9646 H2 Physics
2016 GCE A-Level Suggested Solutions

Paper 1

1 **B**

A: $(10^{-2}\ \text{m})(10^{-1}\ \text{m}) = (10^{-3}\ \text{m}^2)$
B: $(10^{3}\ \text{m})(10^{-3}\ \text{m}) = (10^{0}\ \text{m}^2)$
C: $(10^{6}\ \text{m})(10^{-9}\ \text{m}) = (10^{-3}\ \text{m}^2)$
D: $(10^{-12}\ \text{m})(10^{-6}\ \text{m}) = (10^{-18}\ \text{m}^2)$

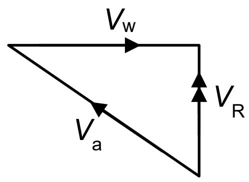
2 **C**

λ of green light ~ 550 nm

$$E = \frac{hc}{\lambda} = \frac{(6.63\times10^{-34})(3.00\times10^{8})}{550\times10^{-9}} = 3.62\times10^{-19}\ \text{J}$$

3 **B**

$v_\text{a} = 700\ \text{km h}^{-1}$
$v_\text{w} = 250\ \text{km h}^{-1}$
$v_\text{R} = \sqrt{{v_\text{a}}^2 - {v_\text{w}}^2} = \sqrt{700^2 - 250^2}$
$= 653.8\ \text{km h}^{-1} = 650\ \text{km h}^{-1}$

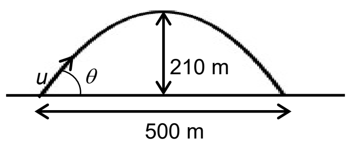


4 **D**

A: velocity-distance graph
B: displacement-time graph
C: acceleration-time graph

5 **D**

Taking upwards as positive:



$${v_y}^2 = {u_y}^2 + 2a_y s_y$$
$$0 = (u\sin\theta)^2 + 2(-g)(210)$$
$$u\sin\theta = \sqrt{420g}$$
$$v_y = u_y + a_y t$$
$$0 = u\sin\theta - gt$$
$$= \sqrt{420g} - gt$$
$$t = \frac{\sqrt{420g}}{g}$$
$$s_x = u_x t$$
$$500 = (u\cos\theta)(2)\left(\frac{\sqrt{420g}}{g}\right)$$
$$u\cos\theta = \frac{250g}{\sqrt{420g}}$$
$$\frac{u\sin\theta}{u\cos\theta} = \frac{420g}{250g}$$
$$\tan\theta = \frac{420}{250}$$
$$\theta = 60°$$

6 **C** Momentum after collision

$= $ Momentum before collision

$= 2(12) + 4(0)$

$= 24 \text{ kg m s}^{-1}$

7 **D** Constant force $\Rightarrow$ constant acceleration
No force $\Rightarrow$ constant speed

8 **D**

$$\begin{aligned}\text{upthrust on concrete} &= m_{sw}g \\ &= \rho_{sw}Vg \\ &= (1020)(3)(4)(5)(9.81) \\ &= 600372\ N \\ \text{weight of concrete} &= m_c g \\ &= \rho_c Vg \\ &= (2300)(3)(4)(5)(9.81) \\ &= 1353780\ N\end{aligned}$$

force required to lift concrete when fully submerged

$= 1353780 - 600372$

$= 753408$

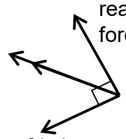
$= 7.53 \times 10^5$ N

force required to lift concrete when out of the water

$=$ weight of concrete

$= 1.35 \times 10^6$ N

9 **B** Assuming there is friction, total reaction force from the slope on skier is the resultant of the normal reaction force and friction.



10 **C** Torque of a couple = force $\times$ perpendicular distance between forces
Since force and distance does not change, torque of the couple remains as M.

11 **A**

$$\frac{16}{100}(48 \times 10^6)x = 400(1 \times 10^3)$$

$$x = 0.0521 \text{ kg}$$

$$= 52 \text{ g}$$

12 **D**

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{(24)(36)(36)} = 7.27 \times 10^{-5} \text{ rad}^{-1}$$

13 **D** On a dry surface, friction provides for centripetal force.

$$f = \frac{mv^2}{r} = \frac{m(16)^2}{r}$$

On a wet surface:

$$\frac{1}{2}f = \frac{mv_1^{\,2}}{r}$$

$$v_1 = \sqrt{(\frac{1}{2}f \Big/ \frac{m}{r})}$$

$$= \sqrt{(\frac{1}{2})(\frac{m(16)^2}{r}) \Big/ \frac{m}{r})}$$

$$= \frac{16}{\sqrt{2}}$$

14 **C** $\phi = -\frac{GM}{r}$, scalar, algebraic summation.

15 **C**

$$\frac{GMm}{r^2} = mr\omega^2 = M\left(\frac{2\pi}{T}\right)^2 r$$

$T^2 \propto r^3$ (Keplar's Law)

$$\frac{T_s^{\,2}}{T_J^{\,2}} = \frac{r_s^{\,2}}{r_J^{\,2}}$$

$$T_s = \left[\left(\frac{1.43\times10^{12}}{7.78\times10^{11}}\right)^3 (11.9)^2\right]^{1/2} = 29.7 \text{ years}$$

16 **A** Maximum KE at equilibrium

$v = \pm\omega\sqrt{x_0^2 - x^2}$

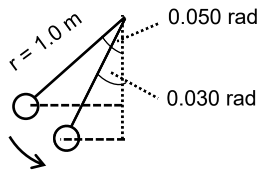
K.E. + P.E. = constant

17 **D** Decrease in GPE = Increase in KE

$$mg(\cos 0.030 - \cos 0.050) = \frac{1}{2}mv^2 - 0$$

$$g(\cos 0.030 - \cos 0.050) = \frac{1}{2}(r\omega)^2$$

$$\omega = 0.125 = 0.13 \text{ rad}^{-1}$$



Similar to $v^2 = \omega^2\left(x_0^{\,2} - x^2\right)$

$$\omega^2 = \Omega^2\left(\theta_0^{\,2} - \theta^2\right)$$

$$\omega^2 = \left(\frac{2\pi}{T}\right)^2\left(0.050^2 - 0.030^2\right)$$

$$\omega = 0.126 = 0.13 \text{ rad}^{-1}$$

18 **A**

$$\frac{P_1V_1}{T_1}=\frac{P_2V_2}{T_2}$$

$$V_1=\left(\frac{P_2V_2}{T_2}\right)\left(\frac{T_1}{P_1}\right)=\frac{(1.0\times10^5)(0.025)}{300}\left(\frac{600}{5.0\times10^5}\right)$$

$$=0.010\ \text{m}^3$$

19 **B**

$\Delta U=Q+W$

ΔU is the same for both processes

$8+(-3)=Q+(-1)$

$Q=6$ J into gas

20 **D**

$$E_k=\frac{3}{2}kT$$

$T\approx 28\ °C$

$$E_k=\frac{3}{2}(1.38\times10^{-23})(28+273.15)$$

$$=6.23\times10^{-21}\ \text{J}$$

21 **B** **Note**: there is inconsistency in the information given in this question

