2020 Raffles Institution Preliminary Examinations – H2 Physics

Paper 1 Suggested Solutions

1 **B** units of $\left(\frac{\hbar G}{c^3}\right)^{1/2} = \left(\frac{\text{J s} \times \text{N m}^2\ \text{kg}^{-2}}{\left(\text{m s}^{-1}\right)^3}\right)^{1/2}$

$$= \left(\frac{\left(\text{kg m s}^{-2}\ \text{m}\right)\ \text{s} \times\ \text{kg m s}^{-2}\ \text{m}^2\ \text{kg}^{-2}}{\text{m}^3\ \text{s}^{-3}}\right)^{1/2}$$

$$= \left(\text{m}^2\right)^{1/2} = \text{m}$$

2 **C** $P = \left(a^{1/2}b^2c^{-3}d^4\right)^{1/2} = a^{1/4}bc^{-3/2}d^2$

$$\frac{\Delta P}{P} = \frac{\Delta a}{4a} + \frac{\Delta b}{b} + \frac{3\Delta c}{2c} + \frac{2\Delta d}{d}$$

$$= \frac{1}{4}(4\%) + 2\% + \frac{3}{2}(6\%) + 2(5\%)$$

$$= 1\% + 2\% + 9\% + 10\%$$

$$= 22\%$$

3 **B** The gradient of the displacement-time graph gives the velocity.
Car M is accelerating as it has an increasing velocity (since gradient increases).
Car N is not accelerating as it has a constant velocity (since gradient is constant). Statement is incorrect.

4 **D** $p = mu$

Since horizontal velocity u remains unchanged, $u = v\cos\theta$.

<u>horizontal direction:</u>
Since horizontal velocity remains unchanged,
initial momentum = final momentum
change in momentum = 0

<u>vertical direction:</u>
initial momentum = 0
final momentum $= mv\sin\theta$ (downwards)
change in momentum $= mv\sin\theta - 0 = m\left(\frac{u}{\cos\theta}\right)\sin\theta = mu\tan\theta = p\tan\theta$ (downwards)

5 **D** Frictional force on the boxes by the belt, in the forward direction, is needed to change their horizontal state of motion from rest to the final speed of 0.80 m s^{-1}.

By Newton's third law, these boxes exert an equal and opposite force (in the backward direction) on the belt which slows it down. An external force that is equal and opposite (in the forward direction) to this force needs to be applied to the belt to keep it moving at constant speed.

horizontal force applied, $F = v\frac{dm}{dt} = (0.80)(2.5) = 2.0$ N

6 **C** Since the pyramid is floating in the water, this means the upthrust on the pyramid is equal and opposite to the weight of the pyramid. (Hence option B is correct since the pyramid remains floating even when a liquid of higher density is added.)

Upthrust is given by the weight of the water displaced by the submerged part of the pyramid.

When the pyramid is inverted and floating, it will sink deeper in order to displace the same volume of water to achieve the same upthrust. This means the pressure at the submerged apex is higher than that at the submerged base when the pyramid is upright. Hence the pressure difference between the surface of the water and the lowest point of the pyramid is *greater* when it is inverted. (This explains why option C is incorrect and why option A is correct.)

Option D is correct as proven below:

$\rho_w V_w g = \rho_o V_o g$ ('w' for water, 'o' for object)

$\frac{V_o}{V_w} = \frac{\rho_w}{\rho_o} =$ constant for water and object of the same density

7 **C** decrease in G.P.E. $=$ increase in K.E. $+$ energy lost to surroundings

energy lost to surroundings $=$ decrease in G.P.E. – increase in K.E.

$$= mg(\Delta h) - \left[\frac{1}{2}mv^2 - \frac{1}{2}mu^2\right]$$

$$= 0.80\left[9.81(10) - \frac{1}{2}(4.0)^2 + \frac{1}{2}(1.2)^2\right]$$

$$= 72.7 = 73 \text{ J}$$

8 **C** Since body is moving up the track with constant velocity, there is no change in its K.E.

power supplied = rate of increase in G.P.E. + rate at which work is done against the resistive forces

$$= \frac{mg(\Delta h)}{t} + \frac{Fd}{t}$$

$$= 70(9.81)(20\sin 30^\circ) + 120(20)$$

$$= 9267 = 9300 \text{ W}$$

9 **A** linear speed $= \frac{\text{total distance}}{\text{total time}}$ or $\omega r = \frac{2\pi}{T}r = \frac{2\pi(200)}{2\times 30} = 20.9 = 21 \text{ m s}^{-1}$

average velocity $= \frac{\text{total displacement}}{\text{total time}} = \frac{2r}{30} = \frac{2(200)}{30} = 13.3 = 13 \text{ m s}^{-1}$

10 **B** By Newton's third law,

force on bridge by car = force on car by bridge (i.e. normal contact force N)

Since speed is constant, for each bridge, the car experiences the same centripetal force. Hence the normal contact force is largest when the car is at the highest point of each curvature.

