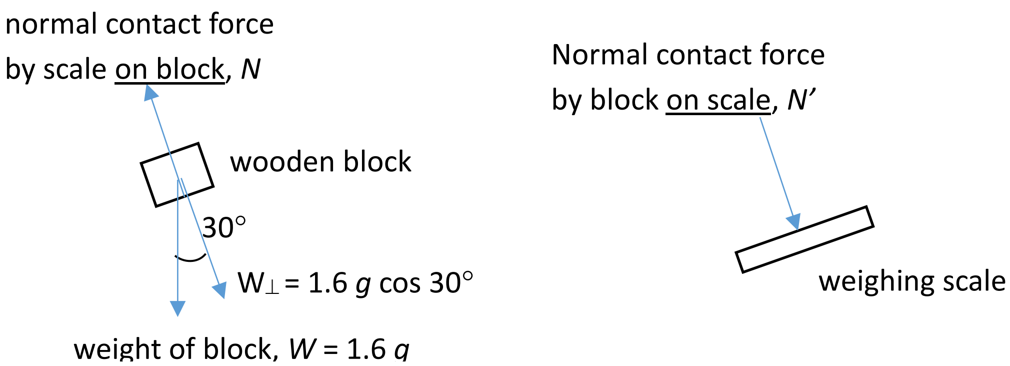
2023 H2 Physics Preliminary Examination Paper 2 Suggested Solutions

Q1	Suggested Solutions	Mark

1 (a)



In the direction normal to the slope, the block is in equilibrium.

net force on the block = 0 N

thus, Normal contact force by the scale on the block, N

= weight component of the block normal to the slope

= 1.6 g cos 30°

The scale measures the normal contact force exerted by the block on the scale, that is equal and opposite to the normal contact force by the scale on the block. (Newton's 3rd Law of Motion) **B1**

Thus, the reading on the scale **B1**

= normal contact force by the block on the scale/ g

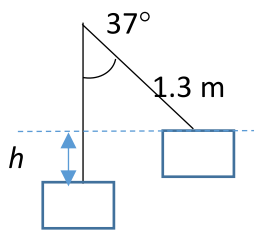
= 1.6 g cos 30° / g = 1.39 or 1.4 kg.

B1

(b) (i)

Consider the block moving from the bottom to maximum height:

Let the velocity of the block immediately after collision be v



By conservation of energy,

Loss in KE = Gain in GPE

$$\frac{1}{2}mv^2 - 0 = mgh$$ **B1**

$$v = \sqrt{2gh} = \sqrt{2(9.81)(1.3 - 1.3\cos 37°)} = 2.3 \text{ m s}^{-1}$$ **B1**

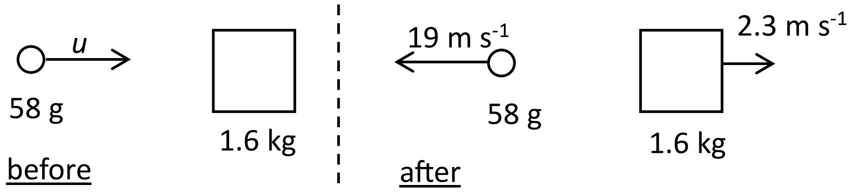
(ii)

applying N2L on the block: $\langle F \rangle = \frac{m(v-u)}{\Delta t} = \frac{1.6(2.3-0)}{0.2}$ **B1**

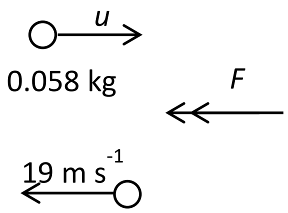
$= 18.4$ N **A1**

			OR variations: $J = \langle F \rangle \Delta t = m(v-u)$; $\langle F \rangle = ma = m\frac{(v-u)}{\Delta t}$	

(iii)



			By conservation of linear momentum, $m_{ball}u_{ball} = m_{block}v_{block} + m_{ball}v_{ball}$	**B1**
			$u_{ball} = (m_{block}v_{block} / m_{ball}) + v_{ball} = \frac{1.6(2.3)}{0.058} - 19 = 44.4$ m s^{-1}	**A1**
			Or $\langle F \rangle_{on\ ball} = \frac{m(v-u)}{\Delta t}$ $18.4 = \frac{0.058(19-u)}{0.2}$ $u = -44$ m s^{-1}	