Approach using intensity:

Let I_X, A_X be intensity and amplitude after passing through 1st polariser

I_Y, A_Y be intensity and amplitude after passing through 2nd polariser

I_Z, A_Z be intensity and amplitude after passing through 3rd polariser

$$I_X=\frac{I}{2}$$

$$I_Y=I_X\left(\cos45°\right)^2=\frac{I}{4}$$

$$I_Z=I_y\left(\cos45°\right)^2=(\frac{I}{4})(\frac{1}{2})=\frac{I}{8}$$

However, if use information given in the second part of the question:

$$A_y=\frac{A}{\sqrt{2}}$$

$$I_y=kA_y{}^2=k\left(\frac{A}{\sqrt{2}}\right)^2=k\frac{A^2}{2}$$

$$I_z=I_y\left(\cos45°\right)^2=\left(k\frac{A^2}{2}\right)(\frac{1}{2})$$

$$=k\frac{A^2}{4}$$

$$=\frac{I}{4}$$

22 **D**

23 **D** Consider vector sum of the two waveforms at every point.

24 C

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$$

$$F_1 = \frac{(3Q)(3Q)}{4\pi\varepsilon_0 (3r)^2} = \frac{QQ}{4\pi\varepsilon_0 r^2} = F$$

25 C

$$E = \frac{Q}{4\pi\varepsilon_0 r^2} = 32.0 \quad (r\text{: side of 1 square})$$

$$E_s = \frac{Q}{4\pi\varepsilon_0 (3r)^2} = \frac{1}{9}(32.0) = 3.6 \text{ N C}^{-1}$$

$$E' = \frac{Q}{4\pi\varepsilon_0 (\sqrt{2}r)^2} = \frac{1}{2}E = 16.0 \text{ N C}^{-1}$$

$$E_R = \frac{Q}{4\pi\varepsilon_0 (\sqrt{4r^2 + r^2})^2} = \frac{Q}{4\pi\varepsilon_0 (\sqrt{5}\ r)^2}$$

$$= \frac{1}{5}E = 6.4 \text{ N C}^{-1}$$

26 B

Terminal p.d. = p.d. across variable resistor
Resistance of variable resistor ↓, p.d. ↓
Effective resistance of circuit ↓
I ↑ ⇒ power loss in internal resistance = I^2R ↑

27 C

$$I = neAv$$

Copper and semiconductor in series

$$I_c = I_s = I$$

$$n_s eAv_s = n_c eAv_c$$

$$v_s = \frac{n_c v_c}{n_s} = \frac{(8.6 \times 10^{28})(0.586 \times 10^{-3})}{4.3 \times 10^{21}}$$

$$= 1.16 \times 10^4 \text{ m s}^{-1}$$

28 A

LDR: Brightness ↑, R ↓
Thermistor: Temperature ↑, R ↓
Smallest voltmeter reading when total resistance is the smallest.

29 B

$$\text{Effective resistance } = \left(\left(\left(\frac{1}{4.0 + 4.0} + \frac{1}{8.0} \right)^{-1} + 4.0 \right)^{-1} + \frac{1}{8.0} \right)^{-1} + 6.0$$

$$= 10\ \Omega$$

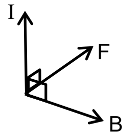
$$I = \frac{20}{10} = 2.0 \text{ A}$$

$$\text{terminal p.d.} = 20 - (2.0)(6.0) = 8.0 \text{ V}$$

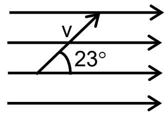
$$I_{8.0\ \Omega} = \frac{8.0}{8.0} = 1.0 \text{ A}$$

$$\text{current through first } 4.0\ \Omega = 2.0 - 1.0 = 1.0\ \text{A}$$
$$\text{p.d. across first } 4.0\ \Omega = (1.0)(4.0) = 4.0\ \text{V}$$
$$V_{xy} = \text{terminal p.d. } - 4.0$$
$$= 8.0 - 4.0 = 4.0\ \text{V}$$

30 **B** Use Fleming's left hand rule:



31 **A** Force perpendicularly out of page.



$$F = Bqv\sin 23°$$
$$7.3\times10^{-16} = (0.084)(1.60\times10^{-19})(v\sin 23°)$$
$$v = 1.39\times10^{5} = 1.4\times10^{5}\ \text{m s}^{-1}$$

The component of the velocity parallel to the magnetic field will cause the electron to move in a helix.

32 **C**

$$E = -\frac{d\Phi}{dt}$$
$$|E| = \left|\frac{\Delta\Phi}{\Delta t}\right| = \frac{|\Phi_f - \Phi_i|}{\Delta t}$$
$$= \frac{|2000(0-0.34)|}{0.24} = 2833$$
$$= 2800\ \text{V}$$

33 **D**

$$\phi = BA,\ \Phi = N\phi$$
$$A = (10.0\times10^{-2})(8.0\times10^{-2})$$
$$= 8.0\times10^{-3}\ \text{m}^2$$

34 **B**

$$\text{peak } V_s = (\tfrac{1}{2})(180) = 90\ \text{V}$$
$$V_{s,rms} = \frac{90}{\sqrt{2}}\ \text{V}$$
$$V_{80\ \Omega} = \frac{80}{80+40}\left(\frac{90}{\sqrt{2}}\right)\ \text{V}$$
$$P_m = \frac{V_{80\ \Omega}}{80} = 22.5\ \text{W} = 23\ \text{W}$$

35 **B** All other options demonstrate the wave-nature of electromagnetic radiation.

