CORPUS CHRISTI COLLEGE
SEQUERE DOMINUM

Year 12 Physics 3AB 2017

TEST 3 Torque and Equilibrium 3.0%

NAME: Adams

Data: See Data Sheet
Approx. marks shown.

(52 marks)

When calculating numerical answers, show your working or reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.

1. Consider the following diagram below. A driver was required to change a flat tyre. However the wheel nuts were too tight to loosen by hand and so the driver stood on the end of the torque wrench shown in the diagram.

(a) Assuming that the wrench is **horizontal** when the person stood on it, estimate the torque applied to the wheel nut. Show your working clearly. [6]

use judgement
For wheel $300 < r < 400$ mm ✓
For nut $20 < r < 30$ mm ✓
For mass $50 < m < 80$ kg

$F = F_g = mg$
$= 50 \times 9.8 = 490$ N ✓

$\tau = Fr$
$= 490 \times 0.3$ ✓ ✓ ✓
$= 147 = 150$ Nm ACW (2sf)
(based on diagram)

(b) Estimate the force applied to the wheel nut. Show your working clearly. [3]

For nut $20 < r < 30$ mm ✓ T of wrench is applied to nut. ✓

$\tau = Fr$
$147 = F \times 0.020$ ✓
$F = 7350$ N $=$ 7400 N (2sf)

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2. A bar of steel 80 cm long is pivoted horizontally at its left end, as depicted in Fig. 2.

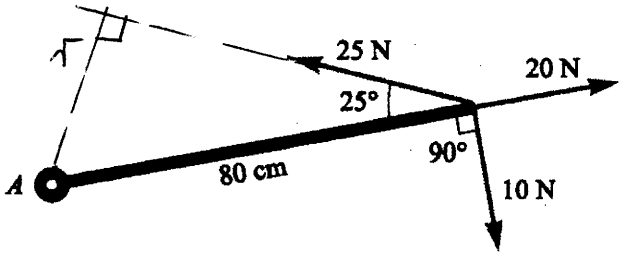

Fig. 2

(a) Find the torque about axis-**A** (which is perpendicular to the page) due to ***each*** of the forces shown acting at its right end. [4]

(b) Hence determine the net torque acting on the bar by the given forces. [2]

10N: $\tau = Fr$ ✓(½) ✓(½)

$= 10 \times 0.80 =$ 8.00 Nm CW

20N: $\tau = Fr$ ✓

$= 20 \times 0 =$ 0 Nm.

25N: $\tau = Fr$ ✓

$= 25 \times 0.338$ ✓ $r = 0.80 \sin 25°$ ✓

$= 8.45$ Nm ACW $= 0.338$ m

∴ Net torque $= 8.45 - 8$ ✓

$= 0.450$ Nm ACW. ✓

3. The arm drawn in Fig. 3 supports a 4.00 kg sphere. The mass of the hand and forearm together is 3.0 kg and its weight acts at a point 15 cm from the elbow.

Assuming all the forces are vertical and the arm is horizontal, determine the force exerted by the biceps muscle. [4]

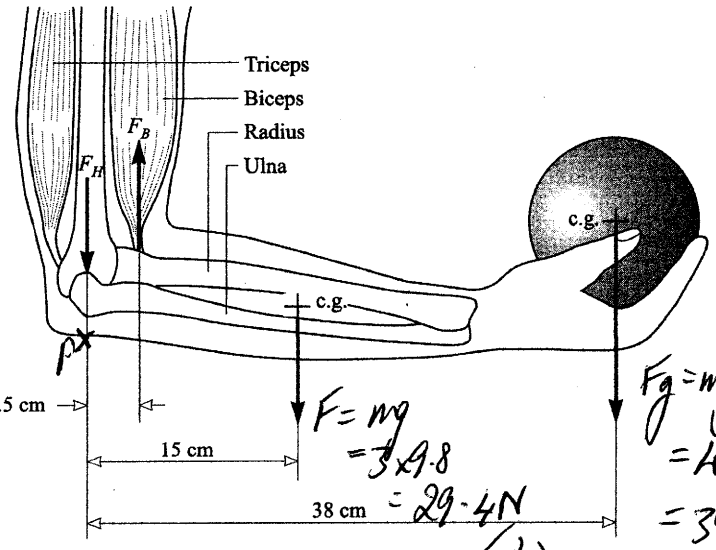

Fig. 3

✓(½)

