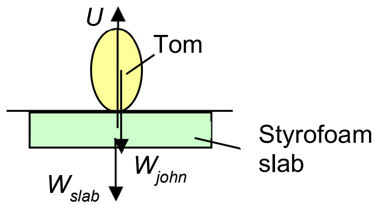
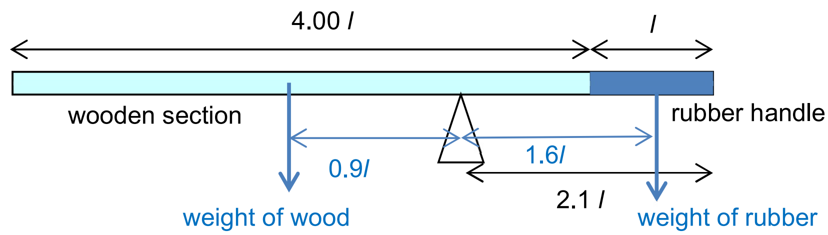
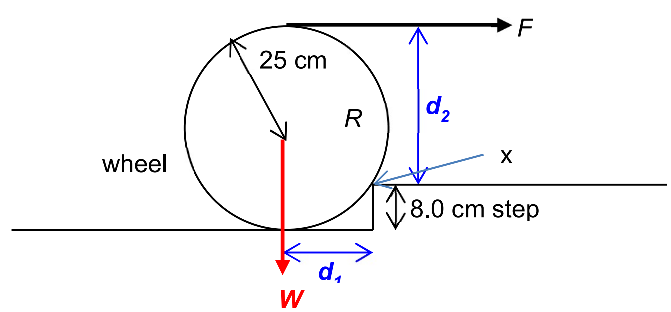
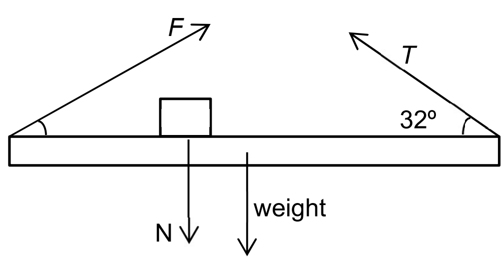
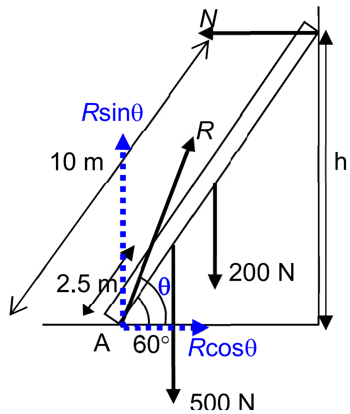
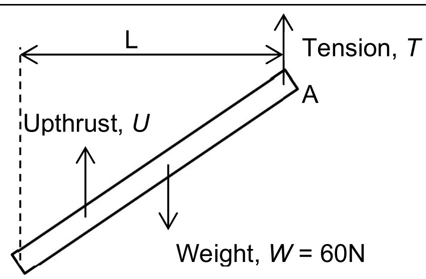
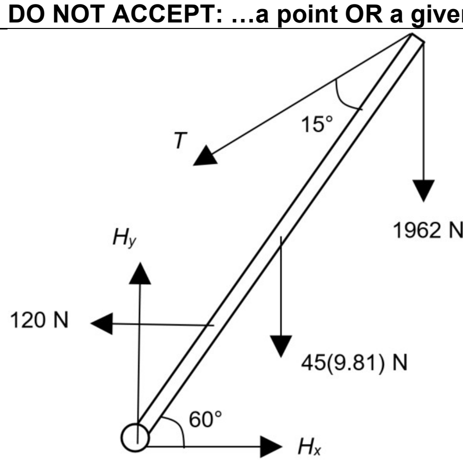
	Hence, max force = weight of concrete = 1.35×10^6 N	
6	 	
	Consider Tom and Styrofoam as a system, and they are in equilibrium, Upthrust on slab, by Floatation Principle, $U = W_{john} + W_{slab}$	[1]
	$V_{slab}\, \rho_f\, g = m_{john}\, g + m_{slab}\, g$ Area $\times$ thickness $\times$ ρ_f = m_{john} + (Area $\times$ thickness $\times$ ρ_{slab}) Area $\times$ 0.100 $\times$ 1000 = 60.0 + (Area $\times$ 0.100 $\times$ 300)	[1]
	$\Rightarrow$ Area = 0.857 m^2	[1]
7 (a)	As the bag rises, hydrostatic pressure due to the water acting on the balloon decreases which in turn causes the volume of air to increase. (due to pV=nRT)	[1]
	In order to maintain a constant speed, upthrust must be equal to the sum of the downward viscous force and the weight of the load (Newton's 1st Law).	[1]
	Therefore, volume of air must stay constant, so that the volume and thus weight of water displaced remains the same (assuming density of water remains constant). As such the expanded volume of air must be released.	[1]
(b)	By Newton's 2nd Law, $F = ma$ $U - W = ma$ where U = Upthrust on cannon + Upthrust due to extra vol of air	[1]
	$(1050)(9.81)\left(0.7+\frac{800}{8000}\right)-800(9.81)=800a$	[1]
	$a = 0.49 ms^{-2}$	[1]