36 **B** $R+T=1$

$R=-T+1$

$y=mx+c$

Gradient $=-1$

y-intercept $=1$

37 **D** N-type semiconductor

38 **C** Higher concentration of electrons in n-type
$\rightarrow$ during formation of depletion regions, electrons diffuse from n to p type (i.e. in the y-direction)
During easy flow of charge
$\rightarrow$i.e. forward bias
Holes move from p to n type (i.e. in the x-direction)

39 **C** $$\frac{N}{N_0}=(\frac{1}{2})^{t/t_{1/2}}\ ,t_{1/2}=\frac{\ln 2}{\lambda}$$

$$\ln(\frac{N}{N_0})=\frac{t}{t_{1/2}}\ln\frac{1}{2}$$

$$t=\ln(\frac{N}{N_0})\times\frac{t_{1/2}}{\ln\frac{1}{2}}=\ln\frac{N}{N_0}\times\frac{\ln 2}{n\ln\frac{1}{2}}$$

$$=\ln\frac{8.6\times10^{21}}{7.7\times10^{23}}\times\frac{\ln 2}{(2.6\times10^{-8})\ln\frac{1}{2}}$$

$$=1.73\times10^{8}\ \text{s}$$

$$=1.7\times10^{8}\ \text{s}$$

40 **C** $N_x=N_0e^{-\lambda t},\ N_y=N_0-N_x$

when the curves intersect,

$$N_x=N_y\Rightarrow N_0e^{-\lambda T}=N_0-N_0e^{-\lambda T}$$

$$e^{-\lambda T}=1-e^{-\lambda T}$$

$$2e^{-\frac{\ln 2}{\tau}T}=1$$

$$-\frac{\ln 2}{\tau}T=\ln\frac{1}{2}$$

$$T=\left(\ln\frac{1}{2}\right)\left(-\frac{\tau}{\ln 2}\right)=\left(\ln 1-\ln 2\right)\left(-\frac{\tau}{\ln 2}\right)=\tau$$

Paper 2

1 **(a)** One ohm is the resistance of a conductor when a potential difference of one volt across it causes a current of one ampere to flow through it.

(b) **(i)**

$$R = \frac{\rho L}{A}$$

$$\rho = \frac{RA}{L} = \frac{(V/I)\pi(d/2)^2}{L} = \frac{\pi V d^2}{4IL}$$

$$= \frac{\pi(1.50)(0.23\times10^{-3})^2}{4(0.32)(40.0\times10^{-2})}$$

$$= 4.869\times10^{-7}$$

$$= 4.87\times10^{-7}\ \Omega\ \text{m}$$

(ii)

$$\frac{\Delta\rho}{\rho} = \frac{\Delta V}{V} + 2\frac{\Delta d}{d} + \frac{\Delta I}{I} + \frac{\Delta L}{L}$$

$$\Delta\rho = \left(\frac{0.01}{1.50} + 2\frac{0.01}{0.23} + \frac{0.01}{0.32} + \frac{0.1}{40.0}\right)(4.869\times10^{-7})$$

$$= 6.202\times10^{-8} = 6\times10^{-8}\ \text{(1 s.f.)}$$

(iii)

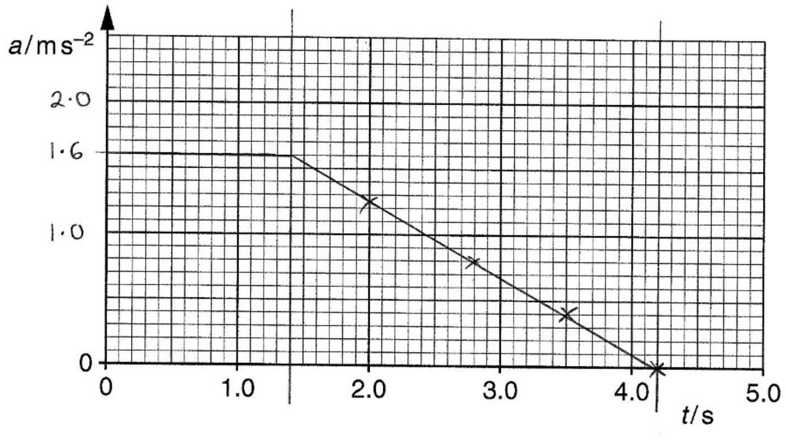
$$\rho = (4.9\times10^{-7} \pm 0.6\times10^{-7})\ \Omega\ \text{m}$$

(c) Accuracy refers to the closeness of the calculated value in **(b)(iii)** to the true value.
Precision refers to the size of the uncertainty (0.6 in this case) relative to the calculated value in **(b)(iii)**.

2 **(a)** $F = ma$

$$a = \frac{F}{m} = \frac{6.4}{4.0} = 1.6\ \text{m s}^{-2}$$

(b)



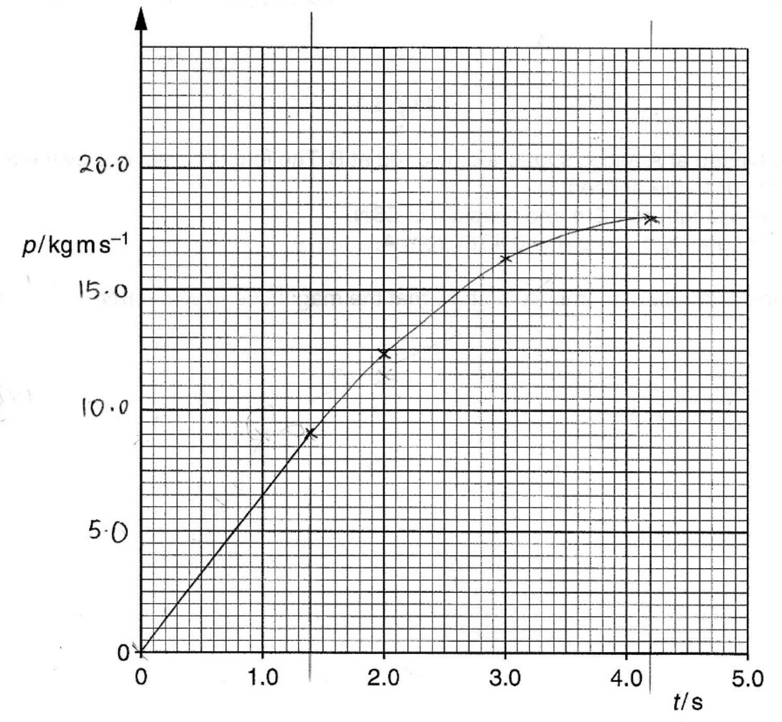
(c) impulse = area under the F-t graph

$= 6.4 \times 1.4$

$= 8.96 \text{ kg m s}^{-1}$

$= 9.0 \text{ kg m s}^{-1}$

(d)



3 **(a)** Taking moments about A:
By Principle of Moments,
Sum of clockwise moments = Sum of anti-clockwise moments

$$36(0.45\cos 60°) = (X\sin 70°)(1.2\cos 60°) + (X\cos 70°)(1.2\sin 60°)$$

$$X = \frac{36(0.45\cos 60°)}{\sin 70°(1.2\cos 60°) + \cos 70°(1.2\sin 60°)}$$

$$= 8.811 = 8.8 \text{ N}$$

(b) **(i)** The principle of moments is satisfied about any axis.
Taking moments about the centre of mass of the rod, a force at A is required to provide a clockwise moment to keep the rod in equilibrium.
OR
The bar is in equilibrium hence the net force must be zero. Therefore, there must be a force at A with both horizontal and vertical component that opposes the horizontal component of the force due to the support rod at B and the weight of the rod, respectively.
The three forces acting on the rod must form a closed vector triangle of forces.

