2023 H2 Prelim P2 Solutions

1.	(a)	Using $s = ut + \frac{1}{2}gt^2 \rightarrow h = \frac{1}{2}gt^2$ $g = \frac{2h}{t^2} = \frac{2(0.600)}{(354\times10^{-3})^2}$ $g = 9.5758$ m s^{-2} $\frac{\Delta g}{g} = \frac{\Delta h}{h} + \frac{2\Delta t}{t}$ $\frac{\Delta g}{9.5758} = \frac{0.001}{0.600} + \frac{2(1)}{354}$ $\Delta g = 0.07$ m s^{-2} $g = (9.58 \pm 0.07)$ m s^{-2}		C1 C1 A1
	(b)	(i)	Steel is a hard magnetic material. The delay is due to the time taken for the electromagnet and steel ball to lose their magnetism.	A1
		(ii)	Systematic error. The constant delay causes the timing measured to be consistently too long.	A1 C1
		(iii)	Place light gate just below steel ball. Recorded time is time delay. OR Graphical method: Measure the timings for different heights of fall and plot a graph of h against t^2. Details: The constant delay is the square root of the x-intercept. OR Experimental method: Use of light gates / high speed camera / etc. Details: Positioning of light gates / view video in slow motion / etc.	M1 C1

2	(a)	head-on : collision takes place along the line joining the centres of the colliding bodies. elastic collision: both the momentum and the kinetic energy are conserved.	C1 C1
	(b)	speed of separation = speed of approach $v_2 - v_1 = u_1 - 0$ $or\ u_1 + v_1 = v_2$ - - - (1)	A1
	(c)	By Conservation of momentum, $mu_1 = mv_1 + 12mv_2$ $\Rightarrow u_1 - v_1 = 12v_2$---(2) (1)+(2) $2u_1 = 13v_2 \Rightarrow v_2 = \frac{2}{13}u_1$ from (1) $v_1 = v_2 - u_1 = \frac{2}{13}u_1 - u_1 = -\frac{11}{13}u_1$ Thus ratio $\frac{v_1}{u_1} = \frac{11}{13}$ = 0.846	C1 C1 A1

	(d)	required fraction $= \dfrac{\frac{1}{2}m\left(u_1^2 - v_1^2\right)}{\frac{1}{2}mu_1^2} = 1 - \left(\dfrac{v_1}{u_1}\right)^2$ $= 1 - \left(\dfrac{11}{13}\right)^2 = 0.28$	C1 A1
	(e)	This is a *head-on elastic* collision between two equal masses. After collision, the incident neutron will stop while the target neutron moves off with the velocity of the incident neutron. (The ratio of the final to the initial speed of the incident neutron would be zero.) The fraction of the kinetic energy of the incident neutron that is transferred to the target neutron would be 1.	C1 A1

3(a) The work done by a force on an object particle is defined as the product of the magnitude of the force and the component of the displacement in the direction of the force. B1

3(b)(i) Change in KE = Net work done

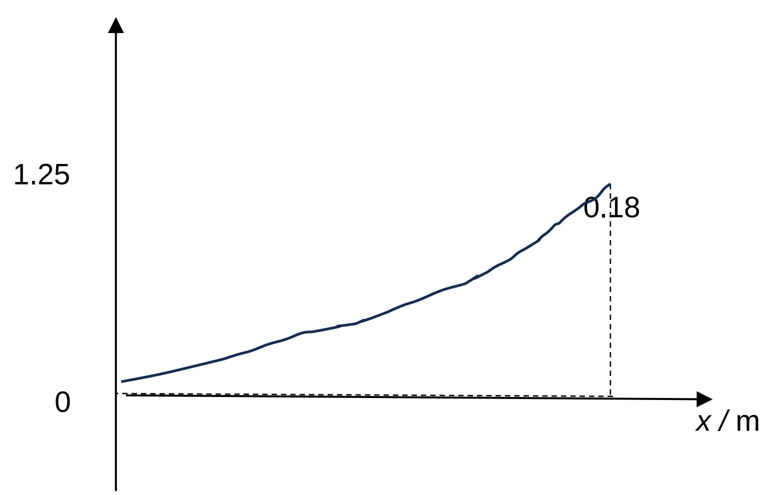
$$0 - \frac{1}{2}mu^2 = -\frac{1}{2}F_{max}x$$ M1

$$(0.400)(2.5)^2 = (14)x$$

$$x = 0.18 \text{ m}$$ A1

(ii)

work done by F / J

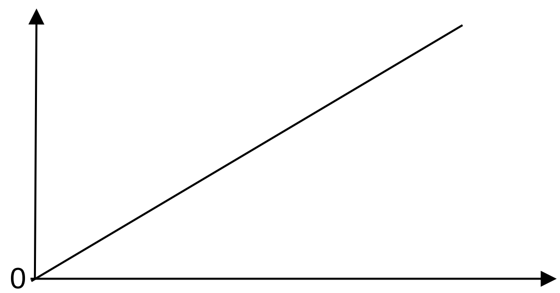


B1

B1

B1 – shape
B1 – x and work done values

(iii)



