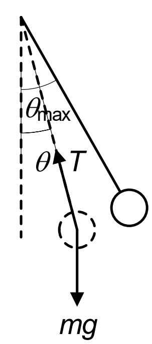
Raffles Institution
Year 5-6 Physics Department

2021 Year 5 H2 Physics Promotional Examination Solution

Section A

Qn	Ans	Solution
1	A	$F = 6\pi\eta rv \Rightarrow \eta = \dfrac{F}{6\pi rv}$ $\eta = \dfrac{\text{base units of } F}{(\text{base units of } r)(\text{base units of } v)} = \dfrac{\text{kg m s}^{-2}}{(\text{m})(\text{m s}^{-1})} = \text{kg m}^{-1}\text{ s}^{-1}$
2	B	For $X+Y$: percentage uncertainty $= \dfrac{(\Delta X + \Delta Y)}{(X+Y)} \times 100\% = \dfrac{(0.1+0.1)}{(51.0+49.0)} = 0.20\%$ For $X-Y$: percentage uncertainty $= \dfrac{(\Delta X + \Delta Y)}{(X-Y)} \times 100\% = \dfrac{(0.1+0.1)}{(51.0-49.0)} = 10\%$ For XY and $\dfrac{X}{Y}$: percentage uncertainty $= \left(\dfrac{\Delta X}{X} + \dfrac{\Delta Y}{Y}\right) \times 100\% = \left(\dfrac{0.1}{51.0} + \dfrac{0.1}{49.0}\right) \times 100\% = 0.40\%$
3	B	Since the ball is thrown and caught at the same height above the ground, $s_y = 0$ Taking upwards as positive: $0 = u_y t - \dfrac{1}{2}gt^2$ $u\sin\theta = \dfrac{1}{2}gt \;\Rightarrow\; \sin\theta = \dfrac{gt}{2u}$ ------- (1) Since Jill is running towards the ball at speed $v = 8.9 \text{ m s}^{-1}$, $s_x = (u\cos\theta)t = d - vt \;\Rightarrow\; \cos\theta = \dfrac{d-vt}{ut}$ ------- (2) where $d = 15$ m $\dfrac{(1)}{(2)}$: $\tan\theta = \dfrac{\frac{gt}{2u}}{\frac{d-vt}{ut}} = \dfrac{gt^2}{2(d-vt)} = \dfrac{(9.81)(0.49)^2}{2[15-(8.9)(0.49)]} \Rightarrow \theta = 6.32°$ From (1): $u = \dfrac{gt}{2\sin\theta} = \dfrac{(9.81)(0.49)}{2\sin 6.32} = 21.8 \approx 22 \text{ m s}^{-1}$
4	A	Consider the forces on the crate and present as a system, $T - (M+m)g = (M+m)a$ $a = \dfrac{30-(2.0+0.30)(9.81)}{(2.0+0.30)} = 3.2335 \text{ m s}^{-2}$ Consider forces on the present, $N - mg = ma$ $N = m(a+g) = 0.30(3.2335+9.81) = 3.91 = 3.9$ N

5	**B**	By the conservation of energy before the projectile explodes, decrease in K.E. = increase in G.P.E. $\frac{1}{2}(2m)(20)^2 - \frac{1}{2}(2m)v^2 = (2m)g(9.0)$ speed at the peak, $v = 14.947$ m s^{-1} (horizontally to the right) By the conservation of momentum, momentum before explosion = momentum after explosion $(2m)(14.947) = m(40) + mv_X$ $v_X = -10.106$ m s^{-1} $= -10$ m s^{-1} speed of X $= 10$ m s^{-1} (Conservation of momentum can be applied though there is an external gravitational force acting on the projectile. This is because the force of explosion between X and Y is much larger than the gravitational force. Thus, the effect on their momentum by the gravitational force is negligible.)
6	**C**	Let the angle that the beam makes with the horizontal be θ. Taking moments about P, $Mg(x\cos\theta) = k(9.0-4.0)(2.0\cos\theta)$ $Mgx = k(9.0-4.0)(2.0)$ ----- (1) Taking moments about Q, $Mg(2.0-x)\cos\theta = k(6.5-4.0)(2.0\cos\theta)$ $Mg(2.0-x) = k(6.5-4.0)(2.0)$ ----- (2) $\frac{(2)}{(1)}$: $\frac{2.0-x}{x} = \frac{2.5}{5.0} = \frac{1}{2}$ $x = 4.0 - 2x$ $x = \frac{4.0}{3} = 1.33 = 1.3$ m Alternative solution: $\frac{T_P}{T_Q} = \frac{6.5-4.0}{9.0-4.0} = \frac{1}{2}$ Taking moments about C.G., $T_P \times x = T_Q \times (2.0-x)$ $\frac{x}{2.0-x} = \frac{T_Q}{T_P} = 2$ $x = \frac{4.0}{3} = 1.33 = 1.3$ m

