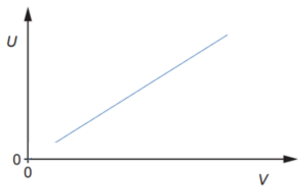
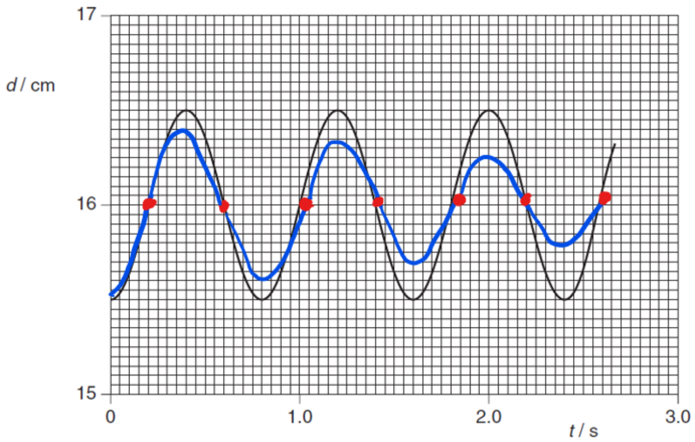
JC2 Prelim (H2 Physics) Paper 3 Solutions

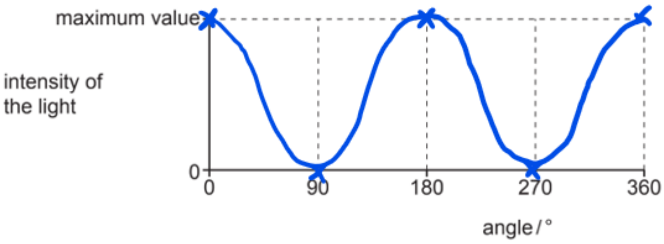
1 (a)(i)	Period of Earth, T = 24 x 3600 s (= 86 400 s) Angular velocity ω = 2π/T = 7.27 x 10^{-5} rad s^{-1} (shown)	[1]
(a)(ii)	a = rω^2 = (6.38 x 10^6) x [Ans in (b) (i)]^2 = 0.0337 m s^{-2}	[1] [1- ecf]
(b)(i)	● There is circular motion at the equator but not at the poles, ● At the equator, part of the gravitational force is used to provide the centripetal force (required to keep any mass located there in circular motion, centripetal force is provided by the gravitational force of Earth) (Hence only the remaining part of the gravitational force is available to provide the acceleration of free fall.) Or ● Gravi force of Earth = (mg + $ma_c)_{equa}$ = (mg + $ma_c)_{pole}$. [1] ● Since $a_{c\ at\ pole}$ = 0, g_{pole} > g_{equa} , ie g is different for the 2 locations[1] Note: g = acceleration of free fall as defined by the question not gravitational field strength. Be careful in use of symbols.	[1] [1]
(b)(ii)	● Value of *g*, at the pole is 9.81 m s^{-2} ● Since centripetal acceleration at equator (in b(ii)) is 0.0337 m s^{-2} , compared to 9.81 m s^{-2}, the difference in g at these 2 locations is small.	[1] [1]
(c)(i)	The gravitational force of attraction between two point masses is proportional to the product of their masses and inversely proportional to the square of their separation.	[1]
(c) (ii)	(By Newton's law), Gravitational force on a (point) mass *m* at Earth's surface, F = $\frac{GMm}{R^2}$ Since field strength *g* is the gravitational force per unit mass at that point, g = F/m = $\frac{GM}{R^2}$	[1] [1]
(d)(i)	●{ Since the gravitational force provides the centripetal force, } $\frac{GMm}{r^2}$ = mrω^2 {where r = dist of satellite fr Earth's centre}	[1]

	(□ $r^3 = GM/\omega^2$, not assessed) -- (1)	
	●From **(c),** $GM = gR^2$ -- (2) { R = Earth's radius }	[1]
	(2) into (1): ($r^3 = gR^2/\omega^2$, not assessed)	
	●Substituting, $r = 4.23 \times 10^7$ m {$g = 9.81$ m s^{-2}, $R = 6.38 \times 10^6$ m, $\omega = 7.27 \times 10^{-5}$ rad s^{-1}}	[1]
(d)(ii)	1. Satellite lies on the equatorial plane of the earth	[1]
	2. Satellite rotates/revolves from west to east or, following the Earth's rotation	[1]

