Marking Schemes

This document was prepared for markers' reference. It should not be regarded as a set of model answers. Candidates and teachers who were not involved in the marking process are advised to interpret its contents with care.

General Marking Instructions

1. It is very important that all markers should adhere as closely as possible to the marking scheme. In many cases, however, candidates may have obtained a correct answer by an alternative method not specified in the marking scheme. In general, a correct answer merits ***the answer mark*** allocated to that part, unless a particular method has been specified in the question.

   In the marking scheme, alternative answers and marking guidelines are in [rectangles].

2. In the marking scheme, answer marks or 'A' marks are awarded for a correct numerical answer with a unit. If the answer should be in km, then cm and m are considered to be wrong units.

3. In a question consisting of several parts each depending on the previous parts, method marks or 'M' marks are awarded to steps/methods or substitutions correctly deduced from previous answers.

4. In cases where a candidate answers more questions than required, the answers to all questions should be marked. However, the excess answer(s) receiving the lowest score(s) will be disregarded in the calculation of the final mark.

Paper 1 Section A

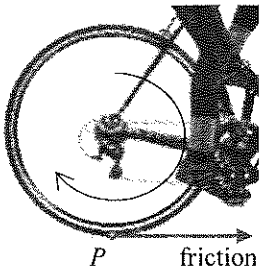
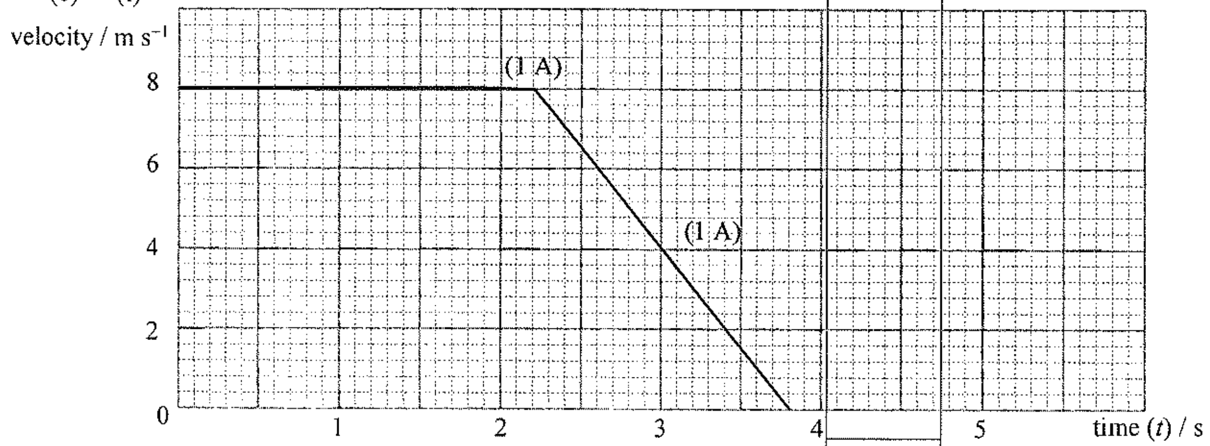
Question No.	Key	Question No.	Key
1.	B (61)	26.	D (68)
2.	D (50)	27.	B (31)
3.	C (78)	28.	C (30)
4.	A (60)	29.	A (55)
5.	B (54)	30.	B (50)
6.	D (70)	31.	C (71)
7.	B (58)	32.	D (56)
8.	C (53)	33.	D (46)
9.	C (45)		
10.	A (31)		
11.	B (51)		
12.	C (44)		
13.	D (37)		
14.	C (88)		
15.	D (50)		
16.	B (61)		
17.	A (71)		
18.	B (64)		
19.	A (67)		
20.	A (79)		
21.	A (65)		
22.	D (60)		
23.	D (30)		
24.	C (62)		
25.	A (48)		

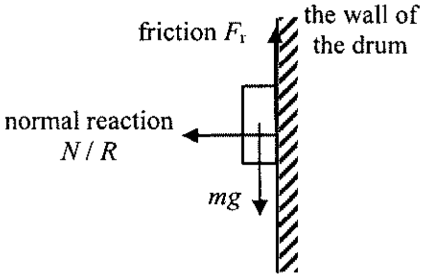
Note: Figures in brackets indicate the percentages of candidates choosing the correct answers.