B1

Since F proportional to x, and v is constant, power also proportional to x

4 (a) The direction of the object changes continuously and hence there is a change in velocity of the object. By Newton's second law, there must be a force acting on the object. M1

Since the speed remains unchanged, this force cannot have a component tangential to the circle/ does no work. This implies that the force is perpendicular to the velocity/displacement of object acting towards centre of circle. C1

(b) i For the block to just make it through the top of the loop, the weight is just providing for the centripetal force.

$mg = mv_{top}^2 / R$ C1

$(0.50)(9.81) = (0.50)(v_{top}^2) / 1.5$

$v_{top} = 3.84$ m s^{-2} [1, also award if student leave as KE = 3.68 J] A1

ii By Conservation of energy, C1

$KE_i + EPE_i + GPE_i$ – work done by friction $= KE_f + EPE_f + GPE_f$

$0 + ½ ke^2 + 0 – Fd = ½ mv_{top}^2 + 0 + mg(2R)$

$½ (78.4)(e^2) – (1.47)(2.5) = ½ (0.50)(3.836^2) + 0.50(9.81)(2 \times 1.5)$ A1

Solving, e = 0.750 m

(c) v_{min} remains unchanged. A1

At C, to stay in contact, centripetal acceleration of the block = acceleration of free fall, $\frac{v_{min}^2}{r} = g$ *Hence* $v_{min} = \sqrt{rg}$, independent of the mass of the block. C1

5 **a** free: oscillation without any loss of energy / no external forces e.g. resistive forces B1

forced: body is made to vibrate by an (external) periodic driving force such that continuous energy is input B1

b From the graph, maximum displacement = 23.00 cm A1

minimum displacement = 11.00 cm

amplitude = 0.5 (23.00 – 11.00)

= 6.00 cm = 0.0600 m

c From graph, A1

T = 2.000 s [M1]

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{2.000} = 3.14 rads^{-1}$$

d Energy of Oscillation = Maximum KE M1

$$= \frac{1}{2} m\omega^2 x_0^2 = \frac{1}{2}(10)(3.14)^2(0.06)^2 = 0.177J$$ A1

e For loss of contact, a > g

At this setting, a_{min} = 9.81 = 3.14^2 (x_{min}) M1

x_{min} = 0.995m A1

6 a (ii)1. $E = \frac{W}{Q} = \frac{2.4\times10^5}{2.2\times10^4} = 11\text{V}$ M1

2 $Q = It = \frac{E}{R}t$

$\Rightarrow t = \frac{QR}{E} = \frac{2.2\times10^4\times3800}{11}$ M1

$= 7.6\times10^6\text{s}$ A1

3 fraction = $\frac{I^2R_T}{I^2R_T + I^2R} = \frac{R_T}{R_T + R} = \frac{1800}{1800+2000}$ M1

= 0.474 A1

Note: fraction must be written in decimal. -1 for answer not written in decimal

b (i) $V_{XY} = \frac{8.0}{8.0+0.50+2.5}\times2.0 = 1.455\ \text{V}$ M1

At null deflection, V_{XJ} = e.m.f. of cell B.

$E = \frac{0.90}{1.0}\times1.455 = 1.31\ \text{V}$ M1

(ii)1 At null deflection, $V_{XJ} = V_{RS}$ M1

$V_{XJ} = \frac{0.75}{1.0}\times1.455 = 1.091\ \text{V}$

$I_{RS} = \frac{V}{R} = \frac{1.091}{6.5} = 0.1679\text{A}$ M1

$E = V + Ir \Rightarrow r = \frac{E-V}{I} = \frac{1.31-1.091}{0.1679} = 1.30\ \Omega$ A1

allowed range of E: 1.20 to 1.40 depending on substitution

With resistor connected in parallel, load resistance of cell B would decrease. B1

This would cause terminal p.d. of cell B to decrease.

Since no change in potential difference per unit length along wire XY, A1

Balance length XJ would decrease.