2(a)	Volume decreases ; hence w is positive (or small volume change so w is 0)	[1]
	As the ice changes state, heat must have been supplied; hence q is positive.	[1]
	internal energy increases	[1]
(b)	gas expands/increase in volume with work done by gas (against atmosphere) or w is negative	[1]
	the sudden increase leaves little time/no time for thermal energy to enter and leave the gas or q = 0	[1]
	internal energy decreases	[1]

3(a)	molecule(s) rebound from wall of vessel / hits walls/ collide	[1]
	change in momentum gives rise to impulse / force	[1]
	average change in momentum/impulse gives rise to the average (constant) pressure/force.	[1]
(b)	$p = 1/3\ \rho <c^2>$ $1.02 \times 10^5 = 1/3 \times 0.900 \times <c^2>$	[1]
	$<c^2> = 3.4 \times 10^5$ $c_{rms} = 580$ m s^{-1}	[1]
(c)	Straight line with positive gradient Line passing through origin (can never reduce the volume to zero thus the graph need not be shown passing through the origin) 	[1]

4(a)	amplitude = 0.50 cm	[1]
b(i)	T = 0.8 s $\omega = 2\pi / T$ $= 7.85 \text{ rad s}^{-1}$ $v = \omega \sqrt{(x_0^2 - x^2)}$ $= 7.85 \times \sqrt{(\{0.5 \times 10^{-2}\}^2 - \{0.2 \times 10^{-2}\}^2)}$ $= 3.6 \text{ cm s}^{-1}$	[1] [1 – ecf for (a)] [1 – ecf for (a)]
(ii)	d = 15.8 cm	[1]
(c)	• same period { Accept: small increase in period) • (For same period) : displacement of damped oscillator is always smaller than that on Fig.4.2 (ignore first T/4) • peak decreases (exponentially) with time  	[1] [1] [1]

5 (a)(i)	light intensity has maximum value at 0°, 180°, 360° and zero intensity at 90°, 270° ‘sinusoidally-shaped’ curve of constant amplitude 	[1] [1]
(a)(ii)	$I = I_0 \cos^2\theta$ $4.2 = 7.6 \cos^2\theta$ $\theta = 42°$	[1]
(b)	wave passes (through) an opening/gap/aperture or, wave passes (by / through / around) an obstacle/edge wave spreads (into geometrical shadow)	[1]
(c)	$n\lambda = d \sin\theta$ $d = (3 \times 4.3 \times 10^{-7}) / \sin 68°$ $= 1.4 \times 10^{-6}$ m $1.4 \times 10^{-6} \times \sin 68° = 2\lambda$ or, $3 \times 4.3 \times 10^{-7} = 2\lambda$ $\lambda = 6.5 \times 10^{-7}$ m	 [1] [1] [1]

<table>
<tr><td>6(a)(i)</td><td>From the graph, R = 80 Ω, T = 40 Ω at 120°C

$E = I R_T$
$3.0 = I (80 + 40)$
$I = 25 \times 10^{-3}$ A = 0.025 A</td><td>[1]

[1]</td></tr>
<tr><td>(ii)</td><td>(When the temperature increases from 0 oC to 75 oC,

magnitude of RATE of Increase of resistance of R is smaller than the

magnitude of RATE of Decrease of resistance of T.}
{Compare their gradients}

Thus, effective resistance decreases at a decreasing rate with respect to temperature.</td><td>[1]</td></tr>
<tr><td>(iii)</td><td>From graph at 30 °C,
resistance of R = 55 ∧ and resistance of T = 110 ∧

By potential divider rule,
p.d. across T = (R_T / R_{total}) x 3.0 V = (110/110+55) X 3.0 = 2</td><td>[1]

[1]</td></tr>
<tr><td>(b) (i)</td><td>faulty lamp: lamp E

nature of fault: lamp fused/ fuse melt/broken filament</td><td>[1]