(ii) $F_x = X\cos 70^o$

$F_y + X\sin 70^o = 36$

$F_y = 36 - X\sin 70^o$

$$F = \sqrt{F_x^{\,2} + F_y^{\,2}}$$
$$= \sqrt{\left(8.8\cos 70^o\right)^2 + \left(36 - 8.8\sin 70^o\right)^2}$$
$$= 27.89 = 27.9 \text{ N}$$

(iii) Force at A is acting upwards and inclined to the right of the vertical (approximately 1 o'clock direction), such that the line of actions of the three forces (F, X and weight) on AB pass through a common point.

4 **(a)** 1. Most of the alpha particles pass through the thin gold foil undeflected, implying that the atom is mostly made up of empty space and that almost all its mass is concentrated in the nucleus at its centre.

2. Very few alpha particles (1 in 8000) are deflected at large angles greater than 90 degrees, implying that the nucleus is small.
It must also be positively charged since electrons are light and negative and very massive (capable of deflecting the massive alpha particles).

(b) **(i)** K.E. of alpha particle = $\left(4.8\times 10^6\right)\left(1.60\times 10^{-19}\right)$

$$\frac{1}{2}(4u)v^2 = \left(4.8\times 10^6\right)\left(1.60\times 10^{-19}\right)$$
$$v = \sqrt{\frac{2\left(4.8\times 10^6\right)\left(1.60\times 10^{-19}\right)}{4(1.66\times 10^{-27})}}$$
$$= 1.52\times 10^7 = 1.5\times 10^7 \text{ m s}^{-1}$$

(ii) Potential at a point in an electric field is the work done per unit positive charge by an external force in bringing the small test charge from infinity to that point (without a change in kinetic energy).

(iii) increase in electric potential energy = decrease in kinetic energy

$$\frac{Q_1Q_2}{4\pi\varepsilon_0 d} - \text{Initial EPE} = \text{Initial KE} - \text{Final KE}$$
$$\frac{(2e)(79e)}{4\pi\left(8.85\times 10^{-12}\right)d} - 0 = \left(4.8\times 10^6\right)e - 0$$
$$d = 4.736\times 10^{-14} = 4.74\times 10^{-14} \text{ m}$$

5 **(a)** p.d across resistive load, $V = V_0 \sin \omega t$

maximum power, $P_0 = \dfrac{V_0^2}{R}$

r.m.s voltage across resistive load, $V_{rms} = \dfrac{V_0}{\sqrt{2}}$

mean power, $\langle P \rangle = \dfrac{V_{rms}^{\ 2}}{R} = \left(\dfrac{V_0}{\sqrt{2}}\right)^2 \times \dfrac{1}{R} = \dfrac{V_0^2}{2R} = \dfrac{1}{2}P_0$

(b) **(i)** 1.5T = 27.0 ms

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{\left(\dfrac{27.0 \times 10^{-3}}{1.5}\right)} = 349.1 = 349 \text{ rad s}^{-1}$$

(ii) $$V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{170}{\sqrt{2}} = 120.2 = 120 \text{ V}$$

(c) $$V_{rms} = \sqrt{\frac{170^2 \times (T/2)}{T}} = 120.2 = 120 \text{ V}$$

(d) **(i)** **1.** The alternating voltage source V_1 results in a sinusoidally alternating magnetic flux produced by the primary coil.
The magnetic field permeates the iron core, cuts the secondary coil and results in a sinusoidally alternating magnetic flux linkage through the secondary coil.
By Faraday's law, an sinusoidally alternating e.m.f. is induced across the secondary coil.

2. As the same magnetic flux cuts through both primary and secondary coil, by Faraday's law, $V_p = N_p \dfrac{d\phi}{dt}$ and $V_s = N_s \dfrac{d\phi}{dt}$ where V_p = p.d. across the primary coil and V_s = e.m.f. induced across the secondary coil. Since the number of turns N_s in the secondary coil is smaller than the number of turns N_p in the primary coil, V_s will be less than V_p.

(ii) $$\frac{V_s}{V_1} = \frac{N_s}{N_p} = \frac{20}{500}$$

$$\frac{I_p}{I_s} = \frac{V_s}{V_1}$$

$$I_p = \frac{V_s}{V_1}\left(\frac{V_s}{15}\right)$$

$$= \frac{20}{500}\left(\frac{\frac{20}{500}(120)}{15}\right)$$

$$= 0.0128 \text{ A}$$

6 (a) (i) As l increase, T increases. For a particular mass, the difference in period T between 2 consecutive graphs decreases with increasing l.

(As l increases, the rate of change of T w.r.t. M increases.)

(ii) If T is proportional to $\sqrt{M}$, $T / \sqrt{M} =$ constant for a fixed value of l, as shown in table below.

l / m	T / s	M / kg	$T / \sqrt{M}$
0.25	0.78	0.20	1.74
	1.1	0.40	1.74
0.50	1.1	0.20	2.46
	1.56	0.40	2.47
0.75	1.35	0.20	3.02
	1.91	0.40	3.02
1.00	1.56	0.20	3.49
	2.2	0.40	3.48

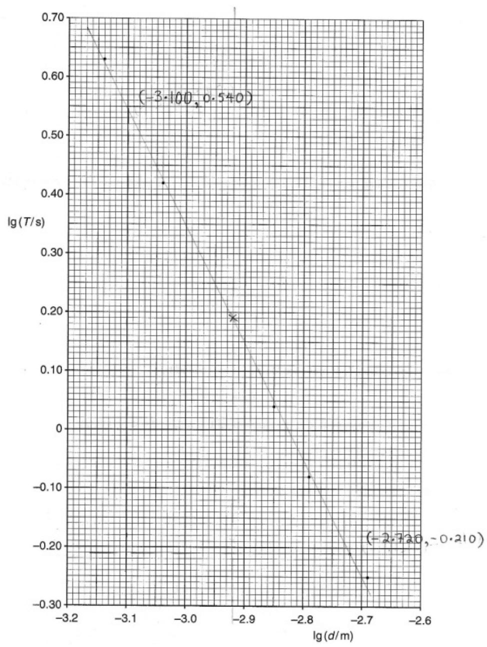
(iii) If T is proportional to $\sqrt{\ell}$, $T / \sqrt{\ell} =$ constant for a fixed value of M, as shown in table below.

