Paper 1 Section A

Question No.	Key	Question No.	Key
1.	C (66)	26.	D (26)
2.	C (65)	27.	C (65)
3.	A (68)	28.	C (61)
4.	A (69)	29.	D (59)
5.	C (64)	30.	C (39)
6.	B (50)	31.	A (36)
7.	B (62)	32.	A (35)
8.	B (47)	33.	D (60)
9.	D (40)		
10.	D (33)		
11.	B (81)		
12.	A (61)		
13.	A (66)		
14.	D (41)		
15.	B (58)		
16.	D (50)		
17.	A (45)		
18.	D (61)		
19.	C (54)		
20.	A (39)		
21.	B (73)		
22.	D (33)		
23.	A (32)		
24.	B (44)		
25.	C (46)		

Note: Figures in brackets indicate the percentages of candidates choosing the correct answers.

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Paper 1 Section B

Solution	Marks	Remarks
1. (a) (i) $\frac{140.51-102.00}{100-0}=\frac{R-102.00}{60-0}$	1M	
$R=38.51\times\frac{60}{100}+102$		
$= 125\ \Omega\ (125.106\ \Omega)$	1A	
	2	
(ii) lower than 60 °C.	1A	
	1	
(b) specific heat capacity = $\frac{\text{heat provided}}{\text{mass of water} \times \text{temp. rise}}$ $\left[c=\frac{E}{m\Delta T}\right]$		
Since the actual final temperature is lower than 60 °C when heating is stopped, <u>or</u> actual $\Delta T < 60$ °C,	1A	
<u>Or</u> heat provided is actually less than it should be when really reaching 60 °C	1A	
the specific heat capacity is smaller than it should be.	1A	
	2	
2. (a) 210 atm × (1.0 × 10^4 cm^3) = 2.0 atm × V	1M	Accept ans. without considering residual volume, i.e. 1.05 × 10^6 (cm^3)
V = 1.05 × 10^6 cm^3		
Volume available = 1.05 × 10^6 – 1.0 × 10^4		
= 1.04 × 10^6 (cm^3)	1A	
	2	
(b) (i) V_0 = 1.04 × 10^6 cm^3 ÷ 60	1M/1A	V_0 = 17500 (cm^3) if residual volume not considered.
= 17333 ≈ 17300 (cm^3) (per minute)		
	1	
(ii) V' : total volume of air at this depth/in this situation		V' = 4.60 × 10^5 cm^3 and length of time = 26.3 min. if residual volume not considered.
$\frac{P_1V_1}{T_1}=\frac{P_2V'}{T_2}$		
$\frac{210\times(1.0\times10^4)}{273+24}=\frac{4.5\times V'}{273+20}$	1M	
V' = 4.60 × 10^5 cm^3		
Volume available = 4.60 × 10^5 – 1.0 × 10^4		
= 4.50 × 10^5 (cm^3)		
Length of time :		
$=\frac{4.50\times10^5}{17333}$	1M	
= 26.0 (min.)	1A	
	3	

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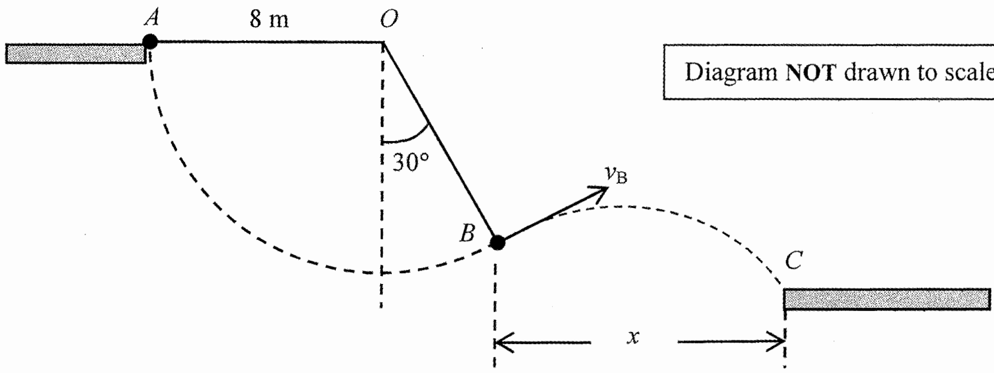
Solution	Marks	Remarks
3. (a)		