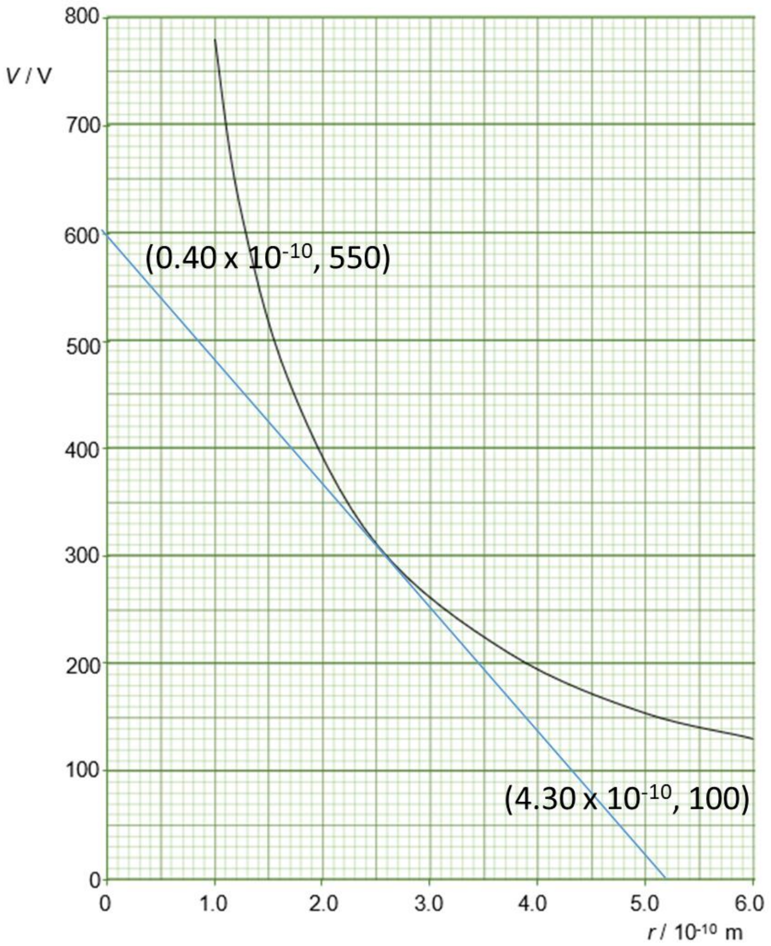


			i.e. v = 44.4 m s^{-1} opposite to the final velocity.	
	(c)	Relative speed of approach = 44 m s^{-1} Relative speed of separation $= 2.3 + 19.1 = 21.4$ m s^{-1} $\neq$ relative speed of approach Thus, the collision is not elastic. OR Initial KE = ½ (0.058)(44)^2 = 56 J Final KE = ½ (0.058)(19)^2 + ½ (1.6)(2.3)^2 = 14.7 J Since total KE s not conserved/ initial KE is greater than final KE, the collision is not elastic.		**B1** **A1**

Q2				Suggested Solutions	Mark
2	(a)			Newton's Law of Gravitation states that every point mass **attracts** every other point mass with a force that is **directly proportional** to the **product of their masses** and **inversely proportional** to the **square of the distance** between them.	B1
	(b)	(i)		The gravitational force on the satellite is always directed towards the centre of the Earth and so *any circular orbit must have its centre at the centre of the Earth*. The orbit must be in the equatorial plane, otherwise *the satellite will sometimes be over the northern hemisphere and sometimes over the southern hemisphere*.	B1 B1
		(ii)	1.	**Gravitational force provides centripetal force (*full statement required*)** Let *G* be the gravitational constant, *M* the mass of the Earth, *m* the mass of the satellite, *r* the radius of the satellite's orbit, *ω* the satellite's angular velocity, and *T* the orbital period, *T* = 24 x 60 x 60 = 86 400 s. $\frac{GMm}{r^2} = m\left(r\omega^2\right) = mr\left(\frac{2\pi}{T}\right)^2$ **(*show equation*)** $r^3 = \frac{GMT^2}{4\pi^2}$ The radius of the orbit of the satellite about the centre of the Earth is $r = \sqrt[3]{\frac{\left(6.67\times10^{-11}\right)\left(6.0\times10^{24}\right)\left(24\times60\times60\right)^2}{4\pi^2}}$ **(*values entered explicitly*)** $= 4.230\times10^7$ m Let *h* be the altitude of the satellite above the surface of the Earth *h* = **4.23 x 10^7 - 6.4 x 10^6 (*show values*)** = 3.59 x 10^7 m	B1 B1 B1 B1
			2.	Linear speed = *rω* $v = r\omega = r\left(\frac{2\pi}{T}\right)$ $= \left(4.230\times10^7\right)\left(\frac{2\pi}{24\times60\times60}\right)$ $= 3080$ m s^{-1}	B1 A1