8 (i)	There is <u>upward pressure on the bottom</u> of the cylinder and <u>downward pressure on the top</u>. Since (hydrostatic) <u>pressure increases with depth</u>, the <u>pressure at the bottom is greater than the pressure at the top</u>. Due to the <u>pressure difference</u> between the bottom of the cylinder and the top of the cylinder, there is a <u>net upward force</u> exerted by the water known as upthrust.	[1] [1] [1]
(ii)	upthrust = V ρ g = (3.2 – 1.4) x 0.45 x 1000 x 9.81 = 7946 N weight of cylinder = (3.2 – 1.4) x 0.45 x 2400 x 9.81 = 19070 N Force by rod = 19070 – 7946 = 11100 N (3 s.f)	[1] [1] [1]
10	Ans: B  It is found that CG of wooden section is 0.9*l* from pivot and CG of rubber handle is 1.6*l*. By Principle of Moments about the pivot, Sum of CW moments = Sum of ACW moments 0.9*l* x weight of wood = 1.6*l* x weight of rubber 0.9*l* x ρ_{wood} x 4*l* x Area x g = 1.6*l* x ρ_{rubber} x *l* x Area x g $\Rightarrow \dfrac{\text{density of rubber}}{\text{density of wood}} = \dfrac{3.6}{1.6} = 2.25$	[1]
11	Ans: C For equilibrium, There must be rotational equilibrium and translational equilibrium. The original setup has attained translational equilibrium already. The additional forces to be added must have translational equilibrium as well. In addition, the original setup has a resultant *clockwise* moment of 6 x 0.02 = 0.12 Nm. Hence, option C, which gave a resultant *anticlockwise* moment of 3 x 0.04 = 0.12 Nm, will be the required option.	[1]
12		
	Taking moments about point X (since R is unknown), Total ACW moments = total CW moments $W \times d_1 = F \times d_2$	[1]
	$(18 \times 9.81) \times \sqrt{[0.25^2 - (0.25 - 0.08)^2]} = F \times (0.50 - 0.08)$ $F = 77$ N	[1] [1]
	Note: There should be no normal reaction force at the point where the wheel just touches the bottom floor, as it is about to leave the floor when it is about to turn. Hence, there is no need to consider any clockwise moment generated by normal reaction.	

15	Ans: B We shall look at all the 4 cases to see if they are in translational equilibrium and rotational equilibrium about the centre. A: Translational equilibrium achieved and net ACW moments. B: No translational equilibrium as it is not possible to achieve closed vector triangle, ie. diagonal F is shorter than the hypotenuse required. Net CW moments. C: Translational equilibrium achieved as a equilateral closed vector triangle is possible. Net ACW moments. D: Leftward resultant force, and rotational equilibrium achieved.	[1]
16	Moments about the cg, $T_1 \times (l/2)l = T_2 \times (l/2 - l/3)\ l$ $T_1 / T_2 = 0.333$ (3 s.f) The word 'heavy' tells us very clearly that the weight of the beam is not negligible. Hence taking moments about the cg & hence eliminating the corresponding unknown moment due to the weight, is a very good choice of the axis of rotation.	 [1] [1]
	Assignment	
17 (i)	(Note that the question simply state ratio of tensions is $\frac{3}{7}$, without stating whether is it $\frac{T_A}{T_B}$ or $\frac{T_B}{T_A}$. In this case, students need to analyse that T_A must be greater than T_B, since it has a smaller perpendicular distance to the centre of mass, so that resultant moment at centre of mass can be 0.) $T_A + T_B$ = weight of the sign and $\frac{T_B}{T_A} = \frac{3}{7} \Rightarrow T_B = \frac{3}{7} T_A$ $T_A + \frac{3}{7} T_A = (4.5)(9.81)$ Solving, $T_A = 30.9$ N and $T_B = 13.2$ N	 [1] [1]
(ii)	Taking moment about the centre of mass, $T_A(d - 0.20) = T_B(0.8 - d)$ Solving, d = 0.38 m.	[1] [1]
(iii)	In order to maintain equilibrium, net force must be zero in all directions. Since weight is perpendicularly downward, the tensions in the support must provide a leftward horizontal component to cancel out the rightward horizontal force provided by the wind on the sign.	[1]
18 (a)	 F is the force exerted on beam by the wall at the hinge N is the normal reaction by the pile of bricks	[1]
(b)	As the pile of bricks is moved to the right, there will be more clockwise moments about the hinge.	[1]
	To keep the beam stationary, the beam needs more anti-clockwise moment. It is done so by having a higher tension of *T*.	[1]
(c)	Taking moments about the hinge, Clockwise moments = Anti-clockwise moments Clockwise moments = (2.7)(150)(9.81) + (4) 210(9.81)	[1]
	Anti-clockwise moments = (8) T sin32º T = 2880 N	[1] [1]