[1]</td></tr>
<tr><td>(ii)</td><td>Resistance of one non-faulty lamp = 30.0 / 2 = 15.0</td><td>[1]</td></tr>
<tr><td>(iii)</td><td>
<table>
<tr><th colspan="3">switch</th><th rowspan="2">ohm-meter reading / Ω</th></tr>
<tr><th>S_1</th><th>S_2</th><th>S_3</th></tr>
<tr><td>open</td><td>open</td><td>open</td><td>∞</td></tr>
<tr><td>closed</td><td>open</td><td>open</td><td>30.0</td></tr>
<tr><td>closed</td><td>closed</td><td>open</td><td>25.0</td></tr>
<tr><td>closed</td><td>closed</td><td>closed</td><td>15.0</td></tr>
</table>
</td><td>- 1 mark for each mistake</td></tr>
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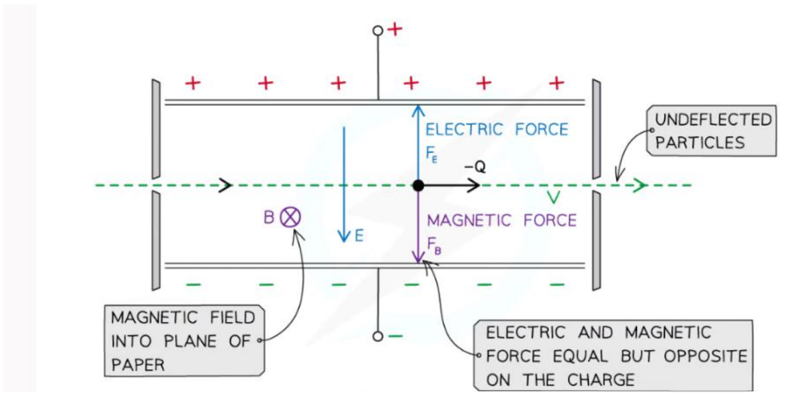
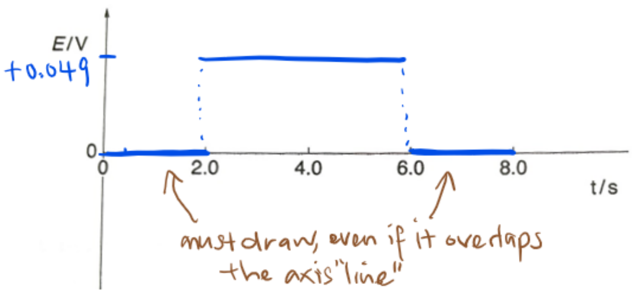
7(a)	Since F = - dEp/dx & dEp/dx is the gradient of graph. Hence force is proportional to the gradient of the curve.	[1] [1]
(b)(i)	Since all values of E_p are negative (Fig 7.2), & $E_P = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r}$ E_p is negative only if the 2 pt charges are of opposite sign. or F = -dE_p/dx Since dE_p/dx is positive, (fr Fig 7.2), F is negative. Since a negative F indicates an attractive force between the charges, the charges are of opposite sign.	[1] [1]
(ii)	When Q_p is doubled: Since $E_P = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r}$, E_p is doubled at every x. Thus gradient would be doubled/increased/become steeper. or, since F = $Q_p Q_Q$ / $(4\square\sum_0 x^2)$, F is doubled for every x. & F = - gradient of graph, gradient is doubled at every x.	[1] [1]
(c)	$E_p = \frac{(charge\ of\ P)(charge\ of\ Q)}{4\pi\varepsilon_o r}$ Since (charge of P) x (charge of Q) = constant E_p 1/r E_p = - 3.6 eV at $x = 4 \times 10^{-10}$ m E_p = - 5.1 eV at x = r 3.6/5.1 = r / 4×10^{-10} r = 2.82×10^{-10} m	 [1] [1]

