with the correct d.p	1
(d)	Graph: Scale, Size & Axes • Sensible scales, no awkward scales (eg 3 units into 10 small squares) • Plotted pts occupy at least ½ **the graph grid in both x & y directions** • Axes labelled with the quantity & unit {ECF for wrong units in (c)} Successive scale markings: no more than 20 small squares apart.	1
	Plotting of Points • ALL observations in table must be plotted • accurate to within half a small square. • **Thickness of plots** (ie the crosses, 'x') ≤ half a small square	1
	Best fit line & Anomaly • **Minimum number of 4** non-anomalous points. • Line drawn with **approx. equal number** of points on either side of line (anomalous points not considered). • Line not be kinked/disjointed or thicker than half a small square • Anomalous plot **clearly indicated** (eg by a circle or labelled.) • Allow 1 anomalous plot only.	1

	• {Rule of thumb: A plot is considered anomalous if it is > 4 mm from line of best fit.}	
	<u>Determination of Gradient</u> □ Recorded the **4 coordinates** for gradient calculation **correctly** □ Hypotenuse of triangle **> half length** of line drawn □ **No obscurity** of the 2 points used for gradient calculation. {Hence triangle must not be drawn too near a data plot.}	1
	<u>Determination of y-intercept</u> Vertical intercept calculated using a <u>point on the line</u> {not from the table} & value of gradient. {Allow reading off the y- intercept if x-axis starts from zero & there is no 'bunching of plots'}	1

m/g	y1/cm	y2/cm	y/cm
60	90.0	84.0	87.0
80	70.0	65.0	67.5
100	51.0	44.0	47.5
110	40.2	34.5	37.4
120	34.0	24.0	29.0
130	24.0	13.0	18.5



Question	Answer	Marks
3(a)(ii)	value of d to nearest 0.01 mm and final value in range 1.50 – 1.70 mm show repeated readings	1
3(a)(iii)	value of θ to nearest degree and final value in range 55°–65°	1
3(a)(iv)	$\Delta\theta$ range from $\pm3°$ to $\pm5°$ percentage uncertainty given to 1 or 2 s.f.	1
3(a)(v)	correct calculation of $\sin^2(\theta/2)$ using values from (a)(iii) substitution of values in your working is needed correct significant figures no units	1
3(b)(i)	Value of e to nearest 0.1 cm and final value in range 0.8 – 1.6 cm. Δe range from $\pm$ 0.2 cm to $\pm$ 0.5 cm percentage uncertainty given to 1 or 2 s.f. clear working and substitutions correct significant figures correct units	2
3(b)(iii)	value of t in range 15.00 – 20.00 s show repeated readings <u>All</u> t values to nearest 0.01 s	1
3(c)	value of θ to nearest degree and final value in range 25°–35° correct calculation of $\sin^2(\theta/2)$ value of t in range 7.00 – 9.00 s show repeated readings for values of t <u>All</u> t values to nearest 0.01 s correct significant figures correct units	2
3(d)(i)	Two values of k calculated correctly. correct significant figures correct units	2
3(d)(ii)	Testing against percentage uncertainty in (a)(iv) and (b)(i) with appropriate conclusion. Do not accept arbituary criterion such as 10% or 20%	1

3(d)(iii)	spring constant of spring / length of wire / mass of wire / angle θ between the straight part of the wire	1
3(e)	• Setup according to Fig. 3.2 and conduct oscillations according to Fig. 3.3. Appropriate procedures with mention of variation of masses and collect corresponding values of t. Conduct at least 6 sets of data for masses and t. • Identify masses attached to end of wire as independent variable, time as dependent variable. Angle of bend, length of wire, spring constant, etc as controlled variable. • Identify stopwatch to record timing and protractor to measure angle. (optional: mass balance to measure calibrated masses). • Plot a graph of time against mass to determine constant gradient of the graph and zero y-intercept. • Light masses may result in unstable oscillating behaviour of the wire / Heavy masses may fall off the wire during oscillating (or not able to conduct experiment since the spring is deformed due to heavy masses)	5
3(f)(i)	values of t (no mass) is less values of t (with mass) Use a table to present the results. Repeats: At least two values of $t \geq 10$ s <u>All</u> t values to nearest 0.01 s correct significant figures correct units	3
3(f)(ii)	When masses are attached to the end of the wire, <u>the centre of gravity shifted lower/away from the pivot point.</u> Since <u>period is proportional to the distance between the pivot and the centre of gravity</u> for a simple oscillating object about the vertical plane, the period increases when masses are added.	1

Qn	Answer	Marks
4	**Diagram**	
	labelled diagram with • retort stand to hold capillary tube; • h labelled; container resting on bench. (Include rule if mentioned in procedure)	1
	Defining the problem	
	Part 1 r is the independent variable and h is the dependent variable or vary r measure h. <u>and</u> density of liquid to be kept constant.	1
	Part 2 ρ is the independent variable and h is the dependent variable or vary r measure h. <u>and</u> r to be kept constant.	1
	Methods to data collection	
	Measure <u>inner</u> diameter d using travelling vernier microscope or allow estimate diameter d by measuring <u>external</u> d using micrometer screw gauge or vernier caliper <u>and</u> $r = d/2$	1
	Measure volume of water using measuring cylinder Measure mass of water using electronic balance. Calculate density using mass / volume (accept measure density using hydrometer)	1
	Measure h using <u>tail</u> of vernier caliper or metre rule clamped vertically.	1
	Method of varying density of liquid. E.g. changing different types of liquid or add solute into solvent. Need to give examples of solute used.	1
	Method of analysis	
	Part 1 Plot $\lg h$ vs $\lg r$; p= gradient	1
	Part 2 Plot Plot $\lg h$ vs $\lg \rho$; q = gradient	1

	Additional detail including safety considerations	max 3
	• Method of ensure capillary tube and instruments used to measure *h* is vertical. E.g. **use of plumbline** or **use set square**	1
	• Ways to check if cross-section of capillary tube is constant. E.g. pass a fixed volume of coloured liquid through tube. Check if length of coloured liquid is constant.	1
	• check that the temperature is constant throughout experiment to <u>prevent expansion or contraction of capillary tube.</u>	1
	• Method to exclude mass of container. E.g. use 'tare' function or subtract mass of empty container.	1
	• take preliminary readings for radius <u>and/or</u> density to obtain range that gives significant variation in *h*. Other good answers • colour the liquid to aid measurement of *h*.	1 1
	Safety: • way to handle broken glass capillary tube. E.g. wear gloves to handle broken glass. *(thick cloth glove should be used, not thin latex glove.)* • way to prevent breaking glass capillary tube. E.g. using foam to cushion clamp. • way to prevent spillage. Eg. put a cloth or container under the beaker. • cloth to wipe off spilled oil/water	max 1
	<u>No marking value (NMV)</u> unrealistic for this experiment - methods pertaining wearing of boots. - methods pertaining electric shock. - methods pertaining splashes of liquid. common expectation in procedure that should be done anyway. - wearing of goggles. - take average of several readings - clean and dry containers and tubes	