v_B correctly drawn with label (roughly perpendicular to OB).	1A	
$\frac{1}{2}mv^2 = mgh$		
$v_B^2 = 2gh = 2 \times 9.81 \times (8\cos 30°)$	1M	
$v_B = 11.7\ \text{m s}^{-1}$ (11.65896) (or $11.77\ \text{m s}^{-1}$ for $g = 10\ \text{m s}^{-2}$)	1A	
	3	
(b) (i) $x = v_x t = 11.7\cos 30° \times 1.25$ [$v_x = v_B \cos 30°$]	1M	
$= 12.6$ m (12.62119)	1A	
(or 12.7 to 12.8 m for $g = 10\ \text{m s}^{-2}$)		
	2	
(ii) $y = ut - \frac{1}{2}gt^2$		
$u = v_y = v_B \sin 30° = 5.83\ \text{m s}^{-1}$	1M	
$y = v_y(1.25) - \frac{1}{2}(9.81)(1.25)^2$	1M	
$y = -0.38$ m (-0.414 to -0.352 m)	1A	
(or -0.455 to -0.4375 m for $g = 10\ \text{m s}^{-2}$)		
Platform C is 0.38 m below B.	3	
(c) Total mechanical energy is the same / unchanged.	1A	
	1	

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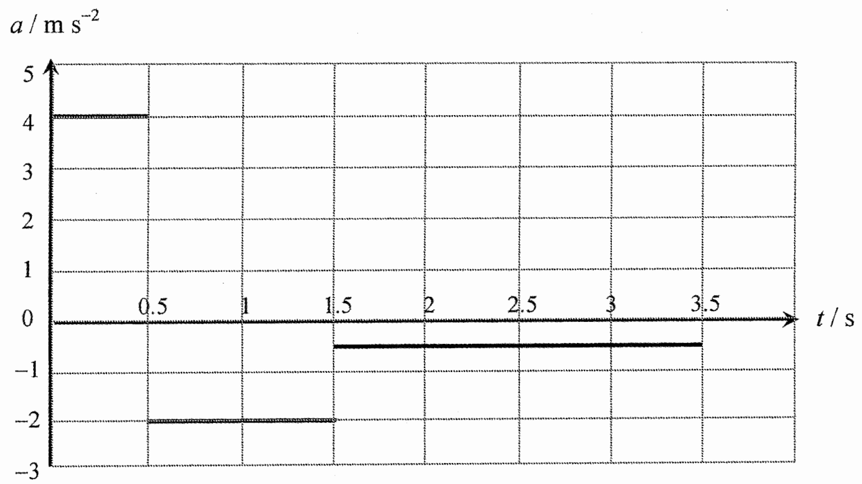
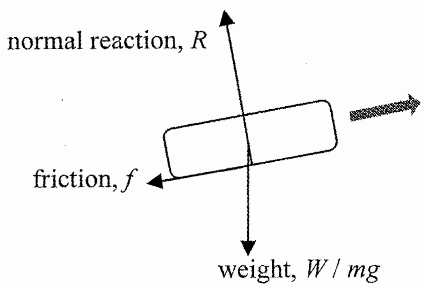
<table>
<tr><th>Solution</th><th>Marks</th><th>Remarks</th></tr>
<tr><td>4. (a) The block decelerates uniformly (until at rest or its velocity is zero at $t = 1.5$ s).
It then moves with uniform acceleration down the plane (until $t = 3.5$ s).</td><td>1A
1A
2</td><td></td></tr>
<tr><td>(b) (i) $a_2 = \left\| \frac{-1-0}{3.5-1.5} \right\|$
$= 0.5 \text{ m s}^{-2}$</td><td>1M
1A
2</td><td></td></tr>
<tr><td>(ii)


Either acceleration correct
All correct</td><td>1A
1A
2</td><td></td></tr>
<tr><td>(c)


Friction correctly indicated
All correct</td><td>1A
1A
2</td><td></td></tr>
<tr><td>(d) Moving upward : $-mg \sin\theta - f = ma$
$-(1)(9.81) \sin\theta - f = (1)(-2)$……………… ①
Moving downward : $-mg \sin\theta + f = ma'$
$-(1)(9.81) \sin\theta + f = (1)(-0.5)$……………… ②
② − ① : $2f = 1.5$
$f = 0.75$ N
(Note: $\theta = 7.32°$)</td><td>1M
1M
1A
3</td><td></td></tr>
</table>