Q3		Suggested Solutions	Mark
3	**(a)**	The incident wave from the oscillator is **reflected at Q.**	**B1**
		The incident and reflected waves have the **same speed, wavelength (or frequency) and amplitude, travelling in opposite directions overlap/meet/superpose** and form a stationary wave.	**B1**
	(b)	Q is a **fixed end or node**. **Destructive interference** must occur, so that the **net displacement is always zero**. Hence there must be a phase change of 180° (or π radians) at Q.	**B1**
	(c)	**(i)** $\lambda/2 = 0.30$ m $\lambda = 0.60$ m $v = f\lambda = (120)(0.60)$ $= 72$ m s^{-1}	 **M1** **A1**
		(ii) $v_0 = \omega x_0 = 2\pi(120)(0.0080)$ $= 6.03$ m s^{-1}	**M1** **A1**

Qn 4	Suggested Solutions	Mark
4(a)	The electric potential at a point is the **work done per unit positive charge**, in bringing a small test charge from infinity to that point.	B1
4(b)(i)	At r = 1.0 x 10^{-10} m, the potential is 780 V. $V = \frac{Q}{4\pi\varepsilon_0 r}$ $= \frac{ne}{4\pi\varepsilon_0 r}$, where n is number of protons $n = \frac{V(4\pi\varepsilon_0 r)}{e} = \frac{780(4\pi)(8.85\times10^{-12})(1.0\times10^{-10})}{1.60\times10^{-19}}$ $= 54$	M1 M1 M1
4(b)(ii)	The distance 2.0×10^{-8} m is considerably greater than the **diameters** *or* **radii** of the nucleus and the proton.	B1
(b)(iii) 1.	The magnitude of the electric field strength at a point is equal to the gradient of the potential-distance curve at that point.	B1
2.	<u>Approach 1</u> determine E by finding gradient of tangent at r = 2.6 x10^{-10} m $E = -\frac{\Delta V}{\Delta r} = -\frac{550-100}{(0.40-4.30)\times10^{-10}} = 1.15\times10^{12}$ NC^{-1} $F_{electric} = qE$ $= (1.60\times10^{-19})(1.1538\times10^{12})$ $= 1.85\times10^{-7}$ N Direction: radially away from the nucleus gradient – 1 mark substitution of values into force equation – 1 mark value of force – 1 mark direction (**radially** must be present) – 1 mark	M1 M1 A1 A1



<u>Approach 2</u>

From Fig. 4.1, when r = 2.6 x10^{-10} m, V = 300 V

$$F_{electric} = qE = q\left(\frac{dV}{dr}\right)$$

$$= q\left(\frac{V}{r}\right) = e\left(\frac{54e}{4\pi\varepsilon_0 r}\right)\left(\frac{1}{r}\right)$$

$$= \left(1.60\times10^{-19}\right)\left(\frac{300}{2.6\times10^{-10}}\right)$$

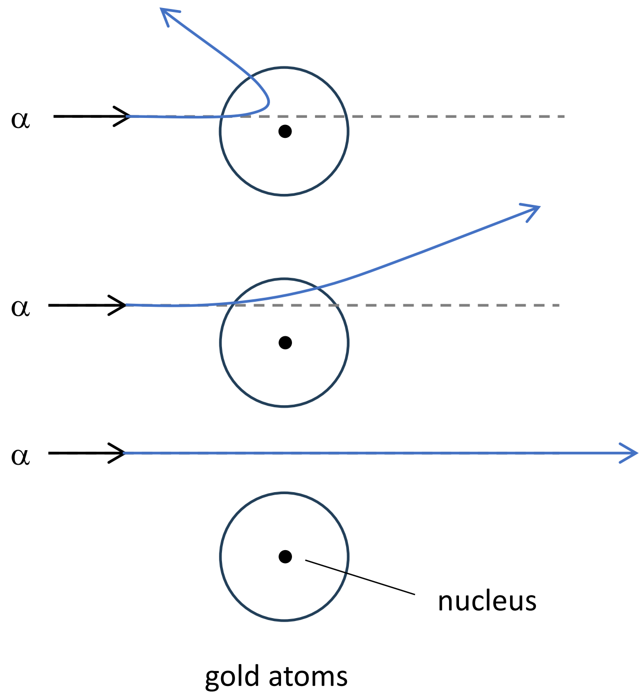
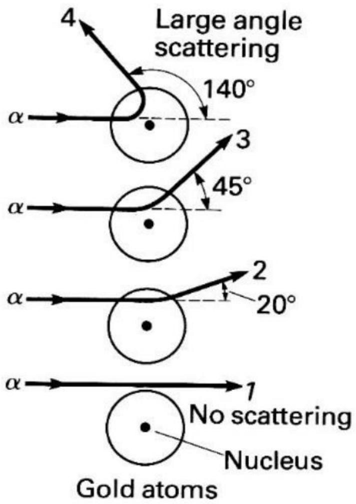
$$= 1.85\times10^{-7}\ \text{N}$$

