H2 Physics Prelim 2022 Solutions

1 **(a)** Thrust = resistive force since velocity is constant. C1

Power = $Fv = Dv$

D x 15 = 90000

D = 90000/15 = 6.0 kN A1

(b) F = Thrust Power = Fv

$F - D = ma$

$P/v - D = ma$

120000/15 – 6000 = 800a M1

a = 2.5 m s^{-2} A1

(c) As the <u>velocity increases with time</u>, the <u>resistive force also increases</u> . B1

The <u>driving force decreases</u> as the speed of the boat increases since driving power stay constant, the <u>net force on the boat decreases</u> and hence <u>acceleration decreases with time.</u> B1 B1

<u>Acceleration drops to zero</u> when the <u>resistive force is equal to the driving force</u> on the boat. B1

2 **(a)(i)** Gravitational force provides centripetal force. Same gravitational force acting on star and planet.

$$F_G = m_p r_p \omega^2 = m_s r_s \omega^2$$ C1

$$2.0\times10^{27}\left(r_p\right) = 6.0\times10^{28}\left(r_s\right)$$

$$\frac{r_s}{r_p} = \frac{2.0\times10^{27}}{6.0\times10^{28}} = \frac{1}{30}$$

$$r_s = \frac{1}{31}\times5.2\times10^{9} = 1.68\times10^{8}\,\text{m}$$ A1

(a)(ii)

$$F_G = F_C$$

$$\frac{Gm_s m_p}{d^2} = m_s r_s \omega^2$$

$$\frac{Gm_s m_p}{d^2} = m_s r_s \left(\frac{2\pi}{T}\right)^2$$ C1

$$\frac{6.67\times10^{-11}\left(2.0\times10^{27}\right)}{\left(5.2\times10^{9}\right)^2} = \left(1.68\times10^{8}\right)\left(\frac{2\pi}{T}\right)^2$$

$$T = 1.16\times10^{6}\ \text{s}$$ A1

(a) (iii)	Planet moves in front of star periodically.	A1

(b) (i) Between starting height 6.40×10^6 m & ending height 7.225×10^6 m

$$g = (-)\frac{d\phi}{dr}$$

$$\Delta\phi = \int g\ dr$$ C1

$= $ area under g-r graph M1

$= 6.74 \times 10^6$ to 7.61×10^6 J kg^{-1}

M1

$$\Delta U = m\Delta\phi = 2300\ \Delta\phi$$

= 1.55×10^{10} to 1.75×10^{10} J

OR

$$g = G\frac{M}{r^2} \text{ and } \phi = -G\frac{M}{r} \Rightarrow \phi = -gr$$ C1

$$\Delta U = m\Delta\phi = m(\phi_f - \phi_i) = 2300(g_i r_i - g_f r_f)$$ M1

$$= 2300(-9.75 \times 6.4 \times 10^6 + 7.625 \times 7.225 \times 10^6)$$ M1

$\approx 1.60 \times 10^{10}$ J

(b) (ii)

$$\Delta U = U_f - U_i = -\frac{GM_E m_s}{r_f} - \left(-\frac{GM_E m_s}{r_i}\right)$$

$$1.6\ x\ 10^{10} = 6.67 \times 10^{-11} M_E\left(2300\right)\left(\frac{1}{6.40 \times 10^6} - \frac{1}{7.225 \times 10^6}\right)$$ C1

$$M_E = 5.85 \times 10^{24}\ \text{kg}$$ A1

(b) (iii) Advantages to low polar orbit:

- High(er) resolution imaging/clearer images A1
- Image more of the planet as the Earth spins underneath the satellite

Geostationary:

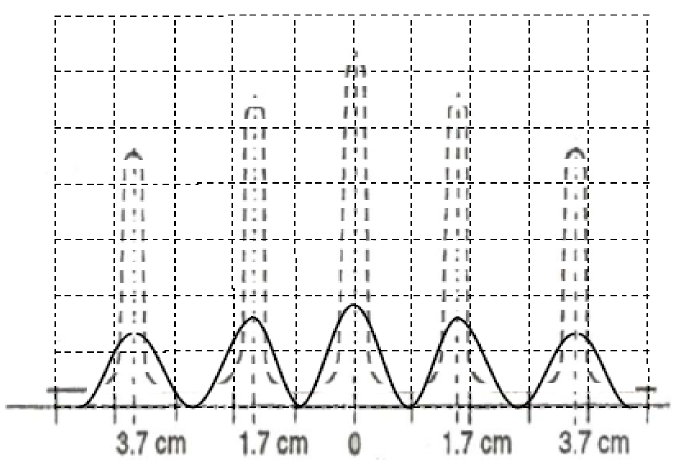
- **Remain at the same position in the sky so satellite dishes can keep locked on to signal/no steerable dishes needed/send & receive signals all the times/continuous/uninterrupted/stable signals** A1
- Higher orbit means greater coverage of the signals

3	(a)	angular speed of grating, ω = 2 π / T = 2 π / 3.0 = 2.1 rad s^{-1}	A1
	(b)	The peaks represent the positions of constructive interference/maxima.	B1
			B1

The effect of diffraction through the slits of diffraction grating causes interference fringes of higher order to have lower intensity than the zeroth order maxima.

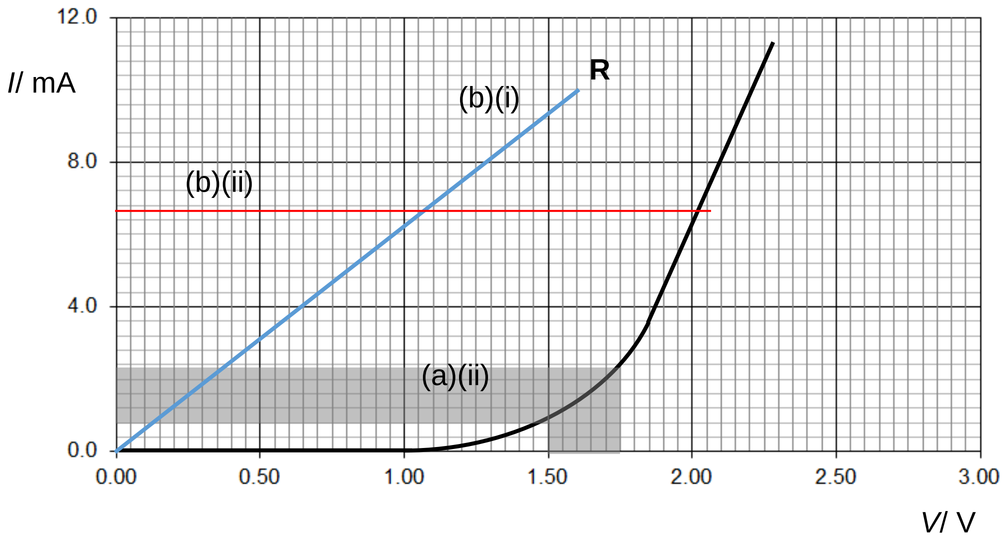
(Peak C corresponds to the zeroth order of the diffraction pattern whereas peaks B and D the first order and Peaks A and E the second order.)

(c) (i)	Time interval = 3.7 x 0.1 = 0.37 s	C1
	$\theta = \omega t = 2.1 \times 0.37 = 0.78$ rad (ecf)	A1
(c)(ii)	Using the grating equation $n\lambda = d \sin\theta$, $d = 1 \times 10^{-3} / 550$	C1
	$\sin\theta_2 = 2 \times 5.5 \times 10^{5} \times \lambda$	
	$\lambda = 640$ nm (ecf)	A1
(c)(iii) 1	Peak E is preferred as the angle θ is larger so the percentage uncertainty for calculating the wavelength is smaller.	C1
(c)(iii)2	From $n\lambda = d \sin\theta$	
	$n < d/\lambda = 1 \times 10^{-3} / 550 \times 640 \times 10^{-9} = 2.8$	C1
	Hence, the highest order observed is 2nd order maxima.	C1
	Total number of orders observed = 2n +1 = 5	A0
(d)	Diagram must show that since the slit separation remains the same, the fringe separation remains the same. Peaks are less intense (poorer contrast) and less sharp (broader and less defined).	M1



