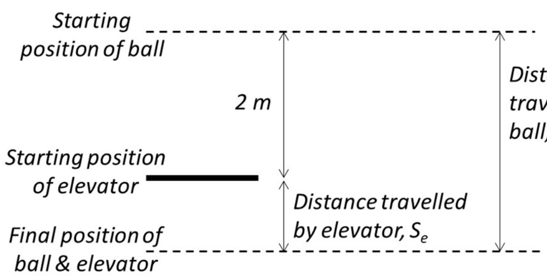
Solutions to Paper 1

1	**D**	Temperature difference = $\theta_f - \theta_i$ = 80 – 20 = 60 °C Absolute uncertainty, = $\Delta\theta_f + \Delta\theta_i$ = 0.5 + 0.5 = 1 °C Percentage uncertainty = $\frac{1°C}{60°C} \times 100\% = 1.7\%$
2	**B**	The object starts from rest and moves along a straight line. Area under the acceleration-time graph represents <u>change</u> in velocity. The triangle below the time axis shows that the change in velocity is in the negative direction. Since the <u>initial velocity is zero</u>, that triangle represents the increasing velocity (in – ve direction). This happens up to the time at A. Beyond A, the acceleration changes direction (from – ve to + ve dir). However, the velocity still points in the – ve direction after A i.e. object continues to travel in the same direction (still getting further away from the starting point), except that since the acceleration and velocity point in opposite directions, the object is slowing down. At point B the object comes to a momentary stop and it is also the furthest from the starting point. Between B and C, the object changes its velocity direction and starts to speed up back towards the starting point. At C, the object possesses maximum speed as it moves towards the starting point. Beyond C, the object slows down but it is still moving towards the starting point. At D, the object is back at the starting point.
3	**D**	 $S_b - S_e = 2$ $2.0 = [ut + (0.5)(9.81)\,t^2] - [ut + (0.5)(5.8)\,t^2]$ t = 1.00 s Or recognise that the effective acceleration = 9.81 – 5.8 = 4.01 m s^{-2}. Using $s = ut + \frac{1}{2}at^2$, $2.0 = \frac{1}{2}(4.01)t^2$, giving t = 1.00 s.
4	**A**	The question asks for the HORIZONTAL forces only. The horizontal force the propels the man forward is the frictional force of pool's floor on his feet. The horizontal resistive force on his motion comes from the drag due to water. Using Newton's second law along the horizontal direction: Net force on man = (mass of man)(acceleration of man) i.e. $f - f_D = ma$

<table>
<tr>
<td>5</td>
<td>A</td>
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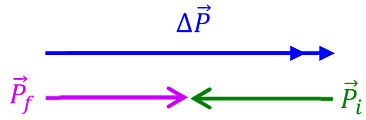
Magnitude of the change in momentum ΔP = area under graph = $\frac{1}{2}(150)(40 \times 10^{-3})$ = $3\,Ns$. This change in momentum takes place in the direction of the force, i.e. opposite to the initial momentum. In the vector diagram below, the ball is approaching the racket from right to left.

$\vec{P}_f - \vec{P}_i = \Delta\vec{P}$

$P_f + P_i = \Delta P$



$(0.060)(30) + P_i = 3$

$P_i = 1.2\,Ns$
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<td>6</td>
<td>C</td>
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The thrust must provide an upward force to propel the rocket upward. This force must be least at equal to its weight.

Thrust = $v\left(\frac{dm}{dt}\right)$

$v\left(\frac{dm}{dt}\right) = Mg$

$\frac{dm}{dt} = \frac{Mg}{v} = \frac{(500)(9.81)}{1000} = 4.9\,kg\,s^{-1}$
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<td>7</td>
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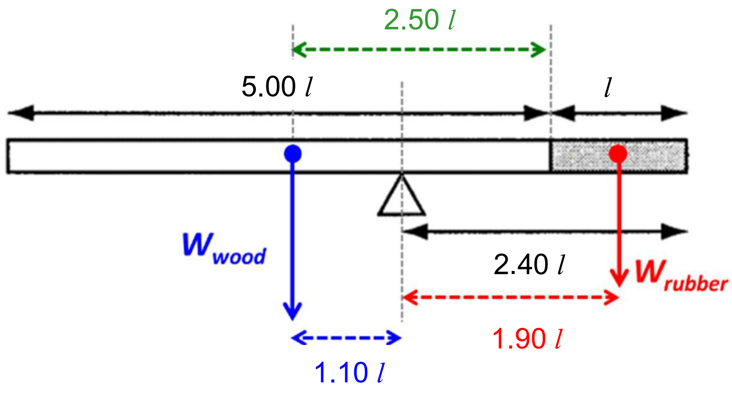

Taking moments about the CG (pivot) and letting *A* be the x-sectional area,

W_{wood} (distance of center-of-mass of wood from pivot) = W_{rubber} (distance of center-of-mass of rubber from pivot)