✓(½)

At equil^m $\Sigma CM = \Sigma ACW$

∴ $29.4 \times 15 + 39.2 \times 38$ ✓

$= F_B \times 4.5$

$1930.6 = 4.5 F_B$ ✓

∴ $F_B = 429$ N (up)

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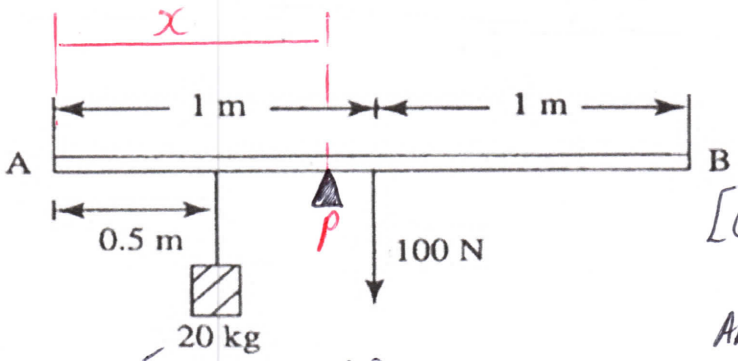
4. A uniform rod AB of weight 100 N and length 2.0 m is balanced horizontally and carries a load of 20.0 kg as shown in the diagram below. Determine the location of the pivot. [4]



[Could also treat as Co/M problem.
About A: ΣCM = ΣACM
196 × 0.5 + 100(1) = 296(x)
x = 0.669 m]

$F_g = mg = 20 \times 9.8$
$= 196\,N$ ✓

Let distance from A to pivot = x.

At equil^m ΣCM = ΣACM.

$100(1-x) = 196(x-0.5)$ ✓✓

$1 - x = 1.96(x - 0.5) = 1.96x - 0.98$

$1.98 = 2.96x$ ✓

$\therefore x = 0.669\,m$ $\therefore$ Pivot is 0.669 m from A.

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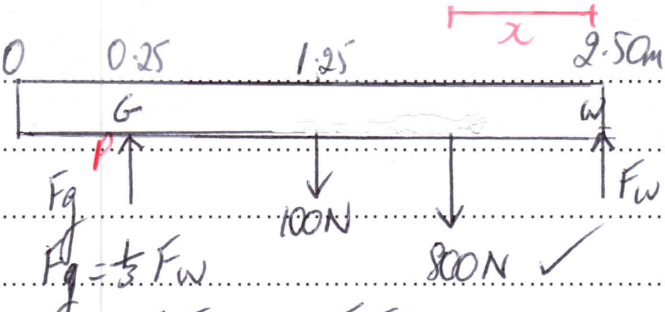
5. Where must a 0.80 kN object be hung on a uniform, horizontal, rigid 100 N pole, 2.50 m long, so that a girl pushing up at 0.25 m from one end supports one third as much as a woman pushing up at the other end? [6]



$F_g = \frac{1}{3} F_W$

Double pivot: $\Sigma F_{up} = \Sigma F_{down}$

$\frac{1}{3} F_W + F_W = 100 + 800$

$\therefore 1\frac{1}{3} F_W = 900$

$\therefore F_W = 900 / 1\frac{1}{3} = 675\ N$ ✓

$\therefore F_g = \frac{1}{3}(675) = 225N$

Let pivot be at grid: At equil^m $\Sigma cm = \Sigma ACM$

Let x = distance from load to woman. ✓✓

$100(1) + 800(2 \cdot 25 - x) = 675(2 \cdot 25)$

$100 + 1800 - 800x = 1518 \cdot 75$

$1900 - 1518 \cdot 75 = 800x$ ✓

$x = 381 \cdot 25 / 800 = 0 \cdot 4766\ m$

$\therefore$ Load located 0·477m from woman.