7 (a) (i) force = qE — M1

in the direction of the field — A1

(ii) no force — B1

(since current/velocity is parallel to B-field)

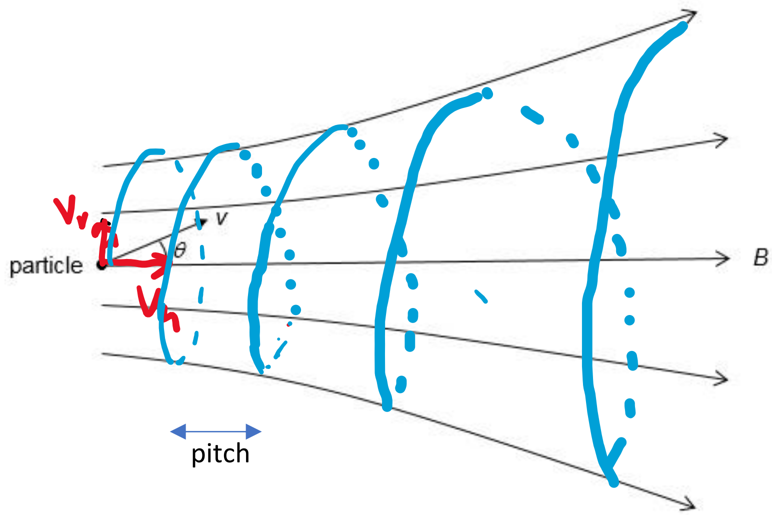
(b) (i) B field pointing into the page/plane of the paper — A1

(ii) resultant force is zero/the 2 forces cancel out — B1

(good to show F_E acts downward and F_B acts upwards)

$Eq = Bqv \Rightarrow v = E/B$ — B1

(c) (i)



- Horizontal component of velocity experience zero force, so constant horizontal motion to the right. — B1

-Vertical component of velocity results in a magnetic force into page which provides centripetal force for circular motion into the page — B1

-Since radius $r = mv/Bq$, as B decreases, radius r increases — B1

(ii) Helical path drawn with increasing radius and longer pitch — B1

(Note: The period of each circle $T = 2\pi m/Bq$, as B decreases T increases, so horizontal pitch $s_x = v_x T$ increases)

8	**(a)(i)**	Activity A of a radioactive substance is defined as the number of disintegrations per unit time.	B1
	(a)(ii)	use of $\lambda = (\ln 2)/t_{½}$	C1
		shows that years have been converted to seconds	
		$\lambda = 2.5 \times 10^{-10}\ s^{-1}$	A1
	(a)(iii)	$N = A/\lambda$	
		$= 0.63 \times 10^{12}/2.5 \times 10^{-10}$ per g (must use value given in the table)	C1
		$= 0.63 \times 10^{12}/2.5 \times 10^{-10} \times 0.16$	C1
		$= 4.0 \times 10^{20}$	
		1 mark awarded if use	A0
		$N = (0.16/238) \times 6.02 \times 10^{23} = 4.0 \times 10^{20}$	
	(b) (i)	Energy per unit time = activity x energy per decay	C1
		Energy per sec = $(0.63 \times 10^{12} \times 0.16) \times 5600 \times 10^{3} \times 1.60 \times 10^{-19}$	C1
		= 0.090 J	A1
	(b) (ii)	$e = 7.5 \times 10^{-4}/0.090 \times 100\%$	C1
		= 0.83%	A1
	(c)	Since Power output is proportional to Activity,	
		$P = P_o e^{-\lambda t}$	C1
		$0.60/0.75 = e^{-\lambda t}$	A1
		$t = 8.9 \times 10^{8}$ s	
	(d)	use $E = mc\Delta\theta$	C1
		$0.68 \times 10^{-3} \times 12 \times 3600 = 6.7 \times 10^{-3} \times 410 \times \Delta\theta$	A1
		$\Delta\theta = 11\ ^{o}C$	
	(e)	-A **slow neutron may cause nuclear fission of Pu-238 and trigger a chain reaction**, which will cause a high amount of energy to be released in a short time. This is undesirable for the pace-maker.	B1
		-It is important to investigate the decay chain to **eliminate the possibility of alpha or gamma emitters in the decay series** of the parent nucleus	B1
	(f)	-**Reject alpha emitters because it can lead to neutron production** and select beta emitters **And** anyone: -**reject Strontium-90 as it is most energetic** of the 3 beta emitters, since it **could produce gamma radiation** OR -**reject Hydrogen-3** due to its **short half-life** (as compared to average human life span), therefore **need constant replacement** (Any one correct reason)	B1
		And -**select Nickel-63** as energy released per decay is suitable/ it has an appropriate half-life (as compared to average human lifespan)	B1