$A(5.00\,l)\rho_{wood}\,g(1.10\,l) = A(l)\rho_{rubber}\,g(1.90\,l)$

$5.00\,\rho_{wood}(1.10) = \rho_{rubber}(1.90)$

$\frac{\rho_{rubber}}{\rho_{wood}} = \frac{5.50}{1.90} = 2.89$
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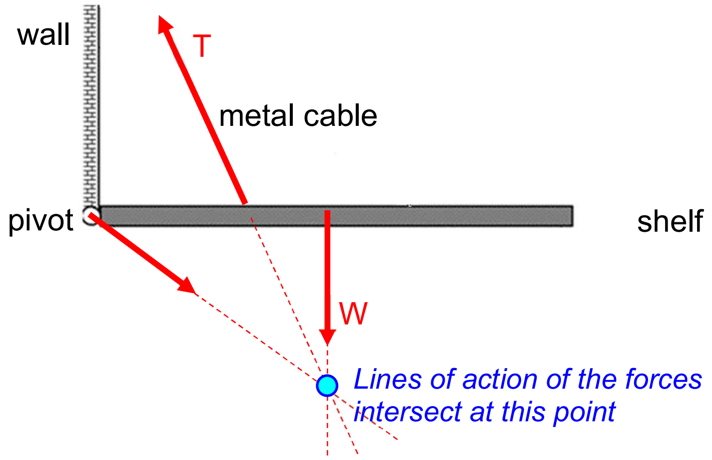
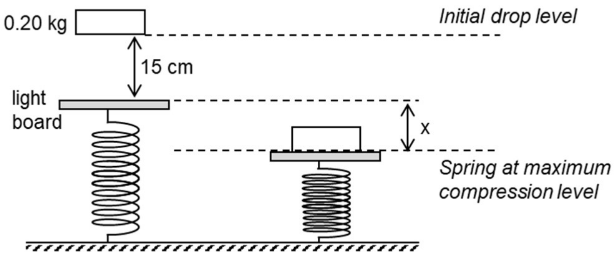
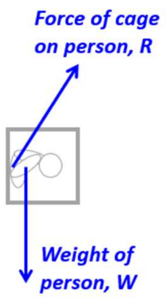
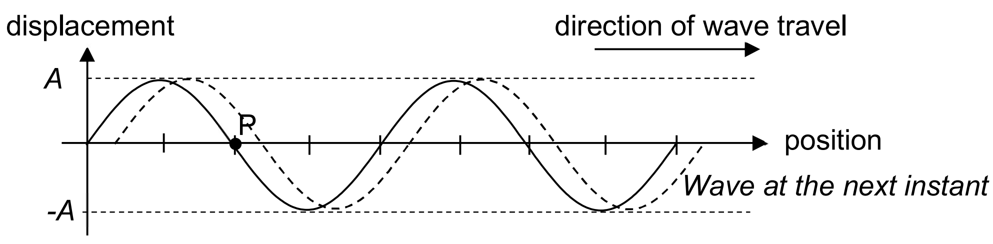
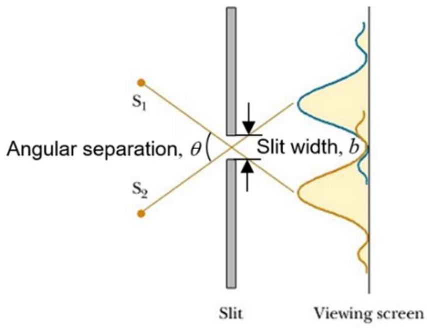
8	**D**	 Lines of action of the three co-planar non-parallel forces intersecting at a point is necessary if the object is in <u>rotational equilibrium</u>. Vector sum of all forces add to zero is necessary if the object is in translational equilibrium. Hence the answer cannot be A.
9	**D**	No kinetic energy at the initial drop level as well at at the final maximum compression of spring. Comparing the total energy at the initial and final positions, gain in elastic potential energy = total loss in gravitational potential energy $\frac{1}{2}kx^2 = mg(0.15+x)$ $\frac{1}{2}(85)x^2 = (0.20\times 9.81)(0.15+x)$ $42.5x^2 - 1.962x - 0.2943 = 0$ $x = 0.109$ m 
10	**C**	At maximum speed, engine force = drag force of kv. Power of boat, P = (engine force) v = kv^2 Hence, $\frac{P_{\text{one engine}}}{P_{\text{two engines}}} = \left(\frac{v_{\text{one engine}}}{v_{\text{two engines}}}\right)^2$ $\frac{32}{64} = \left(\frac{v_{\text{one engine}}}{14}\right)^2$ $v_{\text{one engine}}$ = 9.9 m s^{-1}