Taking M = 0.20 kg from the table in (a)(ii):

l / m	T / s	M / kg	$T / \sqrt{\ell}$
0.25	0.78	0.20	1.56
0.50	1.10	0.20	1.56
0.75	1.35	0.20	1.56
1.00	1.56	0.20	1.56

(b) (i) For d = 1.20 mm, M = 0.40 kg and l = 0.50 m,
T = 1.56 s
lg (T / s) = 0.19
lg (d / m) = –2.92

(ii)



(iii)
$$\text{gradient} = \frac{0.540-(-0.210)}{-3.100-(-2.720)}$$
$$= \frac{0.750}{-0.380}$$
$$= -1.97$$

(c) **(i)**
$$T = Kd^n (M\ell)^{\frac{1}{2}}$$
$$\lg T = n\lg d + \lg K(M\ell)^{\frac{1}{2}}$$

Hence, n is the gradient of the graph of lg T against lg d.

(ii) $n = -2$

(d)
$$\lg T = n\lg d + \lg K(M\ell)^{\frac{1}{2}}$$
Substitute (–3.100, 0.540), n = –2, M = 0.40 kg and l = 0.50 m:
$$0.540 = -2(-3.100) + lg\,K(0.40\times 0.50)^{\frac{1}{2}}$$
$$K(0.20)^{\frac{1}{2}} = 10^{-5.66}$$
$$K = 4.892\times 10^{-6} = 4.89\times 10^{-6}\ \text{s m}^{\frac{3}{2}}\ \text{kg}^{-\frac{1}{2}}$$

(e) **(i)** Measure the angular displacement θ from the equilibrium position at various times t.

(ii) Plot a graph of angular displacement θ against time t. The graph will be sinusoidal, if the oscillations are simple harmonic.

Note: We can also plot θ vs sinωt within 1 period to get a straight line graph through the origin.

7. Problem Definition

<u>Experiment 1</u>

Independent variable:	Vertical height h of the slope
Dependent variable:	Average linear speed v of the spherical object
Control variables:	Diameter d of the spherical object Distance L travelled by the spherical object along the slope

<u>Experiment 2</u>

Independent variable:	Diameter d of the spherical object
Dependent variable:	Average linear speed v of the spherical object
Control variables:	Vertical height h of the slope Distance L travelled by the spherical object along the slope

2. Experimental Set-up

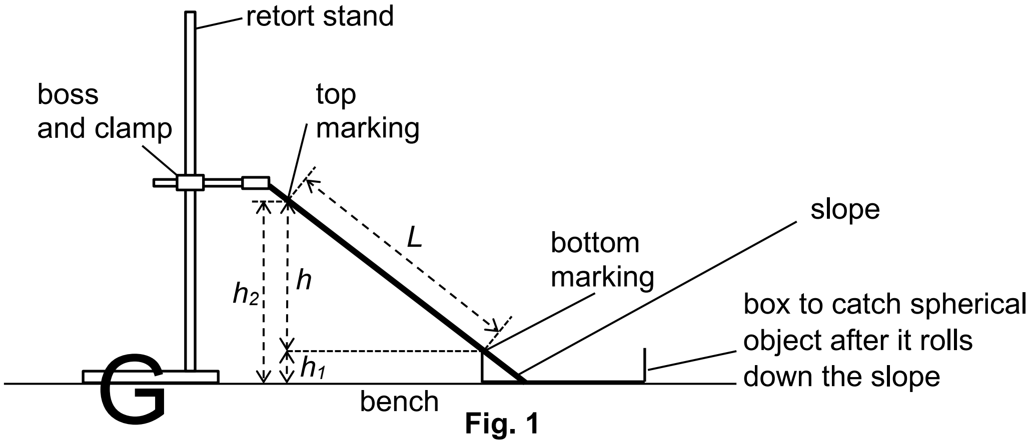


Fig. 1

3. Procedure

1. Set up the apparatus as shown in Fig. 1.
   (a) Make a marking near the top of the slope and another near the bottom.
   (b) Measure and record the distance *L* between the two markings using a metre rule.
   (c) Measure and record the heights h_1 and h_2 of the markings using a vertical metre rule. Determine height of drop using $h = h_2 - h_1$.
   (d) Measure and record the diameter *d* of each spherical object using a micrometer screw gauge

2. Experiment 1: variation of *v* with *h*, keeping *d* constant
   (a) Select one of the spherical object and record its diameter *d*.
   (b) Release the spherical object from rest at the top marking and measure the time taken *t* for it to roll to the bottom marking using a stop watch.
   (c) The average speed of the spherical object is $v = L / t$.
   (d) Repeat steps 2(b) to 2(c) for a total of 6 sets of *v* and *h* by adjusting the position of the clamp to change the angle of the slope.

3. Experiment 2: variation of *v* with *d*, keeping *h* constant
   (a) Fix the height *h* of drop by keeping the clamp and slope in the same position.
   (b) Select one of the spherical object and record its diameter *d*.
   (c) Release the spherical object from rest at the top marking and measure the time *t* taken for it to roll to the bottom marking using a stop watch.
   (d) The average speed of the spherical object is $v = L / t$.
   (e) Repeat steps 3(b) to 3(d) for a total of 6 sets of *v* and *d* by using spherical objects of different diameters *d*.

4. Analysis

$v = C\,d^x\,h^y$

<u>To determine *y* from Experiment 1:</u>

$lg\,v = y\,lg\,h + lg\left(C\,d^x\right)$, where *d* is constant.

Plot a graph of lg *v* against lg *h*, such that gradient = *y* and vertical-intercept = lg Cd^x.

To determine x from Experiment 2:

$lg\, v = x\, lg\, d + lg\left(Ch^{y}\right)$, where h is constant.

Plot a graph of lg v against lg d, such that gradient = x and vertical-intercept k = lg Ch^y.