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6. Find the tensions in the ropes illustrated in Fig 6b below if the supported load of the bird feeder apparatus is 25 kg. Neglect the weight of the ropes.

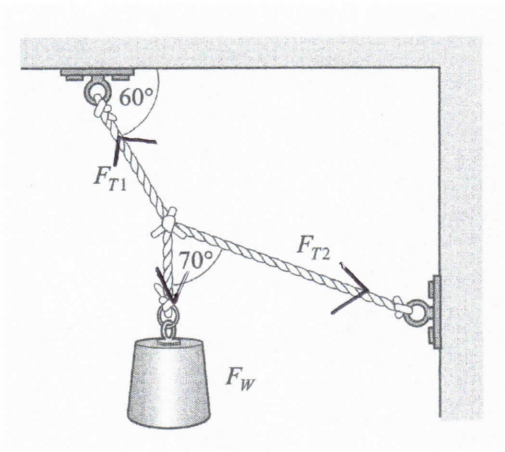
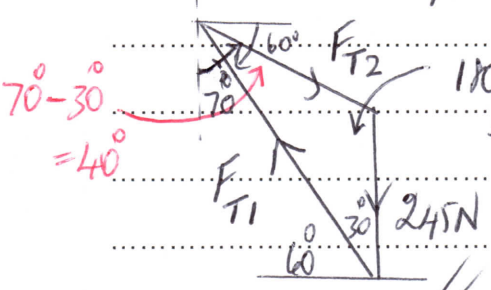


Fig 6b

[5]

Tension in rope $F_W = mg = 25 \times 9.8 = 245\,N$ ✓



✓

$180° - (30° + 40°) = 110°$

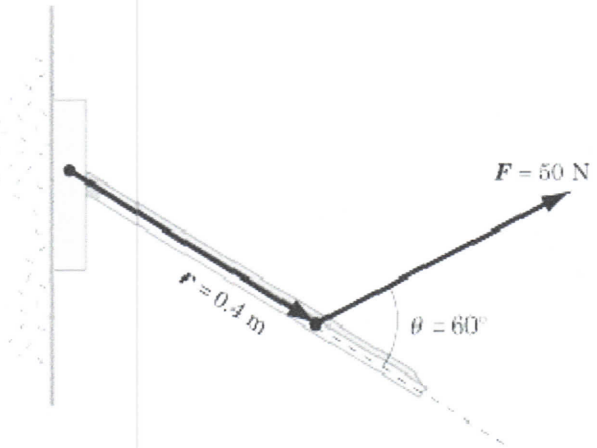
$\frac{F_{T1}}{\sin 110°} = \frac{245}{\sin 40°}$ ✓

$\therefore F_{T1} = 358\,N$ (3sf)

$\frac{F_{T2}}{\sin 30°} = \frac{245}{\sin 40°}$ ✓

$F_{T2} = 191\,N$ (3sf)

7. A uniform plank shown below is 0.75 m long has a mass of M kg. It is suspended at an angle of 40.0° with the wall by a force of 50.0 N as shown below.



(a) Calculate the value of M.

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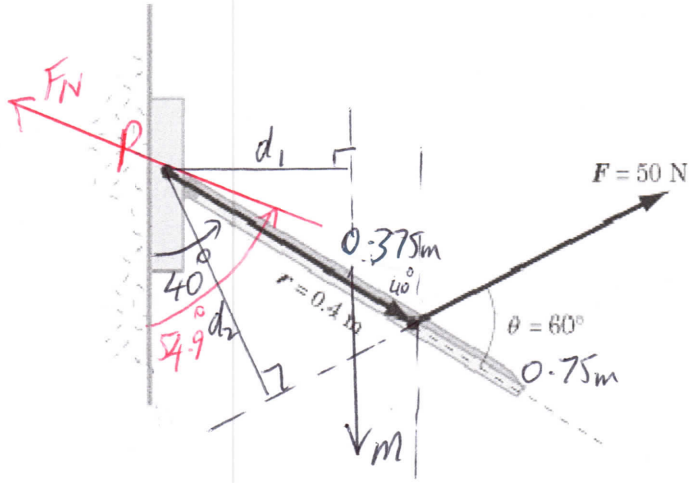
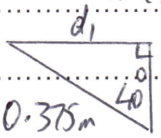
7. A uniform plank shown below is 0.75 m long has a mass of M kg. It is suspended at an angle of 40.0° with the wall by a force of 50.0 N as shown below.