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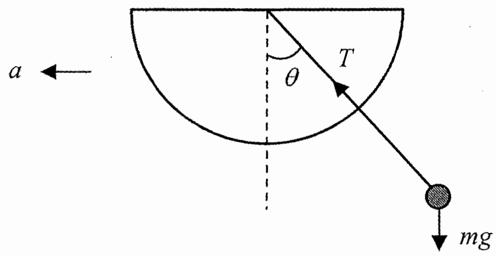
Solution	Marks	Remarks
5. Diagram 	1A	
Tie one end of the string to the metal ball and the other end through the centre/hole of the protractor.	1A	
When the train is at rest, held fixed the protractor in the plane along the direction of motion such that the string is on, say, the 90° mark.	1A	
When the train is accelerating with acceleration a, the string will make an angle, say θ, with the vertical. Measure the angle θ.	1A	
Let T be the tension of the string, Vertically : $T\cos\theta = mg$ .... ① Horizontally : $T\sin\theta = ma$.............. ② where m is the mass of the ball	1M	
$\frac{②}{①}$: $\tan\theta = \frac{a}{g}$ $a = g\tan\theta$	1A	
	6	

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Solution	Marks	Remarks
6. (a) - high temperature gradient; <u>or</u> - long path lengths for light rays.	1A	
<u>Or</u> total internal reflection occurs.	1A	
	1	
(b) (i) $n_1 \sin\theta_1 = n_2 \sin\theta_2 = n_3 \sin\theta_3 = n_4 \sin\theta_4$	1M	
$\sin\theta_1 = \frac{n_4}{n_1}\sin\theta_4$		
$\theta_1 = \sin^{-1}(\frac{1.000221}{1.000261})$	1M	
$= 89.5° \ (89.488°)$	1A	
	3	
(ii) $\frac{h}{L} = \tan\alpha = \frac{1}{\tan\theta_1}$	1M	
$L = h\tan\theta_1 = 1.5\tan 89.5° = 167.72$		
$= 168$ m	1A	Accept 167.7 m to 172.0 m
<u>Or</u> $L = \frac{h}{\tan\alpha} = \frac{1.5}{\tan 0.5°} = 171.88$	1M	
$= 172$ m	1A	
	2	
(c) The same distance away (168 m) because	1A	
the illusion of 'water source' is caused by reflection of the light of distant objects at the same fixed angle. [i.e. $\alpha = 90° - 89.488° = 0.512°$ with the horizontal]	1A	
<u>Or</u> As long as the conditions for bending of the light and internal reflection are still the same,	1A	
the 'water source' remains 168 m away (satisfying the same conditions / angle of reflection).	1A	
	2	

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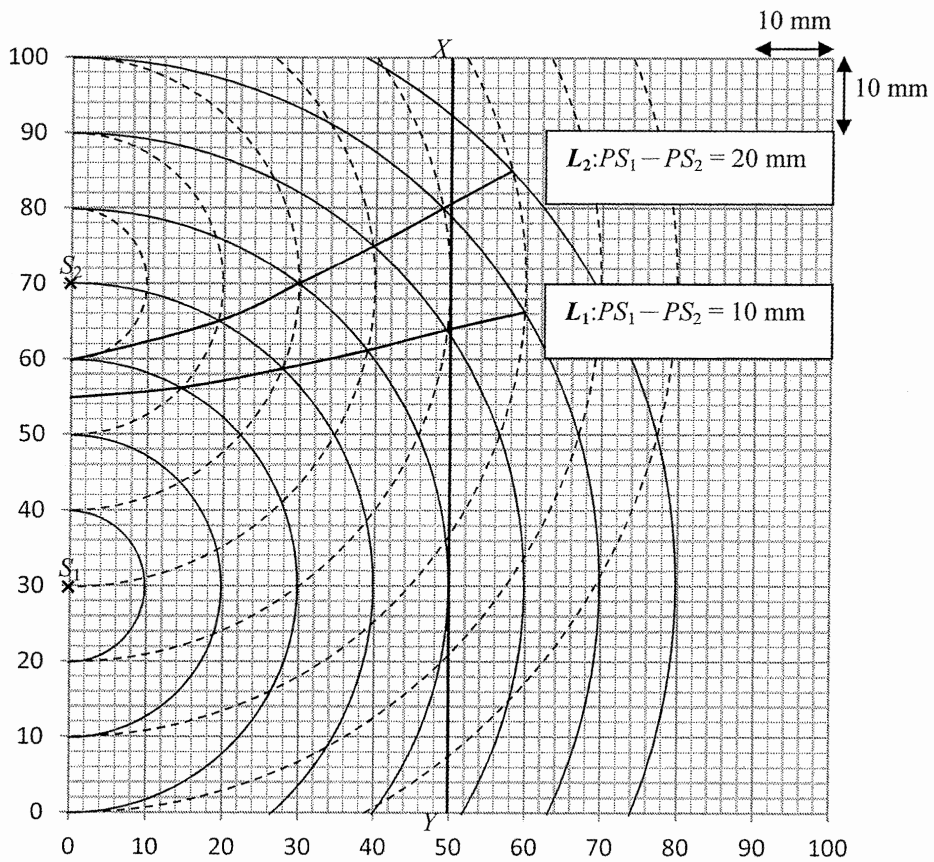
Solution	Marks	Remarks
7. (a) $\Delta y = \dfrac{\lambda D}{a}$	1M	
$= \dfrac{(650\times10^{-9})\times3.0}{0.325\times10^{-3}}$ $= 0.006$ m or 6 mm	1A	
	2	
(b) The screen is uniformly illuminated (The interference patterns exist very briefly and change rapidly such that, to human eyes, they are averaged out).	1A	NOT accept 'interference does not occur'.
The light from the LEDs is incoherent (i.e. no fixed phase relationship between the light coming out from the two LEDs).	1A	
	2	
(c) path difference $PS_1 - PS_2 = 10$ mm, L_1 correct.	1A	
path difference $PS_1 - PS_2 = 20$ mm, L_2 correct.	1A	
Constructive interference (occurs at P)	1A	
	3	