8 (a)(i)	 1 mark for each of 4 pts: 1. Correct directions of uniform E & uniform B fields for a charge particle of a stated sign 2. Correct directions of electric force F_E & magnetic force F_B (they are in opposite directions) 3. Stated $F_E = F_B$ (mag) (to be undeflected & hence exit slit S_3 & be selected) 4. ie $B\,q\,v = q\,E$ { essential } ® $v = \frac{E}{B}$ { essential }	[4]
(b)(i)	• As coil rotates, there is a change in flux (linkage) • due to a change in the area of the coil perpendicular to B field By Faraday's law, an emf is induced (when there is a change in flux linking the coil)	[1] [1]
(ii)	{ For a coil rotating in a B field, instantaneous E = NBAω cos ωt . Hence max emf = NBAω } Any 2 of 4: number of turns, (magnetic) flux density, area of coil & angular velocity/speed of rotation	[2]
(iii)	1. Flux varies sinusoidally with time or, ϕ = BAcosθ where θ = angle between *B* and normal to plane of the coil. 2. By Faraday's law/since induced emf E is equal/proportional to the rate of change of flux linkage, ie Emf = $\frac{d(N\phi)}{dt}$ = NBAω sinθ.	[1] [1]
(c)(i)	E = $\frac{d(N\phi)}{dt}$ = N [$B_i - B_f$] A ÷ ⊗t = 15 [0.018 – 0] (30 x10^{-2}) x (24 x 10^{-2}) ÷ { 6.0 s – 2.0 s } = 4.86 x 10^{-3} = 4.9 x 10^{-2} V	[1] [1]

(ii)	● From 0- 2.0 s, 6.0 – 8.0 s: horizontal line at zero V ● From 2.0 – 6.0 s: horizontal line at +0.049 V, value of “0.049 V” (or 0.50 V) indicated on E- axis (ecf) 	[1] [1]
(d)(i)	Emf induced across axle, V = $(B \sin \theta) Lv$ { straight rod } $= (6.0 \times 10^{-5}) \sin 65^0 \times 1.5 \times 30.0$ $= 2.45 \times 10^{-3}$ V Rate = V^2/ R $= (2.45 \times 10^{-3})^2 / 0.400$ { ecf for V } $= 1.50 \times 10^{-5}$ W	 [1] [1] [1] [1]
(ii)	By Fleming’s Left Hand Rule, the electrons in the axle are deflected by a force towards D, making D the end with a negative potential. Hence C is at a higher potential, or, By Lenz’s law, the (induced) current in CD must flow in such a direction as to oppose the (rightward) motion of the rod; (hence with LEFT Thumb (induced force) pointing to left), by Fleming’s LHR, the (induced) current will flow from D to C. Since rod is an emf source, C is at a higher potential.	[1] [1] [1] [1]

9(a)(i)	discrete/ packet / quantum_of energy of electromagnetic radiation	[1] [1]
(a)(ii)	wavelength = (6.63 x 10^{-34}) / (9.5 x 10^{-28}) = 700 x 10^{-9} m so red	[1] [1]
(a)(iii)	pressure = force / area force = rate of change of momentum = 2 x 9.5 x 10^{-28} x 1.4 x 10^{15} pressure = (2 x 9.5 x 10^{-28} x 1.4 x 10^{15}) / (2.5 x 10^{-6}) = 1.1 x 10^{-6} Pa	 [1] [1]
(b)(i)	greater photon energy (hf) and same work function (Φ) so by hf = Φ + KE_{max} maximum kinetic energy is increased	[1] [1]
(b)(ii)	By I = Nhf/At or *P = N(hf)/ t*, greater photon energy (and same power) so lower number of photons (per unit time) each electron absorbs/interacts with one photon so lower rate of emission	[1] [1]
(c)(i)	(Electron) diffraction	[1]
(ii)	Diffraction is a wave phenomenon electron can behave as a wave / have wave-like property	[1] [1]
(d)	• photon absorbed (by electron) and electron excited • photon energy equal to difference in (energy of two) discrete energy levels • photon energy relates to a single wavelength / single frequency • electron de-excites and emits photon in any direction (only some reach the screen)	[1] [1] [1] [1]
(e)	$\frac{hc}{\lambda} = \Delta E$ ⊗E = $E_3 - E_2$ $\frac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{658 \times 10^{-9}} = E_3 - (-3.40 \times 1.6 \times 10^{-19})$ {As $E_3 - E_2$ is the lowest energy of all the transitions down to E_2, thus ⊗E = hc/⎿ corresponds to that of the longest wavelength} E_1 = –2.42 x 10^{-19} J	 [1 mk per eqn side] [1]

End of solutions