To determine C:

Using the value of y in Experiment 1 and the values of height h and k in Experiment 2, the value of C can be determined using $C = \frac{10^{k}}{h^{y}}$.

5. Safety Precautions

1. Clamp the base of the retort stand to the bench top to prevent it from toppling.

6. Additional Details

1. Measure the diameter of each spherical object in three different orientations to determine its average diameter.
2. Use a spirit level or plumb line to ensure that the ruler used for measuring heights is vertical.
3. Place a metre rule on each side of the slope to restrict the path of the spherical object to a straight line.
4. Determine suitable heights h or distance L of the slope such that the time taken t is more than 20s to reduce percentage error in the measurement of time.
5. Account for any zero error in the micrometer screw gauge.

Paper 3

1 **(a)** increase in K.E. = decrease in E.P.E.

$$\frac{1}{2}mu^2 - 0 = e(\Delta V)$$

$$u = \sqrt{\frac{2e(\Delta V)}{m}}$$

$$= \sqrt{\frac{2\left(1.60\times10^{-19}\right)(850)}{9.11\times10^{-31}}}$$

$$= 1.73\times10^{7}$$

$$= 1.7\times10^{7}\ \text{m s}^{-1}$$

(b) **(i)** acceleration upwards = $\frac{F}{m}$

horizontal motion:

$$s_x = ut$$

$$t = \frac{s_x}{u}$$

vertical motion:

$$v_y = u_y + at$$

$$= 0 + \frac{F}{m}\left(\frac{s_x}{u}\right)$$

$$= \frac{4.0\times10^{-15}}{9.11\times10^{-31}}\left(\frac{5.1\times10^{-2}}{1.7\times10^{7}}\right)$$

$$= 1.32\times10^{7}\ \text{m s}^{-1}$$

(ii)

$$v = \sqrt{u^2 + {v_y}^2}$$

$$= \sqrt{\left(1.7\times10^{7}\right)^2 + \left(1.32\times10^{7}\right)^2}$$

$$= 2.15\times10^{7}\ \text{m s}^{-1}$$

2 **(a)** Evaporation occurs at any temperature while boiling only occurs at a single fixed temperature at a given pressure.
OR
Evaporation takes place at the surface of the liquid while boiling takes place throughout the liquid.

(b) WD against atmosphere $= p(\Delta V)$

$$= \left(1.05\times10^{5}\right)(1.69)$$

$$= 177450$$

$$= 1.77\times10^{5}\ \text{J}$$

(c) no. of molecules in 1.00 kg of liquid water $= \frac{1.00}{18.0\times10^{-3}}\left(6.02\times10^{23}\right)$

total change in internal energy,

$$\Delta u = W + Q$$
$$= \left(-1.77\times10^{5}\right) + \left(1.00\right)\left(2.30\times10^{6}\right)$$
$$= 2.123\times10^{6}\text{ J}$$

$$\text{average increase} = \frac{2.123\times10^{6}}{\dfrac{1.00}{18.0\times10^{-3}}\left(6.02\times10^{23}\right)}$$
$$= 6.35\times10^{-20}\text{ J}$$

3 **(a)** effective resistance of circuit,

$$R_{eff} = \left(\frac{1}{2.0}+\frac{1}{3.0}\right)^{-1} + 1.8$$
$$= 3.0\ \Omega$$
$$I = \frac{E}{R_{eff}}$$
$$= \frac{1.5}{3.0}$$
$$= 0.50\text{ A}$$

(b) terminal p.d. $V_T = V_x = V_Y$

$$= E - Ir$$
$$= 1.5 - (0.50)(1.8)$$
$$= 0.60\text{ V}$$

total power transfer to external resistors

$$= \frac{{V_X}^2}{R_X} + \frac{{V_Y}^2}{R_Y}$$
$$= \frac{0.60^2}{2.0} + \frac{0.60^2}{3.0}$$
$$= 0.30\text{ W}$$

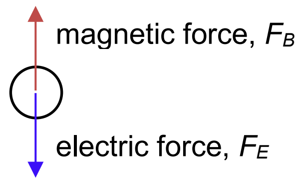
power transfer in cell

$$= I^2 r$$
$$= 0.50^2(1.8)$$
$$= 0.45\text{ W}$$
$$\text{ratio} = \frac{0.30}{0.45} = 0.667$$

(c) When the resistance of X is increased to $4.5\ \Omega$, the effective resistance of X and Y is $1.8\ \Omega$, which is the same as the internal resistance.
By maximum power theorem, half of the power supplied is transferred to the external resistors and the other half of the power is transferred to the internal resistor (OR power transfer to the external resistors is the same as the power transfer to the internal resistor). Hence the ratio will be one.

4 **(a)** In the magnetic field, the particle experiences a magnetic force that always acts perpendicularly to its velocity.
Hence, this force does not do any work on the particle to change its kinetic energy, and the speed of the particle remains constant.
Therefore, the magnitude of the magnetic force ($F = Bqv$) is constant.
Since the particle experiences a force that is always perpendicular to its motion and constant in magnitude, this force serves as the centripetal force which causes it to move in a circular arc.

(b) **(i)**



If the particle moves in a straight line path through the fields, the resultant force on the particle is zero.

$$F_B = F_E$$

$$Bqv = qE$$

$$E = Bv = \left(3.2\times10^{-3}\right)\left(4.7\times10^{5}\right) = 1504 = 1500 \text{ V m}^{-1}$$

(ii) When the speed is increased, the magnetic force on the proton increases in magnitude but the electric force remains unchanged. There will now be a resultant force and the proton will deviate upwards.
However, the deviation upwards will be less than the path shown in Fig. 4.1 as the resultant force is smaller in the presence of the downward electric force.

5 (not in 9749 syllabus)
As temperature rises, electrons in the valence band gain thermal energy and vibrate faster.
When electrons at the top of the valence band gain sufficient thermal energy to jump across the small band gap (forbidden band), they will leave the valence band and enter the empty conduction band.
Once in the conduction band, electrons are mobile to conduct electricity.
As temperature continues to rise, more electrons from the valence band will enter the conduction band. This increases the number of mobile charge carriers in the conduction band.
Hence electrical conductivity increases and resistance decreases.

6 **(a)** **(i)** This is to ensure that the count rate measured is only due to the decay of phosphorus-32. If there are more than one type of decay taking place, the count rate will not decrease exponentially and the half-life of phosphorus-32 cannot be found just from the graph in Fig. 6.1.