11	**A**	There are only two forces acting on the person, force of cage on him, ***R*** and his weight, ***W***. Since the man is in uniform (i.e. constant speed) circular motion, the net force on him is directed toward the centre of the circle, i.e. toward the right. The vector sum of ***R*** and ***W*** must point toward the right. Vertical component of ***R*** must balance the weight. Horizontal component of ***R*** provides the centripetal force (which is also the net force). 
12	**C**	Option A: The variable x is denoted as the distance *above the surface of the earth.* It is not defined from the centre of the Earth. Option B: $F_g = -\frac{dE_p}{dx}$. The force is the gradient of the $E_p - x$ graph, not ratio of E to x. [whereas the resistance is the ratio V to I, and not the gradient as given by dV/dI.] Option C: $F_g = -\frac{dE_p}{dx}$. Take note, for small distances above the Planet's surface, the gravitational field strength is approximately constant. Hence, the gradient of the graph is the same. Option D: The equation does not adhere to $F_g = -\frac{dE_p}{dx}$.
13	**D**	Frictional force by P on Q is the restoring force for Q. Without friction, Q will not move as P slides underneath it. Net force on Q is provided for by the frictional force by P on Q. friction = $ma = m\omega^2 x$ $5.0 = 0.2\{(2\pi)(1.5)\}^2 A$ A = 0.28 m
14	**B**	The components of the particle's motion in the horizontal x-direction is simple harmonic. Hence $a \propto -x$. This holds true for the motion in the y-axis as well.
15	**C**	 When the wave profile is drawn in the next instant (dotted line), one can tell that Particle P will be moving upwards in the positive direction, hence option A is incorrect. As the particle P is undergoing a simple harmonic oscillation, at this instance it is at the equilibrium position, it should have the maximum velocity, zero acceleration. So, options B and D are incorrect. As the displacement-position graph does not show a decreasing amplitude, all particles along the wave (including Particle P) have an amplitude of A. This is one of the distinguishing features between a progressive wave and a stationary wave. For the latter, the amplitude varies from maximum at the antinode and zero at the node.

16 **B**

Resolution or Rayleigh questions necessarily involve small angles.

$$\theta_{\text{min}} = \frac{\lambda}{b}$$



If angle of θ subtended at the opening by the two sources is greater than θ_{min} , the two images will be resolved (distinguished on the screen). This means that in order to make the separation of the images clearer, we can either increase θ or reduce θ_{min} .

Options A and C actually increases θ_{min} while keeping θ constant. This would make the images less resolved.

Option D does not affect either θ_{min} or θ so it should have no effect on the resolution of the images.

For option B, by reducing *D*. the angular separation θ increases for the same θ_{min} , thus the images are better resolved.

17 **A**

Using $d \sin\theta = n\lambda$,

Where there is an overlap between a lower order - longer wavelength and higher order-shorter wavelength, θ is the same. Since the same diffraction grating is used, d is the same.
Hence, $n\,\lambda_{longer} = (n + 1)\,\lambda_{shorter}$

Systematically working out,
When n = 1 and λ_{longer} = 700 nm, (n+1) = 2 and $\lambda_{shorter}$ = 350 nm. Since 350 nm is outside the range of 400 to 700 nm, there is no overlap between the first order's 700 nm and the second order's 400 nm.

When n = 2 and λ_{longer} = 700 nm, (n+1) = 3 and $\lambda_{shorter}$ = 467 nm. Since 467 nm is within the range of 400 to 700 nm, there is an overlap between the second and third orders.

The highest order of diffraction where there is no overlap is n = 1, the 1st order.

<u>Alternatively</u>

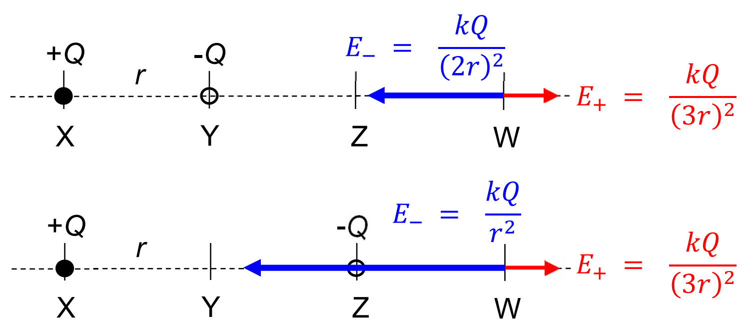
Using $d \sin\theta = n\lambda$, work out the angle of deviation θ for 400 nm light and 700 nm for each order *n*.