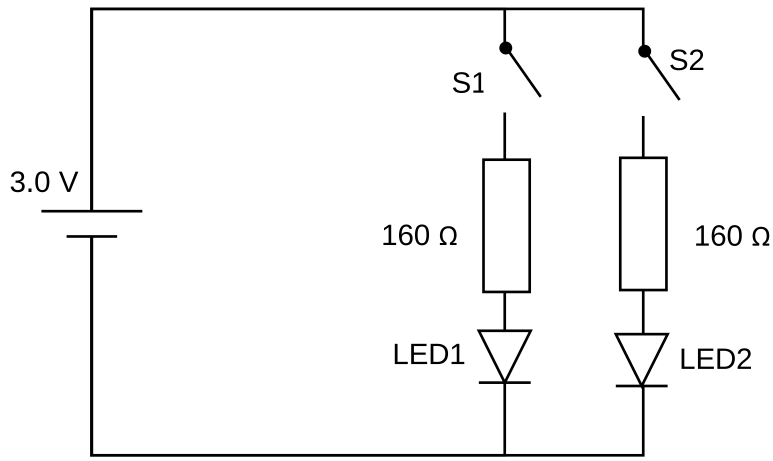
4	**(a)**	**(i)**	2.25/0.0108 = 208 Ω	**C1**

(a)(ii) & (b) (i)



		(a)(ii) correct area shaded	**B1**
		(b)(i) Line R should be a straight line passing through (0,0) and (1.60 V, 10.0 mA)	**M1**
(b)	**(ii)**	Draw a horizontal line on Fig. 4.1 such that the pd across 160 Ω and LED1 adds up to 3.0 V.	**B1**
		I = 6.2 mA	**A1**
	(iii)	With two LEDs, effective resistance of the circuit is lowered,	**B1**
		leading to higher current from battery.	**B1**
		With higher current, the potential difference across the 160Ω resistor is larger, leaving less potential difference across the LEDs.	**B1**
		OR	
		With two LEDs in parallel, effective resistance between the LEDs is lowered.	
		By Potential Divider Principle, the potential difference across each LED is also lowered.	
		From the graph, it can be seen the current decreases with voltage, so the power (P=VI) dissipated in each LED is lower, so brightness is dimmer.	

(c) **B1**



5 **a** DERQ and CFSP [B1]

bi As current flows through the slice in the presence of the magnetic field, it will experience a magnetic force to the left, by Fleming Left Hand rule. Hence a potential difference is generated across DERQ and CFSP.

[B1]

When the current is undeflected at equilibrium, force on charge due to magnetic field equals force due to electric field

$Bqv = Eq$ [B1]

$E = B\,v$

Electric field across faces DERQ and CFSP is constant

$E = V_H / d$ *, where d is the distance between faces DERQ and CFSP* [A1]

$V_H = Bvd$

bii since $I = nAqv$ **where** [M1]

A is the cross-sectional area through which current flows, A= *dt , and t is the distance between faces CDEF and PQRS.*

$$v = \frac{I}{n(dt)q}$$ [C1]

$$V_H = (Bd)\left(\frac{I}{n(dt)q}\right) = \frac{BI}{ntq}$$ [A0]

biii For copper, *n* is very large hence V_H is very small, making it difficult to measure. [B1]