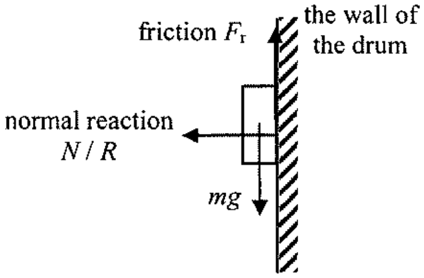
Paper 1 Section B

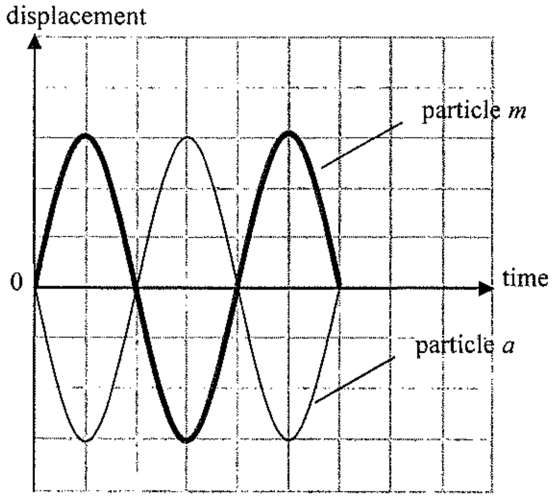
Solution	Marks	Remarks
1. (a) Heat given out by iron cube = Heat gained by water		
$0.2 \times 450 \times (T - 33) = 0.6 \times 4200 \times (33 - 25)$	2M	
$T = 257$ (°C)	1A	
	3	
(b) Some water might become steam (immediately).	1A	
Or Some water in the cup might splash.	1A	
	1	
(c) It is because some heat is lost to the surroundings	1A	
through vaporization of water / as latent heat.	1A	
Or It is because some heat is lost to the surroundings (or polystyrene cup) / The water might not be well stirred,	1A	
otherwise, the water should have reached a temperature higher than 33 °C (i.e. underestimated).	1A	
	2	
(d) (i) Poor thermal contact between the glass bob of the thermometer and the iron cube.	1A	
	1	
(ii) Infra-red (IR) thermometer.	1A	
	1	

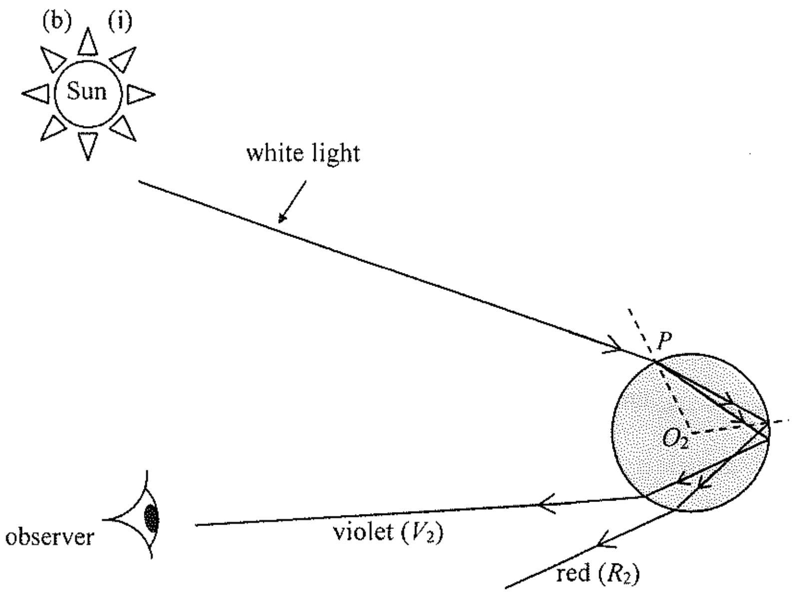
Solution	Marks	Remarks
2. (a) m_0 = density × volume $= 1.20 \times (1.5 \times 10^{-3})$ $= 1.8 \times 10^{-3}$ kg or 1.8 g	1M 1A 2	
(b) (i) $p_1V = n_1RT$ and $p_2V = n_2RT$ As $m_0 \to 4m_0$, $n_2 = 4n_1$ $\therefore p_2 = \frac{n_2RT}{V} = \frac{4n_1RT}{V} = 4p_1 = 4.0 \times 10^5$ Pa (or 4.0 atm)	1M 1A	
Or $pV = nRT$ $p \propto n$ (as V, R and T are constant) Since $m_0 \to 4m_0$, thus $n \to 4n$, p becomes 4 times the original value (= 1.0 atm), $p = 4.0 \times 10^5$ Pa (or 4.0 atm)	1M 1A 2	
(ii) More air molecules hit unit area of surface of wall or bottle / water surface (as $n \to 4n$ moles of molecules trapped in the same volume), The surface of wall or bottle / water surface is hit more frequently OR rate of change of total momentum, i.e. force, per unit area of wall or bottle / water surface increases, pressure increases.	1A 1A 2	
(iii) ΔF = increase in pressure × area $= [(4 - 1) \times 10^5] \times 0.014$ $= 4200$ N	1M 1A 2	error-carried-forward (e.c.f.) from (b)(i)
(c) (i) The pressure force acting on the water results in its change of momentum (a water jet). Magnitude of the force = rate of change of momentum. According to Newton's third law of motion, an equal but opposite force / reaction / thrust acts on the rocket. (According to Newton's second law of motion,) the reaction force causes the rocket to accelerate / move upwards.	1A 1A 2	
(ii) kinetic energy of (the jet of) water / work done on (the jet of) water	1A 1	