(ii) Background radiation is approximately 20 Bq.
This is less than 5% of the initial count rate and will have little effect on the count rate measured in the initial days.
Hence background radiation may be neglected.

(b) Method 1:
Sketch best-fit curve on Fig. 6.1.
Initial count rate, $R_0 = 475\ \text{s}^{-1}$
Number of days for count rate to fall to half its initial value
i.e. $R_1 = \frac{1}{2} R_0 = 237.5\ \text{s}^{-1}$ is 15.5 days.
Hence half-life is 15.5 days.

Method 2:

at $t = 0$, $R_0 = 475\ \text{s}^{-1} = A_0$

at $t = 35$ days, $R = 95\ \text{s}^{-1} = A$

$$\frac{A}{A_0} = \left(\frac{1}{2}\right)^{t/t_{1/2}}$$

$$\ln\frac{A}{A_0} = \frac{t}{t_{1/2}}\ln\left(\frac{1}{2}\right)$$

$$t_{1/2} = \frac{t\ln\frac{1}{2}}{\ln\frac{A}{A_0}} = \frac{35\ln\frac{1}{2}}{\ln\frac{95}{475}} = 15.1 \text{ days}$$

(c) Careful shielding is still necessary as beta particles can penetrate through the skin and cause damage to human cells, which may manifest as health conditions e.g. cancer, in future.

7 (a) (i) **1.** Distance of the mass from the equilibrium position, with a specific direction taken as positive.

2. The maximum distance travelled by the mass from the equilibrium position.

(ii) The oscillatory motion of the mass whose acceleration is directly proportional to its displacement from a fixed equilibrium position and is always directed towards that equilibrium position.

(b) simple pendulum:
The path of the oscillating pendulum describes an arc of a circle.
The restoring force is the tangential component of the pendulum's weight, which is perpendicular to the string and points towards the equilibrium position i.e. position where the pendulum is hanging vertically.

floating block:
The restoring force is the change in upthrust from the upthrust at the equilibrium position. It acts in the vertical direction towards the equilibrium position i.e. position where the block is floating.

(c) The weight of the block at the end of the rod causes the rod to bend and curve downwards.
As a result, the top edge of the strip is stretched / extended and its length is greater than *L*.
The bottom edge of the strip is compressed and its length is smaller than *L*.

(d) $\dfrac{CE}{L^3M}$ is a positive constant. Hence $a \propto (-x)$ which satisfies the definition for simple harmonic motion.
Compare the given equation with the defining equation for simple harmonic motion, $a = -\omega^2 x$. The angular frequency of the oscillations is $\omega = \sqrt{\dfrac{CE}{L^3M}}$.

(e) **(i)** From Fig. 7.4:
Time for 4 cycles = 0.84 s
Time for 1 cycle i.e. period, T = (0.84 / 4) s

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{0.84/4} = 29.92 = 29.9 \text{ rad s}^{-1}$$

(ii)

$$a = -\omega^2 x = -\frac{CE}{L^3M}x$$

$$\omega^2 = \frac{CE}{L^3M}$$

$$C = \frac{\omega^2 L^3 M}{E}$$

$$= \frac{(29.92)^2 (0.80)^3 (150 \times 10^{-3})}{2.0 \times 10^{11}} = 3.438 \times 10^{-10} = 3.44 \times 10^{-10}$$

(f) If the 2 strips have the same frequency of oscillation, then

$$\omega_{Al}^2 = \omega_s^2$$

$$\frac{CE_{Al}}{L^3M_{Al}} = \frac{CE_S}{L^3M_S}$$

$$M_{Al} = \frac{E_{Al}}{E_S}M_S$$

$$= \frac{7.1 \times 10^{10}}{2.0 \times 10^{11}}(150 \times 10^{-3}) = 0.05325 = 0.0533 \text{ kg}$$

8 **(a)** A photon is a quantum of energy
whose energy is given by hf or hc/λ, where f and λ is the frequency and wavelength respectively of the associated electromagnetic radiation.

(b) **(i)** The line emission spectrum has a dark background with coloured lines positioned at specific discrete wavelengths or frequencies.

(ii) Each coloured line on the emission line spectrum is produced by the emission of photons of a specific quantum of energy.
Since the energy of the photons emitted is of a discrete value, they must be emitted when the atoms de-excites between specific energy levels, implying that the energy levels in the atoms are discrete.

(c) **(i)** Energy of a photon of violet light,

$$E_v = \frac{hc}{\lambda} = \frac{\left(6.63\times10^{-34}\right)\left(3.00\times10^{8}\right)}{\left(400\times10^{-9}\right)\left(1.60\times10^{-19}\right)} = 3.11\text{ eV}$$

From the highest level: $\Delta E = (-0.55)-(-13.6) = 13.05$ eV

From the second lowest level: $\Delta E = (-3.41)-(-13.6) = 10.19$ eV

Electron transitions to –13.6 eV produce photons of energies from 10.19 eV to 13.05 eV.
Since the energy of a violet photon is 3.11 eV and the energy of a red photon is even lower, the photons produced when transiting to the energy level of –13.6 eV do not lie within the visible light region.

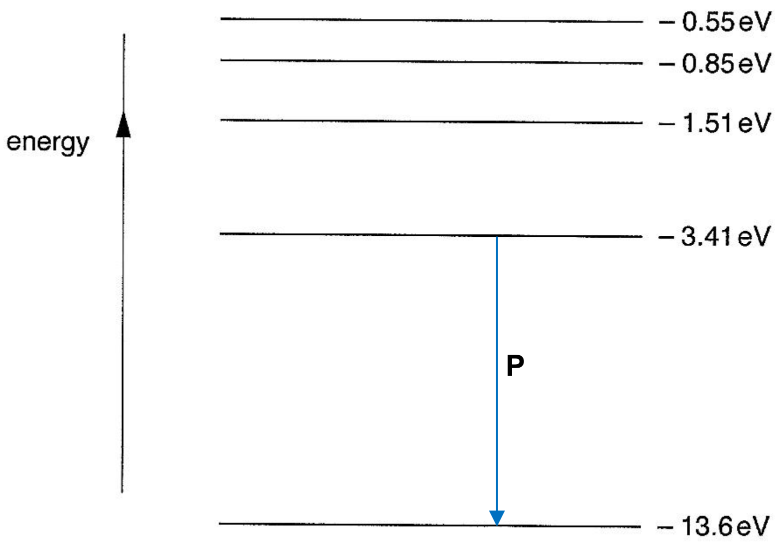
(ii) **1.** 3

(ii) **2.**

$$\Delta E = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{\Delta E} = \frac{\left(6.63\times10^{-34}\right)\left(3.00\times10^{8}\right)}{\left(-0.55-(-3.41)\right)\left(1.60\times10^{-19}\right)} = 4.347\times10^{-7} = 4.35\times10^{-7}\text{ m}$$

(d) **(i)**



(ii)

$$\frac{hc}{\lambda} = \Phi + E_{K,\max}$$

$$(-3.41)-(-13.6) = 5.6 + E_{K,\max}$$

$$E_{K,\max} = 4.59\text{ eV}$$

(e) **(i)**

$$t = \frac{\text{distance}}{\text{speed}} = \frac{2.6\times10^{-10}}{3.00\times10^{8}} = 8.667\times10^{-19} = 8.67\times10^{-19}\text{ s}$$

(ii) The maximum uncertainty in the time would be the time the photon takes to travel the diameter of the gold atom, which is the time calculated in (i).

