Raffles Institution
Year 5-6 Physics Department

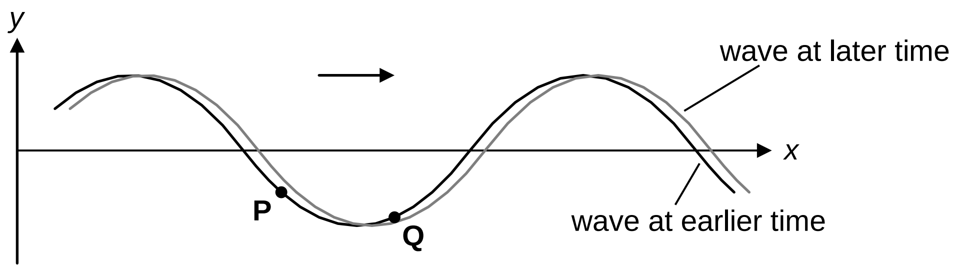
2024 H2 Physics Preliminary Examination Solution

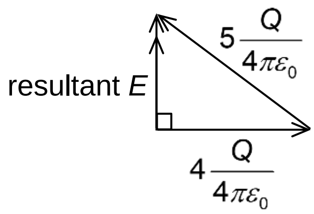
Paper 1

Qn	Ans	Solution
1	**A**	units of $\Delta P = \dfrac{\text{kg m s}^{-2}}{\text{m}^2} = \text{kg m}^{-1}\ \text{s}^{-2}$ units of $\rho = \text{kg m}^{-3}$ units of $\left(\dfrac{\Delta P}{\rho}\right)^n = \left(\dfrac{\text{kg m}^{-1}\ \text{s}^{-2}}{\text{kg m}^{-3}}\right)^n = \left(\text{m}^2\ \text{s}^{-2}\right)^n$ units of $v = \text{m s}^{-1}$ For equation to be homogeneous, units of $\left(\dfrac{\Delta P}{\rho}\right)^n$ = units of v $\text{m}^{2n}\ \text{s}^{-2n} = \text{m s}^{-1}$ comparing indices of m: $2n = 1 \quad \Rightarrow \quad n = \dfrac{1}{2}$
2	**D**	$d = d_2 - d_1 = 16.24 - 12.78 = 3.46$ mm $\Delta d = \Delta d_2 + \Delta d_1 = 0.03 + 0.02 = 0.05$ mm $\dfrac{\Delta d}{d} \times 100\% = \dfrac{0.05}{3.46} \times 100\% = 1.4451 = 1.4\%$
3	**C**	From *a*-*t* graph: From $t = 0$ to $t = t_1$, acceleration is constant which implies that the object's velocity is increasing at a constant rate. From $t = t_1$ to $t = t_2$, acceleration is decreasing which implies that the object's velocity is increasing at a decreasing rate. From $t = t_2$ to $t = t_3$, acceleration is zero which implies that the object's velocity is constant. Since $a = \dfrac{dv}{dt}$, the gradient of the *v*-*t* graph, which gives acceleration, in Option C follows the description above.
4	**D**	Option A: Possible, if lift is decelerating / decreasing in speed on its way up. Option B: Possible, if lift is moving upwards at a constant speed. Option C: Possible, if lift is accelerating / increasing in speed on its way up. Option D: Hence, all the options above are possible, depending on the lift's acceleration.