Solution	Marks	Remarks
(d) (i) $\Delta y = y_2 - y_1 = 31$ mm $- 14$ mm $= 17$ mm ± 2 mm	1A	
	1	
(ii) Screen has to be far away from slits or $D >> a$, (i.e. to satisfy $D >> y$ / consider y to be close to the central maximum)	1A	
Or screen is too close to slits or $D >> a$ not satisfied (i.e. $D >> y$ not satisfied)	1A	
Make use of small angle approximation ($\theta \approx$) $\sin\theta \approx \tan\theta$ / small angle approximation cannot be applied.	1A	
	2	

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Solution	Marks	Remarks
8. (a) (i) $\rho = \frac{RA}{l}$	1M	
$\frac{R}{l} = \frac{\rho}{A} = \frac{2.6\times10^{-8}}{1.3\times10^{-5}}$ $= 2.0\times10^{-3}\ \Omega\ \text{m}^{-1}$ $= 2.0\ \Omega\ \text{km}^{-1}$ or $2.0\ \Omega$	1A	
	2	
(ii) The strands of transmission lines are in parallel / The cross-sectional area of cable is larger than that of each transmission line / Resistance is inversely proportional to the cross-sectional area of the cable	1A	
$R_{\text{cable}} = \frac{R}{40} = 0.05\ \Omega\ \text{km}^{-1}$ or $0.05\ \Omega$ $(\frac{1}{R_{\text{cable}}} = \frac{1}{R} + \frac{1}{R} + \ldots + \frac{1}{R} \rightarrow \frac{1}{R_{\text{cable}}} = \frac{40}{R})$	1M	
	2	
(iii) The resistance of the bird's body is much larger than that of a short segment of the overhead cable.	1A	
Or The bird is in parallel with a short segment of the overhead cable. The potential difference across its feet is very small (very small resistance per km).	1A	
Hence, negligible current flows through the bird's body.	1A	
	2	
(b) (i) $I = \frac{P}{V} = \frac{180\times10^{6}}{400\times10^{3}}$	1M	
$= 450\ \text{A}$	1A	
	2	
(ii) Percentage of power loss $= \frac{P_{loss}}{P_{total}} \times 100\%$	1M	
$= \frac{450^2 \times 0.05 \times 10}{180\times10^{6}} \times 100\%$ $= 0.05625\ \% < 0.1\ \%$	1A	
	2	
(iii) (I) $N_p : N_s = V_p : V_s$ $12 : 1 = 400 : V_s$ $V_s = 33.3\ \text{kV}$	1A	
	1	
(II) Any **ONE** of the followings: Resistance of coils + use thicker wire for the coils / Magnetisation and demagnetisation of core + use soft iron core / Induced eddy currents in core + laminated core / Flux leakage + core design	1A+1A	
	2	