6	**ai**	The *magnetic flux density at a point* is defined as the force acting per unit current per unit length on a current carrying conductor	**M1**
		when the conductor is placed at right angles to the magnetic field.	**B1**
	aii	As AB moves from P towards Q, magnetic flux linkage over the area ABCD enclosed by the frame increases resulting in an induced e.m.f. generated in the frame by Faraday's law.	**B1**
		Since the frame is a conductor, induced current flows. By Lenz's Law, the induced current flows in an anticlockwise direction.	**B1**
		This results in a magnetic force that acts on AB towards the left which oppose motion. Hence the frame slows down.	**B1**
		Alternative:	
		As AB moves from P towards Q, magnetic flux linkage over the area ABCD enclosed by the frame increases resulting in an induced e.m.f. generated in the frame by faraday's law.	**B1**
		Frame is a closed circuit so induced current will flow in the frame. By conservation of energy, KE of the frame is converted to heat energy.	**B1**
		Energy is loss as P= I^2R. Hence frame slows down	**B1**
	aiii	As AB enters the field, the increase in magnetic flux (linkage) $\Phi = BA = B(wx)$ where *x* is the distance AB has moved past P.	**B1**
		Hence, the magnitude of induced emf is given by $E = \frac{d\Phi}{dt} = Bw\frac{dx}{dt} = Bwv$	**B1**
		Induced current that flows in the frame, $I = \frac{Bwv}{R}$	**B1**
		Magnetic force which acts on AB is in opposite direction to motion is the braking force which slows the frame.	**B1**
		Braking force is thus $F = BIw = \frac{B^2w^2v}{R}$	**A0**
	bii	Distance **2*L*** = Area under *v* – *t* graph = ½ (26 + 16 x 2 + 10 x 2 + 6 x 2 + 3.5)(5) = 234 m	**C1**
		PQ = *L* = 117 m, Accuracy: L = 105 to 129 m	**A1**
	biii	Braking force only acts on the train when there is a changing magnetic flux through the frame. There is no braking force on the train when the whole frame is within the magnetic field.	**M1**
		Increasing the length PQ does not change the exit speed.	**A1**

7(a)(i)	$I = \dfrac{P}{S} \Rightarrow P = IS$	
	$P = 5.0\times10^{2}\left(2.6\times10^{14}\right)$	C1
	$= 1.3\times10^{17}$ W	A1
(a)(ii)	1.3×10^{17} W	A1
(a)(iii)	$I = \dfrac{P}{S} = \dfrac{P}{4\pi r^{2}}$	M1
	$= \dfrac{1.3\times10^{17}}{4\pi\left(6400\times10^{3}\right)^{2}}$	M1
	$= 253$ W m^{-2}	A0
(b)(i)	x-axis marked with an arrow labelled M at 900-1100 nm	B1
(b)(ii)	$\lambda_{max}T = k$	
	$1000\left(2900\right) = k$	C1
	$k = 2.9\times10^{6}$ nm K	A1
(b)(iii)	λ_{max} T = 2.90 x 10^{6} nm K	
	Sun: λ_{max} = 2.90 x 10^{6} / 5800 = 500 nm	A1
	Earth: λ_{max} = 2.90 x 10^{6} / 290 = 10000 nm	A1
(b)(iv)	Sun's curve always above the original curve and peak at 500 nm	B1
(c)(i)	Radiation window – range of wavelengths which are transmitted/not absorbed by CO_2	B1
(c)(ii)	At 11000 nm, CO_2 absorbs close to 100% of radiation, so it is not a radiation window	B1
(d)	Sun's peak intensity in the 500 nm visible range. Energy radiated by Sun is able to pass through atmosphere as it is within the radiation window.	B1
	The visible light that reaches Earth is absorbed and re-radiated.	B1
	Earth's peak intensity is in the 10000 nm infrared range. Energy radiated by Earth is trapped by carbon dioxide as it is not in radiation window.	B1
	This leads to increase in temperature within the atmosphere.	

(e)(i)	$m = \rho V \Rightarrow v = \dfrac{m}{\rho}$	C1
	$v = \dfrac{2.8 \times 10^{18}}{1.0 \times 10^{3}} = 2.8 \times 10^{15}\ \text{m}^{-3}$	A1
(e)(ii)	Ice floats thus upthrust = weight of ice. And upthrust equals weight of displaced sea water. When ice melts, melted ice water only occupies the same volume as submerged part of ice pack	M1
	Hence no change to sea level.	A1