Solution	Marks	Remarks
3. (a) 	1A	
	1	
(b) Mechanical power delivered (for work done against the resistive force) $P = Fv$ $= 17.0 \times 8.0$ $= 136$ W	 1M 1A	
	2	
(c) (i) 		
	2	
(ii) Deceleration: $\left\lvert\frac{0-8}{3.8-2.2}\right\rvert = 5.0$ m s^{-2} Resistive force $= 65 \times 5.0$ $= 325$ N	1M 1A	e.c.f. from (c)(i)
Alternative method : Braking distance $= \frac{1}{2}(8)(3.8-2.2) = 6.4$ m $Fs = \frac{1}{2}mv^2 - 0$ $F(6.4) = \frac{1}{2}(65)(8)^2$ $F = 325$ N	 1M 1A	
	2	
(iii) Total distance travelled after $t = 2.0$ s = area under the graph from $t = 2.0$ s to $t = 3.8$ s $= \frac{0.2+1.8}{2} \times 8.0 = 8.0$ m Distance between the bicycle and the obstacle when the bicycle stops $= 9 - 8$ $= 1$ m	1M/1A 1M 1A	
	3	
(d) The padded cushion can increase the contact time of the knee and the ground such that a smaller force acts on the knee.	1A 1A	
	2	

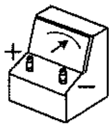
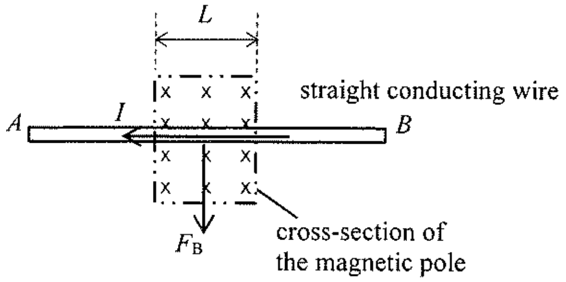
Solution	Marks	Remarks
4. (a) (i) 	2A	
	2	
(ii) Normal reaction (force acting on drum/wall of the drum by the object)	1A	
	1	
(b) (i) $\omega = 78.5$ rad s^{-1}		
rotation speed $= \frac{78.5}{2\pi} \times 60$	1M	
$= 749.619782 \approx 750$ (rev min^{-1})	1A	
Or		
$T = \dfrac{2\pi}{\omega} = 0.0800441$ s and		
$f = \dfrac{1}{T} = 12.493663$ rev s^{-1}	1M	
$= 749.619782 \approx 750$ (rev min^{-1})	1A	
	2	
(ii) centripetal force $= m\omega^2 r$		
$= (2 \times 10^{-5})(78.5)^2(0.25)$	1M	
$= 0.03081125$ N ≈ 0.0308 N	1A	
	2	
(iii) $v = r\omega$		
$= 0.25 \times 78.5$	1M	
$= 19.625 \approx 19.6$ m s^{-1}	1A	
	2	
(iv) I	1A	
	1	