(iii) The uncertainty principle states that $\Delta E \Delta t \geq \frac{h}{4\pi}$, where ΔE and Δt are the uncertainties in the energy and time respectively.
This means that during the time the photon takes to cross the atom, there is an uncertainty in the time (as stated in (ii)) and consequentially there is an uncertainty in its energy.
Hence the energy of the photon may not be equal to that of the photon in free space.

9 (a) (i)

$$g_P = \frac{GM}{x^2}$$

(ii)

$$E_P = -\frac{GMm}{x}$$

(b) (i)

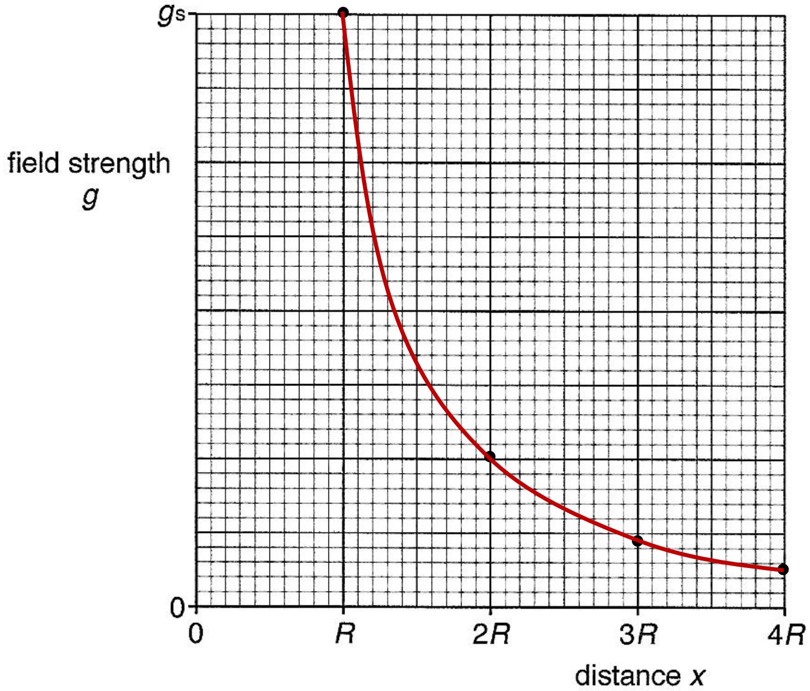
$$g_S = \frac{GM}{R^2}$$

$$g_{2R} = \frac{GM}{(2R)^2} = \frac{1}{4} g_S$$

$$g_{3R} = \frac{GM}{(3R)^2} = \frac{1}{9} g_S$$

$$g_{4R} = \frac{GM}{(4R)^2} = \frac{1}{16} g_S$$

Plot the points on the graph.



(ii) The graph will still follow the $1/R^2$ relationship and the relative *g* values will still be the same i.e.

$$g_S = \frac{GM}{R^2}, \quad g_{2R} = \frac{1}{4}g_S, \quad g_{3R} = \frac{1}{9}g_S, \quad g_{4R} = \frac{1}{16}g_S.$$

As mass decreases, the graph will shift downwards, keeping the above relationships true at all times.

(c) **(i)** Star A and star B attract each other by Newton's law of gravitation. By Newton's third law, the force of attraction on A by B is equal in magnitude and opposite in direction to the force of attraction on B by A. The magnitude of this gravitational force of attraction is $\frac{GM_AM_B}{d^2}$.

Since the only force acting on each star is this gravitational force of attraction, the gravitational force is also the centripetal force on each star. Hence the magnitude of the centripetal force on each star is the same.

(ii)

$$\omega = \frac{2\pi}{T}$$
$$= \frac{2\pi}{4.0 \times 365 \times 24 \times 60 \times 60}$$
$$= 4.981 \times 10^{-8} = 4.98 \times 10^{-8} \text{ rad s}^{-1}$$

(iii) Consider star A and B in circular motion about the same centre of orbit. Star A and B will have the same angular speed.

gravitational force on A = cetripetal force on A = $M_A\omega^2 r_A$

gravitational force on B = cetripetal force on B = $M_B\omega^2 r_B$

Since the gravitational force on A = gravitational force on B,

$$M_A\omega^2 r_A = M_B\omega^2 r_B$$
$$r_A = \frac{M_B}{M_A}(d - r_A) = \frac{1}{3.0}(d - r_A) = \frac{d}{3.0} - \frac{r_A}{3.0}$$
$$r_A + \frac{r_A}{3.0} = \frac{d}{3.0}$$
$$r_A\left(1 + \frac{1}{3.0}\right) = \frac{3.0 \times 10^{11}}{3.0}$$
$$r_A = 7.5 \times 10^{10} \text{ m}$$

(d) Consider star A in circular motion:

$$\frac{GM_AM_B}{d^2} = M_A\omega^2 r_A$$

$$M_B = \frac{\omega^2 r_A d^2}{G} = \frac{\left(4.981 \times 10^{-8}\right)^2\left(7.5 \times 10^{10}\right)(3.0 \times 10^{11})^2}{6.67 \times 10^{-11}} = 2.51 \times 10^{29} \text{ kg}$$

$$M_A = 3.0M_B = 3.0\left(2.51 \times 10^{29}\right) = 7.53 \times 10^{29} \text{ kg}$$

(e) Observe the light intensity of the binary star system.

Minimum intensity occurs when the line joining the 2 stars is along the line of sight from Earth. At these positions, the stars are directly in front or behind each other and thus blocking each other’s intensity the most.

The time between 2 minimum intensities is half a period. Mulitply this time by 2 to obtain the period.