radially away from the nucleus

		M1 M1 A1 A1

Q5		Suggested Solutions	Mark
5	(a)	e.m.f. is the energy per unit charge converted ***from other forms of energy to electrical energy*** as charge is driven through a whole circuit. Potential difference ***between two points in a circuit*** is the energy per unit charge converted ***from electrical energy to other forms of energy*** when charge passes between the two points.	B1 B1
	(b)	Since this is a resistance wire of uniform resistivity and cross-sectional area (by the formula $R = \rho l /A$), the resistance R is proportional to the distance l between the two mentioned points. Since a constant current flows through the whole circuit, the potential difference between two points on the resistance wire is proportional to resistance R and proportional to the distance l between the two mentioned points.	B1 B1
	(c)	(i) When CK is 60.0 cm, AJ is 54.0 cm. Since ammeter reading is zero, p.d. across CK = p.d. across AJ $= V_{AB}$ (AJ/ AB) = 12.0 (54.0/120.0) = 5.4 V	B1 B1
		(ii) When CK = 60.0 cm, resistance across CK = 4.5 Ω . When AJ = 54 cm , p.d. across AJ = 5.4 V p.d. across AJ = p.d. across CK $5.4 = \frac{4.5}{4.5+r}E$ ……………………(1) When CK = 20.0 cm, resistance across CK = 1.5 Ω . When AJ = 45 cm , p.d. across AJ = 4.5 V p.d. across AJ = p.d. across CK $4.5 = \frac{1.5}{1.5+r}E$ ………………………(2) Eqns [1]/[2] , $1.2 = \frac{3(1.5+r)}{4.5+r}$ $5.4 + 1.2r = 4.5 + 3r$ $r = 0.5\ \Omega$	M1 M1

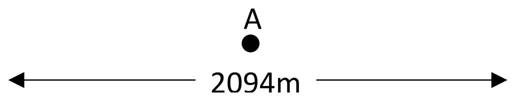
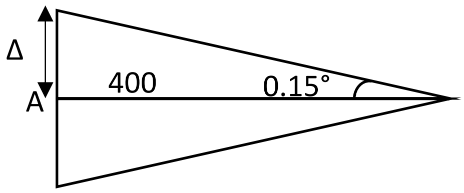
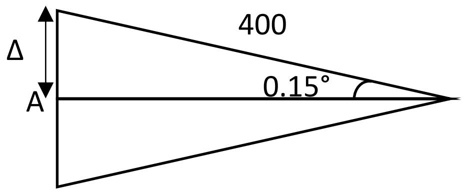
			By eqn [1] , $5.4 = \frac{4.5}{4.5 + 0.5}E$ $E = 6.0\ \text{V}$	M1 A1

Qn 6	Suggested Solutions	Mark
6(a)	 	B3
(b)	*Experimental Evidence:* It was observed that most of the α-particles (more than 99%) will pass straight through or emerge scattered over a small angle. As α-particles are positively charged (and some α-particles are observed to be scattered / deflected), it shows the existence of a charged nucleus (protons are concentrated within the nucleus) within an atom. *Experimental Evidence:* Only a very small fraction of α-particles is observed to be backscattered (i.e. suffer deflections of more than 90°). This shows that the size of the nucleus is so small that the probability of an α-particle coming close enough to a nucleus to be deflected over a large angle is very low.	B1 A1 B1 A1
(c)(i)	The α-particle consists of 2 protons and 2 neutrons.	A1
(c)(ii)	Loss of mass, Δm = (4.00260 + 9.01212) – (1.00867 + 12.00000)	

	$= 0.00605$ u $= 1.0043 \times 10^{-29}$ kg	**B1**
	Energy equivalence of the loss mass, $E = (\Delta m)c^2$	**M1**
	$= (1.0043 \times 10^{-29})(3.0 \times 10^8)^2$	
	$= 9.04 \times 10^{-13}$ J	**A1**

(c)(iii)	Since energy is released after the reaction, the products have a higher total binding energy than the reactants. ***Note:*** As the total number of nucleons before and after the reaction remains the same, the product will have higher binding energy per nucleon (which means the product is more stable).	**A1**