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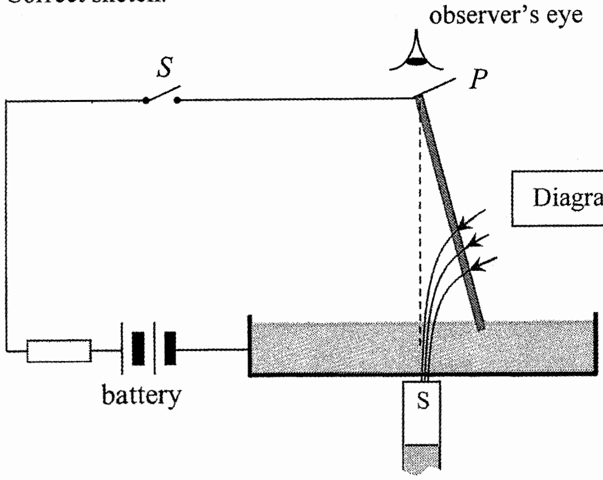
Solution	Marks	Remarks
9. (a) Right (current flowing downward, B-field into paper)	1A	
When the rod reaches the highest point it falls. Then its lower end touches the conducting liquid again and the same magnetic force makes it 'kick' out from the liquid. The process repeats so the rod continually 'kicks' out and then returns.	1A 1A	
	3	
(b) (i) As moment = $F \times d$		
7.2×10^{-4} N m = F (0.09 m)	1M	
$F = \dfrac{7.2 \times 10^{-4}}{0.09} = 8.0 \times 10^{-3}$ N	1A	
	2	
(ii) $F = BIl$	1M	
8.0×10^{-3} N = B (3.2 A) (0.06 m)		
$B = 0.042$ T	1A	
	2	
(c) (i) Correct sketch.  Diagram **NOT** drawn to scale	1A	
	1	
(ii) The rod will rotate anti-clockwise (as viewed from above).	1A	
Or The rod describes a conical pendulum.	1A	
	1	

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Solution	Marks	Remarks
10. (a) Mass deficit $= (2.014102 + 3.016049)\text{ u} - (4.002602 + 1.008665)\text{ u}$ $= 0.018884\text{ u}$	1M	
Energy released $= 0.018884 \times 931$ MeV $= 17.58$ (MeV)	1A	
Or Energy released $= 0.018884 \times 1.661 \times 10^{-27} \times c^2$ $= 2.823 \times 10^{-12}$ J or 17.64 MeV	1A	
	2	
(b) (i) To overcome the (electrostatic) repulsion between the two (positive) nuclei and	1A	
becomes electrical potential energy (of the two nuclei).	1A	
	2	
(ii) High temperature enables them to have sufficient kinetic energy (to overcome electrical repulsion between the nuclei).	1A	
	1	
(iii) Kinetic energy becomes electrical potential energy $E_p = 2 \times \frac{1}{2} m (c_{rms})^2 = 2 \times \frac{3RT}{2N_A}$	1M	Accept without the factor '×2'
$0.4\text{ MeV} = 2 \times (\frac{3 \times 8.31 \times T}{2 \times 6.02 \times 10^{23}})$		$0.4\text{ MeV} = 6.4 \times 10^{-14}$ J
$T = 1.545 \times 10^9$ K i.e. order of magnitude 10^9 (K)	1A	
Alternatively: $E_p = \frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{10^{-15}} = 2 \times \frac{3RT}{2N_A}$	1M	
$T = 5.56 \times 10^9$ K i.e. order of magnitude 10^9 (K)	1A	
	2	