Solution			Marks	Remarks
4.	(a)	(i) 	2A	
			2	
		(ii) Normal reaction (force acting on drum/wall of the drum by the object)	1A	
			1	
	(b)	(i) $\omega = 78.5$ rad s^{-1} rotation speed = $\frac{78.5}{2\pi} \times 60$ $= 749.619782 \approx 750$ (rev min^{-1})	1M 1A	
		Or $T = \frac{2\pi}{\omega} = 0.0800441$ s and $f = \frac{1}{T} = 12.493663$ rev s^{-1} $= 749.619782 \approx 750$ (rev min^{-1})	1M 1A	
			2	
		(ii) centripetal force $= m\omega^2 r$ $= (2 \times 10^{-5})(78.5)^2(0.25)$ $= 0.03081125$ N ≈ 0.0308 N	1M 1A	
			2	
		(iii) $v = r\omega$ $= 0.25 \times 78.5$ $= 19.625 \approx 19.6$ m s^{-1}	1M 1A	
			2	
		(iv) I	1A	
			1	

Solution	Marks	Remarks
5. (a) (i) *a / i / q*	1A	
	1	
(ii) *c / k / s*	1A	
	1	
(b) (i) wavelength (4 grids) = 4 × 50 cm = 200 cm or 2 m	1A	
	1	
(ii) speed = frequency × wavelength frequency = speed ÷ wavelength = 340 ÷ 2 = 170 Hz	1M 1A	
	2	
(iii) 	2A	
	2	
(c) Displacement increases, i.e. further to the left.	1A	
	1	

Solution				Marks	Remarks
6.	(a)	(i)	$\sin r = \frac{\sin 45°}{1.325}$	1M	
			$r = 32.253454° \approx 32.3°$	1A	
				2	
		(ii)	$c = \sin^{-1}\frac{1}{1.325}$	1M	
			$c = 49.000646° \approx 49.0°$	1A	
			r (or $\angle OBA$) = 32.3° < c = 49.0°,		
			therefore total internal reflection does not occur at point B.	1A	
				3	
	(b)	(i)		2A	
				2	
		(ii)	There is more light energy absorbed by water droplet	1A	
			due to a longer path.	1A	
			Or		
			There is more light energy transmitted to air at the point of	1A	
			reflection as the light undergoes reflection twice.	1A	
				2	

Solution	Marks	Remarks
7. (a) $R = \rho \frac{l}{A} \Rightarrow 0.50 = \rho \frac{0.20}{8.0 \times 10^{-7}}$	1M	
$\rho = 2.0 \times 10^{-6} (\Omega\ \text{m})$	1A	
	2	
(b) (i) Terminal **3**	1A	
	1	
(ii) When switch S is connected to terminal **2**, the equivalent resistance across MN		
$R = \frac{1}{\frac{1}{2.0} + \frac{1}{0.5} + \frac{1}{0.5+0.5+0.5}}$	1M	
$= 0.315789\ \Omega \approx 0.316\ \Omega$	1A	
	2	
(iii) (p.d. across R_2 is) greater than (p.d. across R_1)	1A	
	1	
(iv) zero	1A	
as no p.d. across CF / no current in the coil.	1A	
	2	

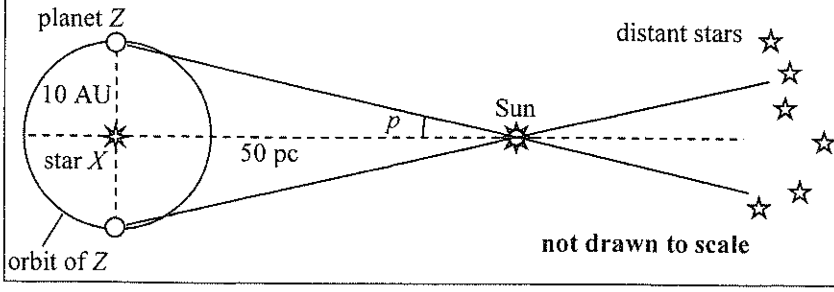
<table>
<tr><th>Solution</th><th>Marks</th><th>Remarks</th></tr>
<tr><td>8. (a)

</td><td>1A
1</td><td></td></tr>
<tr><td>(b)