5	**C**	Applying Newton's second law on the system of both crates, $F_{net,both} = m_{both}a$ $100-(2.0+3.0)(9.81)=(2.0+3.0)\times a$ $a=\dfrac{100-(2.0+3.0)(9.81)}{(2.0+3.0)}=10.19\text{ m s}^{-2}$ Applying Newton's second law on the 2.0 kg crate, $F_{net,2kg} = m_{2kg}a$ $100-2.0(9.81)-T=2.0(10.19)$ $T=60\text{ N}$ OR $F_{net,3kg} = m_{3kg}a$ $T-3.0(9.81)=3.0(10.19)$ $T=60\text{ N}$
6	**B**	Motorcycle travels in the same direction during the whole duration. Impulse or the change in momentum is the area under the force-time graph. $\Delta p=\int F dt$ $(400)(v-4.5)=\frac{1}{2}(1.0)(400)-\frac{1}{2}(2.0)(800)$ $v-4.5=-1.5$ $v=4.5-1.5=3.0\text{ m s}^{-1}$
7	**D**	Since cube is floating, there is vertical equilibrium. $U_1+U_2=W_{cube}$ $V_1\rho_1 g+V_2\rho_2 g=(V_1+V_2)\rho_c g$ $V_1\rho_1+V_2(3\rho_1)=(V_1+V_2)(2\rho_1)$ $3V_2-2V_2=2V_1-V_1$ $V_2=V_1$ $\dfrac{V_1}{V_2}=1$
8	**A**	Work done by the force to extend the spring is given by the area under force-extension graph i.e. the area bounded by the graph and the vertical axis of the graph given. This work done goes to increase the potential energy of the spring. The potential energy represented by area *P* is released upon the removal of the force. The potential energy represented by area *Q* is retained in the spring that is permanently stretched i.e. the energy used to separate the particles of the spring further apart.

9	**D**	At constant speed, engine force = resistive force rate at which energy is delivered = rate at which energy is dissipated $P = Fv$ $12\times10^{3} = F\left(\dfrac{72\times10^{3}}{60\times60}\right)$ $F = 600\text{ N}$ $E_{\text{from fuel}} = E_{\text{to car}}$ $(0.30)(40\times10^{6})(m) = (12\times10^{3})(1\times60\times60)$ $m = 3.6\text{ kg}$
10	**C**	The minute hand takes 1 hour to go round the clock once. $\omega_m = \dfrac{2\pi}{60\times60}\text{ rad s}^{-1}$ The hour hand takes 12 hours to go round the clock once. $\omega_h = \dfrac{2\pi}{12\times60\times60}\text{ rad s}^{-1}$ $\dfrac{v_m}{v_h} = \dfrac{r_m\omega_m}{r_h\omega_h} = \left(\dfrac{1.5r_h}{r_h}\right)\left(\dfrac{12\times60\times60}{60\times60}\right) = 18$
11	**C**	Option C (correct): $g = -\dfrac{d\phi}{dr} \quad \Rightarrow \quad d\phi = -\int g\,dr$ Hence, the area under the *g*-*r* graph gives the change in the gravitational potential ϕ. Options A and B (incorrect): The total gravitational potential between the two planets is always negative. Gravitational potential is zero only at infinity. Option D (incorrect): The gradient of the graph does not give any meaningful quantity.
12	**A**	The gravitational force on each star provides the centripetal force for the star to orbit about the common centre of mass of the system. For two stars, mass *M* and *m*, at a distance *d* apart, $\dfrac{GMm}{d^2} = mr\omega^2 = MR\omega^2$ $mr\omega^2 = MR\omega^2$ $mr = MR$ *R* and *r* are the orbital radii of the stars of masses *M* and *m* respectively. The gravitational force on each star is always directed towards the common centre of mass of the system as the stars orbit. Hence the stars should be on opposite sides of their orbital path, lying along the same straight line through the common centre between them. To maintain this, the stars must also have the same angular velocity ω. Hence star X having a larger mass should have a smaller orbital radius.