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Paper 2

Section A : Astronomy and Space Science

1. A(34%)	2. C(53%)	3. D(57%)	4. B(46%)
5. B(40%)	6. C(60%)	7. A(46%)	8. D(52%)

Solution	Marks	Remarks
1. (a) (i) radial velocity is the component of the star's velocity along the observer's line of sight / velocity along the observer direction or the line joining the star and the observer.	1A	
	1	
(ii) Point *D*	1A	
	1	
(b) $v_1 = 180 \text{ km s}^{-1}$	1A	
$v_1 = \frac{2\pi r_1}{T} = \frac{2\pi r_1}{40\times 60\times 60}$ (Period $T = 40$ hr)	1M	
$r_1 = 4.125 \times 10^6$ km or 4.125×10^9 m	1A	
From figure, $v_2 = 120 \text{ km s}^{-1}$; and by ratio or similar calculation gives $r_2 = 2.75 \times 10^6$ km or 2.75×10^9 m	1A	
	4	
(c) $\frac{Gm_1m_2}{(r_1+r_2)^2} = m_1(\frac{2\pi}{T})^2 r_1 = \frac{m_1v_1^2}{r_1}$ $[\omega = \frac{2\pi}{T}]$ $\frac{(6.67\times10^{-11})\,m_2}{(4.125\times10^9+2.75\times10^9)^2} = \frac{(180\times10^3)^2}{4.125\times10^9}$	1M	
Therefore, $m_2 = 5.57 \times 10^{30}$ kg	1A	
	2	
(d) $\frac{v_r}{c} = \frac{\Delta\lambda}{\lambda} = \frac{0.5\text{ nm}}{656.28\text{ nm}} \Rightarrow v_r = 228.3 \text{ km s}^{-1} > 180 \text{ km s}^{-1}$;	1M	
Or $\frac{\Delta\lambda}{\lambda} = \frac{v_r}{c} = \frac{180\times10^3}{3\times10^8} \Rightarrow \Delta\lambda = 0.394 \text{ nm} < 0.5 \text{ nm}$;	1M	
therefore NOT suitable. Accept using 120 km s^{-1}, $\Delta\lambda = 0.263 \text{ nm} < 0.5 \text{ nm}$	1A	
	2	

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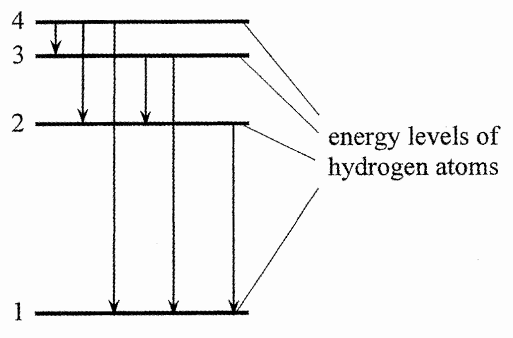
Section B : Atomic World

1. D(40%)	2. A(42%)	3. D(62%)	4. B(66%)
5. C(47%)	6. C(44%)	7. A(42%)	8. B(36%)

Solution	Marks	Remarks
2. (a) - the electron is considered as a particle revolving around the nucleus in definite orbits/circular motion; or - the centripetal force is provided by the Coulomb force; or - the electron's motion obeys Newton's laws of motion	1A	
	1	
(b) lowest energy level or most stable state	1A	
	1	
(c) $p=\frac{h}{\lambda}=\frac{hc}{\lambda}\cdot\frac{1}{c}$	1M	
$p=\frac{E}{c}$	1A	
	2	
(d) (i) $E_4=-\frac{13.6}{4^2}=-0.85\text{ eV}$, $\Delta E_{1\to 4}=E_4-E_1=-0.85-(-13.6)=12.75\text{ eV}$ $E_5=-\frac{13.6}{5^2}=-0.544\text{ eV}$, $\Delta E_{1\to 5}=E_5-E_1=-0.544-(-13.6)=13.056\text{ eV}$	1M	
12.75 eV < 12.9 eV < 13.06 eV, therefore at most to the 3rd excited state (n = 4).	1A	
Alternatively : $\Delta E=E_n-E_1=-13.6\left(\frac{1}{n^2}-\frac{1}{1^2}\right)=12.9\text{ eV}$	1M	
n = 4.41 and as n is an integer, it can at most take n = 4 (3rd excited state).	1A	
	2	
(ii) $mvr_n=\frac{nh}{2\pi}\Rightarrow 2\pi r_n=\frac{nh}{mv}=n\lambda$ (from postulate)	1M	
When n = 4, $2\pi(0.053)(4^2)=4\lambda$ Therefore, λ = 1.33 nm	1A	
Alternatively: $r=(0.053)\,4^2\text{ nm}=0.848\text{ nm}=8.48\times10^{-10}\text{ m}$	1M	
$\frac{1}{4\pi\varepsilon_0}\cdot\frac{e^2}{r^2}=\frac{mv^2}{r}\Rightarrow v^2=\frac{1}{4\pi\varepsilon_0}\cdot\frac{e^2}{r}\cdot\frac{1}{m}=9\times10^9\times\frac{(1.6\times10^{-19})^2}{8.48\times10^{-10}}\cdot\frac{1}{9.11\times10^{-31}}$ $\Rightarrow v=5.46\times10^5\text{ m s}^{-1}$		
$\lambda=\frac{h}{mv}=\frac{6.63\times10^{-34}}{(9.11\times10^{-31})(5.46\times10^5)}=1.33\times10^{-9}\text{ m}=1.33\text{ nm}$	1A	
	2	
(iii) 	2A	
	2	