Compare the normal contact force at the highest point of each curvature.

For P and Q:

$$W - N = m\frac{v^2}{r} \qquad \Rightarrow \qquad N = W - \frac{mv^2}{r}$$

P has a smaller radius, hence $N_P < N_Q$

For R:

$$N_R - W = m\frac{v^2}{r} \qquad \Rightarrow \qquad N_R = W + \frac{mv^2}{r}$$

For S: $N_S = W$

Therefore $N_P < N_Q < N_S < N_R$

11 A Gravitational force provides the centripetal force for the satellite.

$$\frac{GMm}{r^2} = \frac{mv^2}{r}$$

$$\frac{GM}{r} = v^2$$

$$-\phi = v^2$$

$$\frac{v_1^{\,2}}{v^2} = \frac{-\phi_1}{-\phi}$$

$$v_1 = \sqrt{\frac{\phi_1}{\phi}}v = \sqrt{\frac{-16}{-25}}v = \frac{4}{5}v$$

12 D The minimum kinetic energy that the object has just before it hits the surface of Planet Y at R is when the object just reaches Q i.e. K.E. is zero at Q.

By the conservation of energy, for the object moving from Q to R,
increase in K.E. = decrease in G.P.E.

$$E_{k,R} - 0 = m\left(\phi_Q - \phi_R\right)$$

$$E_{k,R} = 5.0\left(-1.2 - \left(-62.0\right)\right) = 304 \text{ MJ}$$

13 D The pressure of the gas on the walls is due to the force per unit area the gas molecules exert on the walls when they collide with the walls.

This force is due to the rate of transfer of momentum to the wall which increases with increased frequency of collisions when the gas is compressed to a smaller volume. Hence pressure increases.

14 D For the isothermal process: $\Delta U_1 = Q_1 + W_1 \Rightarrow 0 = Q + W_1 \quad \Rightarrow -W_1 = Q$
For the adiabatic process: $\Delta U_2 = Q_2 + W_2 \Rightarrow \Delta U_2 = 0 + W_2 \Rightarrow \Delta U_2 = W_2$

Compare area under the *p*-*V* curves for each process,
$|W_2| > |W_1| \Rightarrow W_2 > -W_1 = Q \Rightarrow \Delta U_2 = W_2 > Q$

15 D The total distance travelled in one period T is $4x_0$. So average speed is

$$\langle v \rangle = \frac{4x_0}{T} = \frac{4x_0}{2\pi/\omega} = \frac{2\omega x_0}{\pi} = \frac{2v_0}{\pi}$$

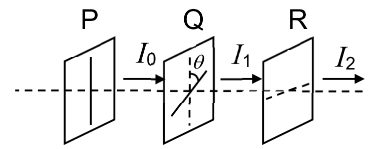
16 C The frequency of forced oscillations will follow that of the driving force.

17 **A** Air molecules immediately to the left of P have positive displacement i.e. they are moving to the right towards P. Air molecules to the right of P have negative displacement i.e. they are moving to the left towards P. Hence, Point P is a point of compression.

18 **C** Using Malus' Law

$I_1 = I_0 \cos^2 \theta$

$I_2 = I_1 \cos^2(90° - \theta) = I_0 \cos^2 \theta \sin^2 \theta = \frac{I_0}{4} \sin^2 2\theta$



When $\theta = 0°$ and $\theta = 90°$, $I_2 = 0$. When Q is being rotated through 90°, I_2 increases then decreases.

19 **D** At resonance, a stationary wave is formed in the tube.
If *f* is the fundamental frequency of the air column in the tube, for resonance to occur, frequency of the tuning fork can be *f*, 3*f*, (2n–1)*f* for $n = 1, 2, 3\ldots$ (i.e. odd harmonics).

20 **A** In order to increase the resolving power of the instrument, the limiting angle of resolution $\theta_{\min}$ of the aperture should be made smaller.

From Rayleigh criterion, $\theta_{\min} \approx \frac{\lambda}{b}$, decreasing λ (i.e. increasing *f*) and increasing the aperture size *b* would decrease $\theta_{\min}$.

21 **B** Graph of option B satisfies the following points:

The negative of the potential gradient gives the electric field strength ($E = -\frac{dV}{dr}$).