13	**D**	From $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT \quad \Rightarrow \quad m = \frac{3kT}{c_{rms}^2} \quad \Rightarrow \quad m \propto \frac{T}{c_{rms}^2}$ $\frac{m_X}{m_Y} = \frac{T_x}{T_y}\left(\frac{c_{rms,Y}}{c_{rms,X}}\right)^2 = \left(\frac{T_x}{2T_x}\right)\left(\frac{3c_{rms,X}}{c_{rms,X}}\right)^2 = \frac{9}{2} = 4.5$
14	**B**	Both the inlet and outlet temperatures and the room temperature must be kept the same so that the rate of heat loss to the surrounding is kept constant for both experiments and can be eliminated.
15	**D**	$v = v_0 \cos\omega t$ $4.0 = v_0 \cos\left(\frac{2\pi}{9.0}\times 3.0\right)$ $v_0 = -8.0 \text{ m s}^{-1}$ $E_K = \frac{1}{2}\times 0.020\times(-8.0)^2 = 0.64 \text{ J}$
16	**C**	Oil is more viscous than water hence has a greater damping effect on the oscillating mass compared to water. With greater damping, the frequency response curve when the mass is in oil will have smaller amplitudes at all frequencies and the frequency at which resonance occurs will be smaller.
17	**B**	
18	**B**	For astronaut to see the light sources, $P_{\text{received}} = \frac{P_{\text{source}}}{4\pi r^2}\times A_{\text{pupil}} \geq P_{\text{min}}$ $r \leq \sqrt{\frac{P_{\text{source}}A_{\text{pupil}}}{4\pi P_{\text{min}}}} = \sqrt{\frac{10\pi(0.0050/2)^2}{4\pi(2.0\times10^{-13})}} = 8838.8 \text{ m}$ $r_{\text{max}} = 8800 \text{ m}$
19	**A**	Diffraction is pronounced when the wavelength of the wave is comparable to the width of the obstacle. Sound waves with a longer wavelength than the diameter of the pillar can bend around the pillar. Light waves with a much shorter wavelength than the diameter of the pillar cannot bend around the pillar.

20	**A**	For light sources to be resolved, angle of separation of the 2 sources $\geq$ minimum angle of separation by Rayleigh criterion $\theta \geq \theta_{\text{min}}$ $\frac{S}{D} \geq \frac{\lambda}{d}$ where S is the distance between the 2 sources $S \geq \frac{\lambda D}{d}$ The best combination is the one that can resolve the smallest distance S between the two sources i.e. shorter λ and D and larger d.
21	**D**	Charge of sphere is Q. $V = \frac{Q}{4\pi\varepsilon_0 R} \quad \Rightarrow \quad Q = 4\pi\varepsilon_0 RV$ $F = \frac{Qq}{4\pi\varepsilon_0 r^2} = \frac{4\pi\varepsilon_0 RVq}{4\pi\varepsilon_0 r^2} = \frac{qVR}{r^2}$
22	**B**	magnitude of E at P due to +64Q $= \frac{64Q}{4\pi\varepsilon_0 (4.0)^2} = 4\frac{Q}{4\pi\varepsilon_0}$  magnitude of E at P due to $-125Q$ $= \frac{125Q}{4\pi\varepsilon_0 (5.0)^2} = 5\frac{Q}{4\pi\varepsilon_0}$ These two E vectors form a right-angle triangle, with the resultant E pointing upwards with magnitude $\sqrt{\left(5\frac{Q}{4\pi\varepsilon_0}\right)^2 - \left(4\frac{Q}{4\pi\varepsilon_0}\right)^2} = 3\frac{Q}{4\pi\varepsilon_0}$.
23	**A**	$I = \frac{E}{R} = \frac{E}{\frac{\rho L}{A}} = \frac{EA}{\rho L} = \frac{E\pi(d/2)^2}{\rho L}\ \frac{\pi d^2 E}{4\rho L}$ Hence $I \propto \frac{d^2}{\rho}$ since L and E across the wires in parallel are constants. $\frac{I_X}{I_Y} = \frac{{d_X}^2}{\rho_X} \times \frac{\rho_Y}{{d_Y}^2} = \frac{\left(\frac{1}{4}d_Y\right)^2 \times \rho_Y}{{d_Y}^2 \times \frac{1}{2}\rho_Y} = \frac{2}{16} = \frac{1}{8}$ $\frac{I_X}{I_{total}} = \frac{1}{9}$