Q7	Suggested Solutions	Mark
7(a)(i)	For multiple-source interference, with source separation d emitting waves of wavelength λ, maxima are formed at angles θ to the horizontal: $d\sin\theta = m\lambda = m\dfrac{c}{f}$, where m = 0, 1, 2, … $6.0\sin\theta = m\left(\dfrac{3.00\times10^{8}}{30.0\times10^{6}}\right)$ $\sin\theta = m\times\dfrac{10}{6}$ But since $\sin\theta\le1$, this equation is only valid if the order m = 0. OR Solving for m at $\theta=90^\circ$, we get $m=\dfrac{3}{5}=0.60<1$ Therefore, there is only one central maximum (the zeroth order maximum)	M1 M1 A0
7(a)(ii)	$\sin\dfrac{\alpha}{2}=\dfrac{\lambda}{b}$ $=\dfrac{c}{fb}$ $\dfrac{\alpha}{2}=\sin^{-1}\left(\dfrac{3.00\times10^{8}}{(30.0\times10^{6})(42.0)}\right)$ $=13.77^\circ$ $\alpha=13.77^\circ\times2$ $=27.5^\circ$	M1 M1 A1
7(b)(i)	From Fig 7.2, at 400 km from station, altitude = 5400 m	A1
7(b)(ii)	$\text{speed}=\dfrac{\text{distance travelled}}{\text{time}}=\dfrac{AB}{\tau}=\dfrac{5000}{51.4}=97.3\text{ ms}^{-1}$	A1
7(b)(iii)	From (ii), speed $u_x=97.3\text{ ms}^{-1}$. $s_y=\dfrac{1}{2}gt^2$ ––––––(1) $s_x=u_xt$ –––––––(2)	M1

	$\frac{(2)^2}{(1)}: \quad \frac{s_x^2}{s_y} = \frac{2u_x^2}{g}$ $s_x = \sqrt{\frac{2u_x^2 s_y}{g}} = \sqrt{\frac{2(97.3)^2(5400)}{9.81}}$ $= 3230 \text{ m}$ OR $s_y = \frac{1}{2}gt^2 \Rightarrow t = \sqrt{\frac{2s_y}{g}} = \sqrt{\frac{2 \times 5400}{9.81}} = 33.18 \text{ s}$ $s_x = u_x t = (97.3)(33.18) = 3230 \text{ m}$	**M1** **A1**
7(b)(iv)	It will not hit the target. The bomb has the same time of flight (same height and vertical velocity at release), but has a greater horizontal speed at release, so it will land beyond the target.	 **M1** **M1**
7(b)(v)	The width of each beam, 400 km from the station, is about $2 \times 400 \times 10^3 \times \tan\frac{0.3^\circ}{2} = 2094 \text{ m}$ OR $2 \times 400 \times 10^3 \times \sin\frac{0.3^\circ}{2} = 2094 \text{ m}$ OR since θ is small, $s = r\theta$ = 400 x 10^3 x 0.3° (π/180°) = 2094 m  Thus the uncertainty in the position of A is $\frac{2094}{2} = \pm 1000 \text{ m}$ (1 s.f.) OR  $\tan 0.15^\circ = \frac{\Delta x}{400 \times 10^3}$ $\Delta x = 1047 \approx 1000 \text{ m}$ OR  $\sin 0.15^\circ = \frac{\Delta x}{400 \times 10^3}$ $\Delta x = 1047 \approx 1000 \text{ m}$	**B1** **A1** **M1**

		A1
7(c)(i)	By the principle of moments, the sum of anticlockwise moments is equal to the sum of clockwise moments. About the centre of gravity, $L_w \times x_F = L_t \times x_B$ Since vertically, $W = L_w + L_t$ (applying Newton's 1st Law) $(W - L_t)x_F = L_t x_B$ $Wx_F = L_t(x_F + x_B)$ $L_t = \frac{Wx_F}{x_F + x_B}$	**B1** **B1**
7(c)(ii)	Line of action of F_D passes through the centre of gravity, hence there is no moment about the centre of gravity.	**B1**

7(c)(iii)	Net force = 0, thus drag force F_D = thrust T $P = 2 \times 990 \times 10^3 = 1.98 \times 10^6$ W Power P = Thrust T x speed v $P = Tv \Rightarrow T = \frac{P}{v} = \frac{1.98 \times 10^6 \text{ W}}{200 \times 1000/3600 \text{ ms}^{-1}}$ $= 3.56 \times 10^4$ N Therefore $F_D = T = 3.56 \times 10^4$ N	**B1** **B1** **M1** **A1**