</td><td>3A
3</td><td></td></tr>
<tr><td>(c)
<table>
<tr><th></th><th>magnetic force F_B</th></tr>
<tr><td>using a stronger magnet of the same dimensions</td><td>increase</td></tr>
<tr><td>using another support such that the position of the horizontal wire is slightly lowered</td><td>unchanged</td></tr>
<tr><td>using a longer wire and the current is kept unchanged</td><td>unchanged</td></tr>
</table></td><td>1A
1A
1A
3</td><td></td></tr>
<tr><td>(d) (i) (Switch on the power source.)
Adjust the power source to deliver a small current, say, 0.5 A to the wire and record the ammeter and the balance readings.
Adjust the power source to increase the current stepwise (0.5 A) and record the corresponding balance reading.</td><td>1A
1A
2</td><td></td></tr>
<tr><td>(ii) The balance reading increases linearly with the current.</td><td>1A
1</td><td></td></tr>
<tr><td>(iii) The graph does not pass through the origin because the balance has not been reset to zero initially before the experiment.</td><td>1A
1</td><td>Accept:
because of the weight of the support / wire</td></tr>
</table>

Solution	Marks	Remarks
9. (a) (i) alpha particle / α	1A	
	1	
(ii) 6 α-decays, 4 β-decays		
$4\,n_\alpha = 232 - 208$ $n_\alpha = 6$	1A	
$2\,n_\alpha + (-1)\,n_\beta = 90 - 82$ $n_\beta = 4$	1A	
	2	
(b) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{t}{t_{1/2}}} = \left(\frac{1}{2}\right)^{\frac{10}{1.41\times10^{10}}}$	1M	$N = N_0\, e^{-\lambda t}$ and $\lambda = \frac{\ln 2}{t_{1/2}}$
Portion $= 1 - \frac{N}{N_0} = 1 - \left(\frac{1}{2}\right)^{\frac{10}{1.41\times10^{10}}}$ $= 4.9159 \times 10^{-10} \approx 4.9 \times 10^{-10}$ (2 sig. fig.)	1A	$\lambda = \frac{\ln 2}{t_{1/2}} = 4.9159 \times 10^{-11}\ \text{yr}^{-1}$ $1 - \frac{N}{N_0} = 1 - e^{-\frac{\ln 2}{t_{1/2}}t}$ $= 1 - e^{-\frac{\ln 2}{1.41\times10^{10}}(10)}$ $\approx 4.9 \times 10^{-10}$
	2	
(c) (i) Aluminium body blocks alpha and/or beta particles emitted from thoriated glass.	1A	
Or Short range of α particles	1A	
	1	
(ii) Thorium-232 has an extremely long half-life.	1A	
Or As part (b) suggests, only an extremely small fraction (4.9×10^{-10}) of thorium decaying in 10 years.	1A	
	1	

Paper 2

Section A : Astronomy and Space Science

1. B (46%)	2. B (41%)	3. C (52%)	4. A (64%)
5. D (45%)	6. C (35%)	7. A (40%)	8. D (27%)

Solution	Marks	Remarks
1. (a) By Stefan's law, $L_S = \sigma(4\pi R_S^2)T_S^4$ $L_X = \sigma(4\pi R_X^2)T_X^4$ where L_S, R_S, and T_S represent the luminosity, the radius and the surface temperature of the Sun respectively, while L_X, R_X, and T_X represent the respective quantities of star X.		
$\frac{L_X}{L_S} = \left(\frac{R_X}{R_S}\right)^2\left(\frac{T_X}{T_S}\right)^4$	1M	
On solving, $R_X = \sqrt{(1000)\left(\frac{5800}{20000}\right)^4}\, R_S$ $= 2.659476\ R_S \approx 2.66\ R_S$	1A	Accept $(2.65 \sim 2.67)\ R_S$
	2	
(b) It is indeterminate.	1A	
Although the two stars have the same apparent magnitude, their distances from Earth are unknown and so one cannot determine which star has a greater absolute magnitude (i.e. their absolute magnitudes may be equal or different).	1A	
As absolute magnitude determines the luminosity / surface temperature, the surface temperature of star Y may be higher, lower or equal to that of star X.	1A	
	3	
(c) Star X is approaching the Earth with a minimum speed of $v = \frac{\lambda_{obs} - \lambda_0}{\lambda_0} \times c = \frac{-0.4}{486.1} \times 3.0 \times 10^8$	1M	
$= -246.863\ (\text{km s}^{-1}) \approx -246.9\ (\text{km s}^{-1})$	1A	Accept $246 \sim 247$ (km s^{-1})
Negative sign means star X is approaching the Earth.	1A	
	3	
(d) The parallax angle $p\ [\text{arcsec}] = \frac{r\,[\text{AU}]}{D\,[\text{parsec}]}$, where r is the orbital radius in units of AU and D is the distance to the Sun in units of parsec.	1M	
Thus, $p = \frac{10\,[\text{AU}]}{50\,[\text{parsec}]} = 0.2$ (arcseconds).	1A	Note: $\frac{0.2\pi}{3600 \times 180°} = 9.696 \times 10^{-7}$ rad
		