(a) Calculate the value of M. [4]

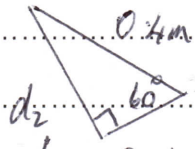
At equil^m $\Sigma CM = \Sigma ACM$

$M \times 9.8 \times d_1 = 50 \times d_2$ ✓



$d_1 = 0.375 \sin 40°$

$= 0.241$ m ✓



$d_2 = 0.4 \sin 60°$ ✓

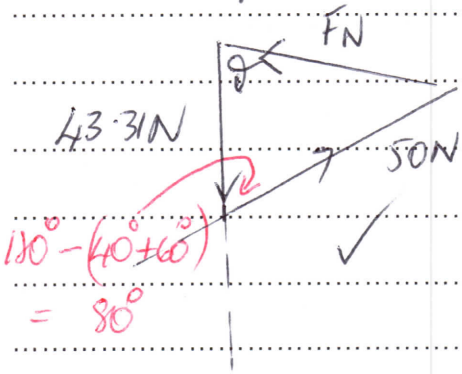
$= 0.2078$ m.

$\therefore M \times 9.8 \times 0.241 = 50 \times 0.2078$

$M = 4.42$ kg ✓

(b) Calculate the magnitude and direction of the reaction of the wall at the hinge. Show this force on the diagram. [5]

wt = Fg of M = $4.42 \times 9.8 = 43.31$ N ✓



✓

$F_N^2 = 50^2 + 43.31^2 - 2(50)(43.3)\cos 80°$

$F_N = \sqrt{3625.6}$ ✓

$= 60.197 = 60.2$N (3sf)

$\frac{\sin\theta}{50} = \frac{\sin 80°}{60.2}$

$\theta = \sin^{-1}(0.8180)$ ✓

$= 54.9°$ (3sf)

Slow on diag ✓

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(c) If the force of 50.0 N were applied closer to the pivot what would be the effect on your answer to (b)? Explain your reasoning. [3]

If r decreases then d_2 increases ✓(½)
No change to d_1
∴ M decreases ✓(½)
∴ weight of M decreases but 50 N remains same
∴ F_N decreases ✓
and θ increases, angle to wall increases.

8. The Figure 8A below shows an Automated Lifting System for use in the construction of tall buildings. It shows the lifting table of the system. The Figure 8B shows the base of the system.

Figure 8A

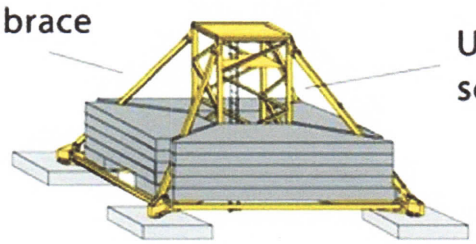

Figure 8B

Using the concepts of Torque and Centre of mass,

(a) briefly explain why the system become less stable as the building becomes taller, and [2]

As the building becomes taller the lifting table will move higher. This raises the combined Centre of Mass & the higher the Centre of Mass the less stable the system.

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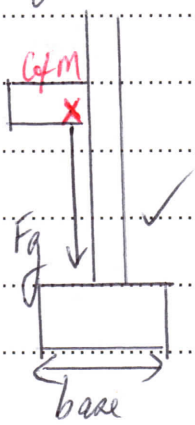
(b) briefly explain the shape and construction of the base of the system. [4]

The base has been constructed of heavy materials. This lowers the Combined C of M of system making it more stable. (½)



The base is wide so that the Combined C of M is still over ✓ the base. Therefore $\uparrow = 0$

$\curvearrowright = F \uparrow = 0$ ✓

Hence the torque due to the weight does not cause the lifting system to tip over. (½)

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