The closer the electric field lines, the larger the electric field strength *E*.
Field lines point from a region of higher potential to a region of lower potential.

22 **B** $F = Eq = ma \quad \Rightarrow \quad a = \frac{Eq}{m}$

$y = \frac{1}{2}at^2 = \frac{1}{2}\frac{Eq}{m}\left(\frac{L}{u}\right)^2$

where *L* is the length of the plate and *u* is the initial horizontal speed

$y \propto \frac{q}{mu^2} \quad \Rightarrow \quad y \propto \frac{0.5q}{K.E.}$

$\frac{y_\alpha}{y_p} = \frac{0.5(2e)}{4K} \times \frac{K}{0.5e} = 0.50$

$y_\alpha = 0.50y$

OR

Since the mass of the alpha particle is four times the mass of the proton and the alpha particle's K.E. is also four times the proton's K.E., this implies that the proton and the alpha particle had the same initial speed.

$y \propto \frac{q}{mu^2} \quad \Rightarrow \quad y \propto \frac{q}{m}$

$\frac{y_\alpha}{y_p} = \frac{2e}{4m_p} \times \frac{m_p}{e} = 0.50$

$y_\alpha = 0.50y$

23 **A** Same current flows through both lamps in series. Hence, $P \propto R$.

$$\frac{P_X}{P_Y} = \frac{R_X}{R_Y} = \frac{V_X}{V_Y}$$
$$\frac{1}{3} = \frac{V_X}{24 - V_X}$$
$$V_X = \frac{24}{4} = 6 \text{ V}$$

24 **A** Since $V_{PQ} = 3\text{ V}$ and $V_{PS} = 6\text{ V}$, potential at Q is 3 V higher than the potential at S. The p.d. across QS is 3 V.

Since $V_{QR} = 5\text{ V}$ and potential at Q is higher than the potential at S by 3 V, the p.d. across SR is 2 V.

25 **A** magnetic flux density at centre of coil Q, $B_Q = \frac{\mu_0 N I_Q}{2r} = \frac{\mu_0 I_Q}{2r}$

magnetic flux density at a distance 2*r* from wire P at centre of coil Q, $B_P = \frac{\mu_0 I_P}{2\pi d} = \frac{\mu_0 I_P}{2\pi(2r)}$

For the resultant magnetic field to be zero at the centre of coil Q,
B_Q and B_P a the centre must be equal in magnitude and opposite in direction.

$$B_Q = B_P$$
$$\frac{\mu_0 I_Q}{2r} = \frac{\mu_0 I_P}{2\pi(2r)}$$
$$I_Q = \frac{I_P}{2\pi}$$
$$I_P = 2\pi I_Q$$

Since B_Q is out of the page at the centre of coil Q, B_P must be into the page at the centre. Hence direction of current in wire P flows to the right.

26 **D** Using Fleming's left-hand rule, electrons moving to the left will experience a magnetic force upwards and so will drift towards edge Q.
Hence Q will be at a lower potential and R will be at a higher potential.

Note: For electrical current, the charge carriers are electrons that are moving in the opposite direction to the conventional current.

27 **B** The changing magnetic flux through coil X and coil Z are equal at any point in time.
However, the magnetic flux linkage through coil X is larger than that in coil Z since coil X has more turns.

By Faraday's law, e.m.f. induced in coil X is larger than the e.m.f. induced in coil Z.

28 **C**
$$\begin{aligned}\text{power input to factory} &= \text{power from a.c. generator} - \text{power loss in cables}\\ &= P - I^2R\\ &= P - \left(\frac{P}{V}\right)^2 R\end{aligned}$$

29 **A** Electron transition from n = 4 to n = 2 produces a photon of wavelength 497 nm, which is within the visible light spectrum. This is within the Balmer series, which produces visible light.

30 **B** momentum $p = mv$

$$\frac{\Delta p}{p} = \frac{\Delta m}{m} + \frac{\Delta v}{v} = \frac{0.7}{7.0} + \frac{0.1}{2.5} = 0.14$$

$$\Delta p = 0.14\left(7.0 \times 10^{-18}\right)\left(2.5 \times 10^{-6}\right) = 2.45 \times 10^{-24}\text{ kg m s}^{-1}$$

$$\Delta x \Delta p \geq h$$

$$\Delta x \geq \frac{h}{\Delta p}$$

$$\Delta x \geq \frac{6.63 \times 10^{-34}}{2.45 \times 10^{-24}}$$

$$\Delta x \geq 2.7 \times 10^{-10}\text{ m}$$

Hence minimum uncertainty is 3×10^{-10} m.