	2	

Section B : Atomic World

1. B (39%)	2. A (48%)	3. C (36%)	4. A (65%)
5. D (49%)	6. A (53%)	7. B (41%)	8. C (46%)

Solution	Marks	Remarks
2. (a) (i) $m_e v r = n\frac{h}{2\pi}$ $2\pi r = n\frac{h}{m_e v} = n\lambda$ $2\pi r_n = 2\pi n^2 a_0 = n\lambda_n$ $\lambda_n = n \times 2\pi a_0$	1A 1	
(ii) $\lambda_1 = 1 \times 2\pi a_0 = 2\pi \times 5.29 \times 10^{-11}$ $= 3.323805 \times 10^{-10}$ m $\approx 3.32 \times 10^{-10}$ m	1A 1	Accept $(3.30 \sim 3.33) \times 10^{-10}$ m
(b) (i) X: $n = 5$ to $n = 2$ (i.e. 4th excited state to 1st excited state)	1A 1	
(ii) $\lambda = \frac{hc}{E} = \frac{6.63\times10^{-34}\times 3\times10^{8}}{(-0.87-(-5.45))\times10^{-19}} = 4.34279476 \times 10^{-7}$ m ≈ 434 nm	1M 1A 2	Accept (432 ~ 434) nm
(iii) Transition from $n = 6$ to $n = 2$ gives $\Delta E = (-0.60 - (-5.45)) \times 10^{-19}$ J $= 4.85 \times 10^{-19}$ J (within visible) There is a transition that gives a visible spectral line.	1M 1A	
Or $\lambda = \frac{hc}{E} = \frac{6.63\times10^{-34}\times 3\times10^{8}}{(-0.60-(-5.45))\times10^{-19}}$ $= 410.103093$ nm ≈ 410 nm (within visible)	1M 1A	
Or For a transition from 6 to n, if the emitted photon is visible, $4.97 \times 10^{-19} \geq (-0.60 \times 10^{-19} - E_n) \geq 2.84 \times 10^{-19}$ $-3.44 \times 10^{-19} \geq E_n \geq -5.57 \times 10^{-19}$ $n = 2$ ($E_n = -5.45 \times 10^{-19}$ J) fulfill this requirement.	1M 1A	
However, no such visible emission line is found beyond the shortest visible line X. Thus, the excitation by the monochromatic radiation is from $n = 1$ to $n = 5$.	1A 3	
(c) photon energy $= [-0.87 - (-21.8)] \times 10^{-19}$ J $= 20.93 \times 10^{-19}$ J $= 13.08125$ (eV) ≈ 13.1 (eV) ultra-violet (UV)	 1A 1M/1A 2	Accept (13.0 ~ 13.1) (eV)