Order, n	θ for 400 nm	θ for 700 nm
1	6.9°	12.1°
2	13.9°	24.8°
3	21.1° (inside 2nd order)	

18 **C**

Statements A, B, D are correct assumptions while statement C is incorrect. The molecules are assumed to undergo elastic collisions with the walls of the container i.e. after the collisions the molecules move off in the opposite direction while having the same speed. Hence the change in momentum of the molecules Δp as shown below is not negligible.

$$\Delta p = mv - m(-v) = 2mv$$

19	**A**	From the ideal gas equation: $pV = NkT$ ………(1) and total internal energy of the gas molecules in the box, $U = \frac{3}{2}NkT$ Introducing additional N molecules of the same gas into the box $\Rightarrow$ $p'V = (2N)kT'$ ………(2) and total internal energy of the gas molecules, $U' = \frac{3}{2}(2N)kT'$, where p' & T' are the new pressure and temperature, and U' is the new internal energy of the gas in the box. $U = U' \rightarrow \frac{3}{2}NkT = \frac{3}{2}(2N)kT'$, resulting in $T' = \frac{1}{2}T$ (2) $\div$ (1) $\rightarrow p' = p$
20	**C**	A: $U = k\frac{Q_1Q_2}{r_{12}}$. When r increases, U becomes less negative, i.e. the potential energy increases. B:  C: $V_W = k\frac{Q_1}{r_{1W}} + k\frac{Q_2}{r_{2W}}$. When -$Q$ is moved to Z, which is closer to W, V_W becomes more negative, i.e. the potential at W decreases. D: +Q and -Q are at the same distance from Y. Based on the formula above, the potential at Y is zero.
21	**D**	Volume V is constant, express cross-sectional area A in terms of V and L: $AL = V \Rightarrow A = V/L$ Hence, the resistance variation with L is given by : $R = \frac{\rho L}{A} = \frac{\rho L^2}{V} \propto L^2$
22	**B**	Resistance of each of the lamp : $R = \frac{V^2_{rating}}{P_{rating}}$ since, both of them have the same voltage rating: $\frac{R_A}{R_B} = \frac{P_{rating,B}}{P_{rating,A}} = \frac{40}{10} = \frac{4}{1}$ Since, both lamps are connected in series, the same current passes both lamps and power emitted by each lamp : $P_{emitted} = I^2R$. $\frac{P_{emitted,A}}{P_{emitted,B}} = \frac{R_A}{R_B} = \frac{4}{1} \Rightarrow P_A = 4P_B$

23	**A**	Consider the secondary circuit: when temperature is low the resistance of the thermistor is high. This means that the terminal p.d. across the secondary cell is larger. (note that if the secondary cell has no internal resistance it would not matter what the resistance of the thermistor was, as the terminal p.d. would always simply be the secondary cell's e.m.f.) Consider the driver circuit: when it is dark the resistance of the LDR increases. This means that less of the driver cell e.m.f. drops across wire PQ. With a smaller p.d. per unit length of PQ, a longer balance length is needed.
24	**B**	The force per unit length acting on Z by X, $\frac{F_{XZ}}{l_Z} = B_X l_Z = \frac{\mu_o\, l^2}{2\pi\,(2d)} = F$ The force per unit length acting on Z by Y, $\frac{F_{YZ}}{l_Z} = B_Y l_Y = \frac{3\mu_o\, l^2}{2\pi\, d} = 6F$ Currents in Y and Z are in the same direction: Y attracts Z. Currents in X and Z are in opposite direction: X repels Z. Hence, the net force of 5*F* towards Y.
25	**C**	The copper disc "sees" the magnet rotating. The portion of the disc either "sees" an approaching pole or a pole moving away. By Lenz's law, in order to "oppose" the change (which again, is the rotation of the magnet), the disc will tend to rotate in the same direction as the magnet so that the magnet will appear "stationary" from the disc's perspective.
26	**B**	Using the potential divider principle, potential difference across the secondary coil = $80 \times \left(\frac{1500}{1000}\right) = 120V$ Current passing through the secondary coil = $I = \frac{V}{R} = \frac{80}{1000} = 0.080A$ Power dissipated by secondary coil = $IV = 0.080 \times 120 = 9.60W$ Potential difference across the primary coil = $120 \times \frac{200}{500} = 48.0V$ Power dissipated by primary coil = $V_p I_p = 9.60 \rightarrow I_p = \frac{9.60}{48.0} = 0.20A$
27	**C**	
28	**B**	Energy of photon = $\frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34})(3 \times 10^{8})}{(435 \times 10^{-9})} = 4.57 \times 10^{-19} J = 2.86\ eV$ Transition B, the difference in energy level = $(-0.54) - (-3.40) = 2.86\ eV$
29	**B**	Energy released = BE of helium – BE on reactants 3.26 = 2.54 × 4 – 4 × BE/nucleon of deuterium BE/nucleon of deuterium = 1.725 MeV
30	**B**	Let the background count-rate be C_B. $\frac{1}{4}(600 - C_B) = 180 - C_B$ $0.75C_B = 30$ C_B = 40 counts min^{-1}