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Section C : Energy and Use of Energy

1. A(33%)	2. D(50%)	3. B(67%)	4. C(21%)
5. B(28%)	6. C(28%)	7. C(47%)	8. A(32%)

Solution	Marks	Remarks
3. (a) (i) Time required $= \dfrac{\text{heat to remove } (mc\Delta T)}{\text{cooling capacity}}$	1M	
$= \dfrac{[(20.0\times3.0)\times1.2]\times1000\times(33-25)}{6.80\times1000}$		
$= \dfrac{576000}{6800} = 85$ s (1.42 min. or 0.0236 hr)	1A	
	2	
(ii) **ANY ONE**: Heat has to be removed from wall, furniture etc. / Heat transferred from outside to the room has to be removed / Other reasonable factors such as bad air ventilation for air-conditioner / Doors or windows are not closed properly / Installation position is facing west or exposed to sunlight directly, etc. / Heat gain from surroundings / Poor conductor (air) lengthens the time for heat transfer	1A	
	1	
(b) (i) $P_{in} = \dfrac{2525}{1200} = 2.1$ (kW) or 2100 W	1A	
	1	
(ii) $\dfrac{\text{cooling capacity}}{\text{electrical power input}}$ (COP) $= \dfrac{6.80}{2.1} = 3.24$	1M/1A	
Conservation of energy is not violated.	1A	
For each joule of electrical energy consumed by the air-conditioner/compressor, 3.24 J of heat will be transferred/removed, but not created, by the air-conditioner.	1A	
	3	
(c) (i) ($C \rightarrow$) $B \rightarrow A \rightarrow D$	1A	
component B (<u>or</u> condenser)	1A	
	2	
(ii) reverse the direction of flow of refrigerant	1A	
<u>Or</u> interchange/swap the positions of B (condenser) and D (evaporator) <u>or</u> A (expansion valve) and C (compressor)		
	1	

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Section D : Medical Physics

1. B(47%)	2. D(45%)	3. D(26%)	4. D(29%)
5. B(64%)	6. C(58%)	7. A(50%)	8. A(60%)

Solution	Marks	Remarks
4. (a) (i) *A*: eardrum *B*: semi-circular canals *C*: cochlea *D*: oval window	1A	
C (cochlea) is for discriminating different frequencies of incoming sound waves / convert sound waves to nerve signals / auditory sensor cells inside send signals to brain.	1A	
	2	
(ii) 25 ÷ 20 = 1.25 (i.e. 25% increase)	1M/1A	
	1	
(b) (i) 60 (phons)	1A	
The ear is less sensitive (compared to 1~2 kHz frequency) to sound of low or high frequencies / more sensitive to middle frequencies / need a higher sound intensity to give the same loudness at high and low frequencies.	1A	
	2	
(ii) Curve *C*.	1A	
Curve shifted upwards such that a greater intensity level for threshold of hearing (or giving the same loudness sensation), especially significant in kHz range.	1A	
	2	
(c) Change in sound intensity level		
$L_1 = 10\log\frac{80}{I_0}$ $L_2 = 10\log\frac{2.5\times10^{-5}}{I_0}$	1M	
$L_2 - L_1 = 10\log\frac{80}{2.5\times10^{-5}}$	1M	
$= -65$ (dB)	1A	Accept ± 65 dB
Alternatively: Assume $I_0 = 10^{-12}$ W m^{-2} $L_1 = 10\log\frac{80}{10^{-12}} = 139.03$ dB $L_2 = 10\log\frac{2.5\times10^{-5}}{10^{-12}} = 74.03$ dB	1M	
$L_2 - L_1 = -65$ (dB)	1M+1A	
Or $10\log\left(\frac{I_{\text{noise reduced}}}{I_{\text{original}}}\right)$ $= 10\log\left(\frac{2.5\times10^{-5}}{80}\right)$	2M	
$= -65$ dB ∴ reduced by 65 (dB)	1A	
	3	

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