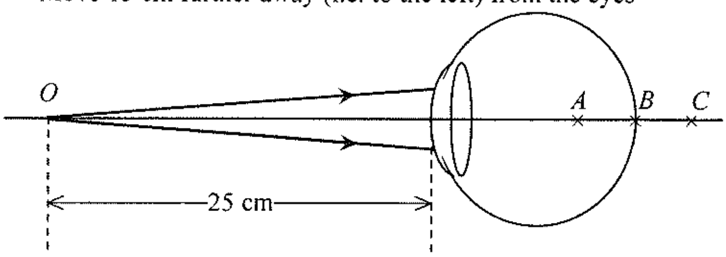
Section C : Energy and Use of Energy

1. B (56%)	2. D (37%)	3. C (75%)	4. D (41%)
5. C (46%)	6. B (17%)	7. A (70%)	8. D (52%)

Solution	Marks	Remarks
(a) (i) At the evaporator indoor, liquid refrigerant evaporates and absorbs latent heat from the air indoor.	1A	
At the condenser outdoor, vapour refrigerant condenses and releases latent heat to the air outdoor.	1A	
	2	
(ii) (2): leaving the compressor	1A	
	1	
(iii) Energy consumed by the air-conditioner / work W has to be done on the refrigerant, and it is released in addition to the heat removed Q_C. (i.e. by conservation of energy, $Q_H = Q_C + W$.)	1A	
	1	
(b) (i) $Q_C = 2.04 \times 10^6 = C_p \times 4 \times 60$	1M	
$C_p = 8500\text{ W} = 8.50\text{ kW}$	1A	
	2	
(ii) $Q_C = mc\Delta\theta$		
$2.04 \times 10^6 = (1.20 \times 13.4 \times 5.0 \times 3.0) \times 1000 \times \Delta\theta$	1M	
$\Delta\theta = 8.457711\ °\text{C} \approx 8.46\ °\text{C}$	1A	Accept (8.4 ~ 8.5) °C
	2	
(iii) $W = Q_C \div 6.2$		
$Q_H = Q_C + W = Q_C + \frac{Q_C}{6.2} = (2.04 \times 10^6) \times (1 + \frac{1}{6.2})$	1M	
$= 2.369032 \times 10^6\text{ J} \approx 2.37 \times 10^6\text{ J}$	1A	Accept (2.35×10^6 ~ 2.40×10^6) J
Or		
Electrical power input $P = \frac{C_P}{6.2}$	1M	
$Q_H / t = C_P + P = C_P + \frac{C_P}{6.2} = 8500 \times (1 + \frac{1}{6.2})$ $= 9870.9677\text{ W} \approx 9871\text{ W}$		
$Q_H = 9871 \times (4 \times 60) = 2.369032 \times 10^6\text{ J} \approx 2.37 \times 10^6\text{ J}$	1A	
	2	

Section D : Medical Physics

1. A (49%)	2. D (43%)	3. A (40%)	4. C (61%)
5. D (17%)	6. B (35%)	7. C (40%)	8. B (68%)

Solution	Marks	Remarks
4. (a) Rods do not register colour but are more sensitive to light than cones so can operate at lower light intensities (thus for scotopic (dim light or night time) vision).	1A	
Cones differentiate colour as they contain three visual pigments. They need higher light intensities than rods (thus for photopic (bright or daylight) vision).	1A	
	2	
(b) (i) It is the closest point / shortest (object) distance at which an eye can focus (comfortably) / see a clear / sharp image.	1A	
	1	
(ii) The lens loses its flexibility and reduces its refractive power (accommodation) for focusing an object at near distance /	1A	
Or The weakening (muscles around eye's lens) ciliary muscles that control / contract the lens thickness.	1A	
	1	
(iii) Accommodation of the eyes refers to the ability of the eyes to focus / change focal length / change thickness of lens at different distances (from near point to far point).	1A	
	1	
(iv) The range of accommodation Δ_{20} at 20 years old: At far point, P_f power of eyes $= \frac{1}{0.025} = +40$ D At near point, P_n power of eyes $= \left(\frac{1}{0.10} + \frac{1}{0.025}\right) = +50$ D	1M	
Δ_{20} is from +40 D to +50 D, i.e. $\Delta_{20} = 10$ D	1A	
The range of accommodation changes, Δ_{70} at 70 years is decreased by considering the change of near point (assume the far point is fixed at 20 and 70 years old) $+50\text{ D} - \left(\frac{1}{1.00} + \frac{1}{0.025}\right) = +50\text{ D} - (+41\text{ D}) = 9\text{ D}$	1A	Note: Δ_{70} at 70 years old is narrowed to +40 D → +41 D, i.e. $\Delta_{70} = 1$ D only
Or $\Delta = \Delta_{20} - \Delta_{70} = \frac{1}{0.10} - \frac{1}{1.00} = 9\text{D}$	1A	
	3	
(c) Point *C* (behind the retina)	1A	
Move 15 cm further away (i.e. to the left) from the eyes	1A	
		
	2	