24	**D**	Since ammeter reading is zero, there is also no current in the middle wire joining the circuits on the left and right. There is no potential difference between the two ends of this wire and there is no current exchange between the two circuits. 50 Ω and 100 Ω resistors are in series. *R* and 200 Ω resistors are in series. Potential difference across the 100 Ω and 200 Ω resistors is the same. $V_R = 24 - V_{200}$ $V_R = 24 - V_{100}$ $\frac{R}{R+200} \times 24 = 24 - \frac{100}{100+50} \times 12$ $\frac{R}{R+200} \times 24 = 16$ $R = 400\ \Omega$
25	**C**	The current in X produces a magnetic field along the circumference of coil Y in the clockwise direction. This magnetic field produced is parallel to the current in each part of coil Y, hence there is no magnetic force induced on coil Y in all directions.
26	**B**	As the wire is raised vertically, it cuts the horizontal component of the Earth's magnetic flux density. $E = B_H L v$ $= (B\cos 50°) L \left(\frac{d}{t}\right)$ $= (3.0 \times 10^{-5}) \cos 50° \times 15 \times \frac{5.0}{150 \times 10^{-3}}$ $= 0.0096418\ \text{V}$ $= 9.6\ \text{mV}$
27	**A**	For an ideal transformer, $I_p V_p = I_s V_s$ $I_s = \frac{I_p V_p}{V_s}$ $= \frac{50 \times 240}{50 \times 10^3}$ $= 0.24\ \text{A}$ $\%\text{ power loss} = \frac{P_{\text{loss}}}{P_{\text{supplied}}}$ $= \frac{I_s^2 R}{I_p V_p}$ $= \frac{0.24^2 (100)}{50(240)} \times 100\%$ $= 0.048\%$

28	**C**	Momentum of particle, $p=\sqrt{2mE}$ Uncertainty in momentum, $\Delta p=0.010\sqrt{2mE}$ Minimum uncertainty in position, $\Delta x=\dfrac{h}{\Delta p}=\dfrac{h}{0.010\sqrt{2mE}} \quad \Rightarrow \quad \Delta x\propto\dfrac{1}{\sqrt{mE}}$ $\dfrac{\Delta x_{electron}}{\Delta x_{baseball}}=\sqrt{\dfrac{m_{baseball}E_{baseball}}{m_{electron}E_{electron}}}=\sqrt{\dfrac{0.150\times100}{\left(9.11\times10^{-31}\right)\left(1.0\times10^{6}\times1.60\times10^{-19}\right)}}=1.01\times10^{22}$ Order of magnitude: 10^{22} Note: The mass of the electron is in the data sheet. The mass of the baseball needs to be estimated to the correct order of magnitude.
29	**C**	An isotope of the parent nuclide will have the same number of protons but different number of neutrons. Hence the <u>atomic number of the isotope is the same</u> as the parent nuclide while its <u>mass number is different</u> after the decays. alpha particle – ${}^{4}_{2}He^{2+}$, beta particle – ${}^{0}_{-1}e$, gamma particle – massless, no charge Option C (correct): One alpha decay – mass number decreases by 4, atomic number decreases by 2 Two beta decays – mass number remains the same, atomic number increases by 2 Overall – daughter nuclide <u>mass number decreases</u> by 4, <u>atomic number remains the same</u> Option A (incorrect): The release of a gamma photon does not affect the atomic and mass numbers. Option B (incorrect): One alpha decay – mass number decreases by 4, atomic number decreases by 2 One beta decay – mass number remains the same, atomic number increases by 1 Overall – daughter nuclide mass number decreases by 4, atomic number decreases by 1 Option D (incorrect): Two alpha decays – mass number decreases by 8, atomic number decreases by 4 One beta decay – mass number remains the same, atomic number increases by 1 Overall – daughter nuclide mass number decreases by 8, atomic number decreases by 3
30	**B**	For X: $\left(\dfrac{1}{2}\right)^{\frac{t}{T_X}}=\dfrac{1}{8} \quad \Rightarrow \quad \dfrac{t}{T_X}=\dfrac{\lg(1/8)}{\lg(1/2)}=3 \quad \Rightarrow \quad T_X=\dfrac{t}{3}$ For Y: $\left(\dfrac{1}{2}\right)^{\frac{t}{T_Y}}=\dfrac{1}{4} \quad \Rightarrow \quad \dfrac{t}{T_Y}=\dfrac{\lg(1/4)}{\lg(1/2)}=2 \quad \Rightarrow \quad T_Y=\dfrac{t}{2}$ $\dfrac{T_X}{T_Y}=\dfrac{2}{3}=0.66667=0.67$