7	**D**	Since the block is in equilibrium, resultant force and resultant moment about any point must be zero. For the block not to slide down, there must be frictional force acting upwards along the slope on the block to counter the component of its own weight downwards along the slope. Since the lines of forces of the normal contact force, frictional force and weight must coincide, this point of intersect has to be along the vertical where the line of force of the weight meets the surface of the slope. The contact force of the slope on the block, which is the vector sum of the normal contact force and frictional force, must then act at this point of intersection. Furthermore, the contact force must also pass through the centre of gravity (C.G.) of the block, so that the resultant moment about its C.G. is zero. The contact force is thus pointing vertically upwards, ensuring that the resultant force in both the vertical and horizontal directions are zero.
8	**D**	$F_{net} = \frac{dp}{dt} = \frac{m\Delta v}{\Delta t} = \frac{m(v-u)}{t} \Rightarrow mv = Ft$ (since $u = 0$) $E_k = \frac{1}{2}mv^2 = \frac{1}{2}\frac{(mv)^2}{m} = \frac{1}{2}\frac{(Ft)^2}{m} \Rightarrow E_k \propto \frac{1}{m}$ Gain in KE $= E_{k,final} - E_{k,inital} = E_{k,final}$ since $E_{k,inital} = 0$ $\frac{E_{k,final,P}}{E_{k,final,Q}} = \frac{m_Q}{m_P} = \frac{2m}{m} = 2.0$
9	**D**	The answer can be deduced by elimination. The pendulum is describing part of a circular path. Hence the tension of the string when it is vertical must be greater than *mg*, so that there is a resultant force towards the centre of the circular path. At angular position θ, $T - mg\cos\theta = \frac{mv^2}{L}$ (1)  By the principle of conservation of energy, increase in K.E. = decrease in G.P.E. $\frac{1}{2}mv^2 - 0 = mgL(\cos\theta - \cos\theta_{max})$ $mv^2 = 2mgL(\cos\theta - \cos\theta_{max})$ Substituting into (1), $T = 2mg(\cos\theta - \cos\theta_{max}) + mg\cos\theta = mg(3\cos\theta - 2\cos\theta_{max})$

10	**B**	Recall or derive: $E_T = -\dfrac{GMm}{2r}$ and $E_k = \dfrac{GMm}{2r}$ When the satellite experiences atmospheric drag, its total energy decreases. When its total energy decreases (i.e. becomes more negative), its orbital radius decreases and its kinetic energy increases. Since kinetic energy is proportional to $v^2_{orbital}$, orbital speed also increases.
11	**C**	The speed of the mass is next zero again when it is at the amplitude on the other side of the equilibrium position. $0.50 = \dfrac{1}{2}T$ $T = 1.0\text{ s}$ $v_{\max} = \omega x_{\max} = \dfrac{2\pi}{T}x_{\max} = \dfrac{2\pi}{(1.0)}(0.10) = 0.6283 = 0.63\text{ m s}^{-1}$
12	**C**	Resonance occurs when the cart moves over the grooves at 8.0 m s^{-1}. At this speed, the frequency which the cart moves over the grooves = driving frequency of the oscillations = natural frequency of mass spring system frequency which the cart moves over the grooves $= \dfrac{1}{2\pi}\sqrt{\dfrac{25}{0.050}} = 3.5588\text{ Hz}$ separation between the grooves $= \dfrac{v}{f} = \dfrac{8.0}{3.5588} = 2.247 = 2.2\text{ m}$
13	**A**	$v = f\lambda \Rightarrow \lambda = \dfrac{v}{f} = \dfrac{300}{500} = 0.60\text{ m}$ $\phi = \dfrac{0.75}{0.60}\times 2\pi = 2.5\pi$ Equivalently, $\phi = 2.5\pi - 2.0\pi = 0.50\pi$ rad
14	**D**	Option A: The particles between adjacent segments are in antiphase. Option B: The speed of the wave (energy transfer) is given by the product of frequency and wavelength. Option C: The separation between the node and adjacent antinode is a quarter of a wavelength.
15	**C**	A stationary wave is formed by the superposition of two progressive waves of the same amplitude and has the same wavelength as its component waves. At the antinode the waves undergo constructive interference: $2A_{progressive} = A_{stationary}$ $A_{progressive} = \dfrac{A_{stationary}}{2} = \dfrac{2}{2} = 1\text{ cm}$ $L = \dfrac{3}{2}\lambda$ $\lambda = \dfrac{2}{3}(45) = 30\text{ cm}$