(d)	Since the beam is stationary, Sum of horizontal components = 0 $F_x - 2880 \cos 32^o = 0$ $F_x = 2440$ N Sum of vertical components = 0 $F_y + 2880 \sin 32^o - 150(9.81) - 210(9.81) = 0$ $F_y = 2010$ N	[1]
	Therefore, $F^2 = F_y^2 + F_x^2 \rightarrow F = 3160$ N	[1]
19		
	Taking moments about A, Sum of anticlockwise moments = sum of clockwise moments $N \times h = (200 \times 5 \cos 60°) + (500 \times 2.5 \cos 60°)$ where $h = 10 \sin 60°$	[1]
	$\therefore$ N = 130 N	[1]
	For translation equilibrium, Vector sum of forces in y-direction = 0 N $R \sin\theta = 500 + 200$ -------------(1) Vector sum of forces in x-direction = 0 N $R \cos\theta = 130$ --------------(2)	[1]
	By solving (1) and (2), $\theta = 79.5°$ R = 712 N	[2]
20 (i)		[2]
(ii)	Let the 'horizontal length" of the rod be L. Since tension T is unknown, taking moments about point A, $\Sigma\tau_B = 0$ U x 0.75L – (W x 0.5L) = 0	[1]
	$V_{immersed\ rod}\ \rho_{water}\ g \times 0.75 - (60 \times 0.5) = 0$ $V_{immersed\ rod} = 0.004077$ m^3	[1]
	ρ_{wood} = mass of wood/ volume of wood = (60/9.81) / 2(0.004077) = 750 kg m^{-3} {Need to know that upthrust always acts thru the cg of the submerged portion.}	[1]
(iii)	From (1), U = 0.5W /0.75 = 40 N Taking upwards as positive, $\Sigma F_y = 0$ T + U = W	[1]
	T = 60 – 40 = 20 N	[1]

Solutions to Additional Questions

1(a)	If X = 0 N, then Y has to be 60.0 N upwards. {to balance the downward force of the weight} Thus magnitude of Y = 60.0 N, Angle = 90°	[1] [1]
(b)	For horizontal eqm, Y_x = 200 cos 30° = 173.21 N leftwards For vertical eqm, Y_y = 200 sin 30° - 60.0 = - 40.0 N downwards Thus magnitude of Y = 178 N Angle = $\tan^{-1}$(40.0 / 173.21) = 13.0° Following the defined angle in the diagram, angle = -13.0° {Note: angle of Y is negative since Y acts below the horizontal.}	 [1] [1] [1]
(c)	There will always be a non-zero horizontal component of X (X cos 30°). For equilibrium, the resultant of the horizontal component of Y and weight must equal X cos 30°. Since weight has no horizontal component, Y must have a horizontal component and thus rope B cannot be parallel to weight of S (vertical).	[1] [1]
2(a)	<u>Net</u> force is zero (in all direction). <u>Net</u> moment is zero about <u>any</u> point. **DO NOT ACCEPT: …a point OR a given point**	[1] [1]
(b)	 Evidence of angle between *T* and boom (in working) = 15° Taking moments about the hinge, (Tsin 15°)(3) + (120sin 60°)(0.75) = (45)(9.81)(1.5cos 60°) + (1962)(3cos 60°) T = 4116 = 4.1 kN	[1] [2]
(c)	(Let H_y and H_x be the vertical and horizontal components of the force hinge acts on the boom) H_y = 1962 + 45(9.81) + Tcos 45° = 5314 N H_x = 120 + Tsin 45° = 3030 N Therefore, magnitude of force hinge acts on boom = $\sqrt{5314^2+3030^2}$ = 6120 N Direction of the force = $\tan^{-1}$ (5314 / 3030) = 60.3° above horizontal	 [1] [1] [1] [1]
3(i)	Given that it is in equilibrium, Upthrust = Weight of ball (Note: ½ of the ball is submerged, while ¾ of ball remains!) ρ_W × ½ V × g = ρ_{Ball} × ¾ V × g 1000 × ½ V × g = ρ_{Ball} × ¾ V × g ⇒ ρ_{Ball} = **667** kg m^{-3}	 [1] [1]
(ii)	Given that it is in equilibrium, Upthrust = Weight of ball + tension ρ_W × ¾ V × g = ρ_{Ball} × ¾ V × g + 300 1000 × ¾ V × g = 667 × ¾ V × g + 300	 [1]