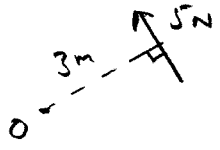
MEI MECHANICS 2 MOMENTS EXERCISE 3A

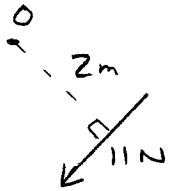
1) i)



$5 \times 3 = 15$

$+15$ Nm

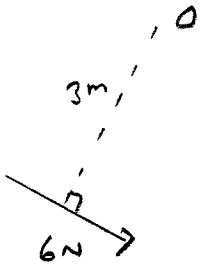
ii)



$2 \times 11 = 22$

-22 Nm

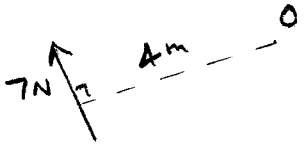
iii)



$6 \times 3 = 18$

$+18$ Nm

iv)



$7 \times 4 = 28$

-28 Nm

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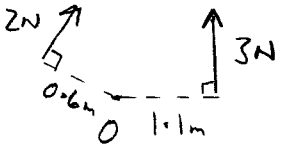
2) i)



Total moment $= 3 \times 1.1 - 2 \times 0.6$

$= +2.1$ Nm

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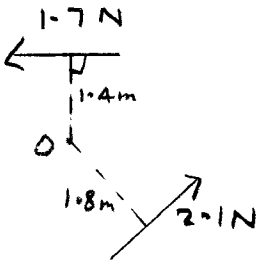
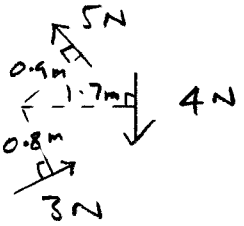
ii)



Total moment $= 2.1 \times 1.8 + 1.7 \times 1.4$

$= +6.16$ Nm

2iii)

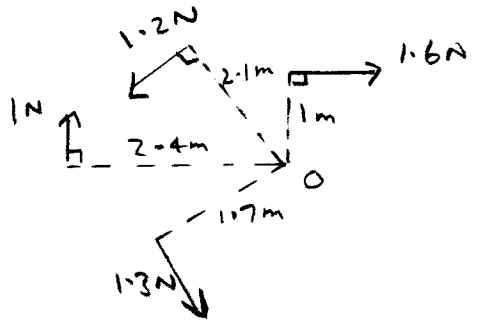


Total moment =

$5 \times 0.9 + 3 \times 0.8 - 4 \times 1.7$

$= +0.1$ Nm

2iv)



Total moment =

$1.2 \times 2.1 + 1.3 \times 1.7 - 1 \times 2.4 - 1.6 \times 1$

$= +0.73$ Nm

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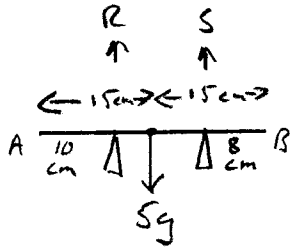
3)



$R + S = 5g$ ①

Moments about A (In equilibrium)

$10R + 22S = 15 \times 5g$

$10R + 22S = 75g$ ②

From ① $R = 5g - S$

3 cont) Subst for R in (2)

$10(5g - S) + 22S = 75g$

$50g - 10S + 22S = 75g$

$12S = 25g$

$S = \frac{25g}{12} = 20.4\ N$

$R = 5g - 20.4 = 28.6\ N$

Reaction at support nearest left-hand end = 28.6 N
Reaction at support nearest right-hand end = 20.4 N

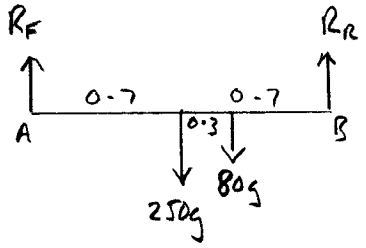
4)

i) Centre of mass midway between wheels therefore

$R_{front} = R_{rear} = \frac{250g}{2}$

$= 1225\ N$

ii)



$R_F + R_R = 330g$ (1)

Moments about A

$1.4R_R = 250g \times 0.7 + 80g \times 1.0$

$1.4R_R = 255g$

$R_R = \frac{255g}{1.4} = 1785\ N$

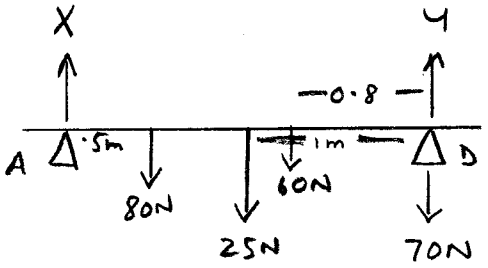
$R_F = 330g - R_R$

$= 330g - 1785$

$= 1449\ N$

Front wheel reaction = 1449 N
Rear wheel reaction = 1785 N

5)



$X + Y = 80 + 25 + 60 + 70$

$X + Y = 235\ N$

Moments about D

$80 \times 1.5 + 25 \times 1 + 60 \times 0.8 = 2X$

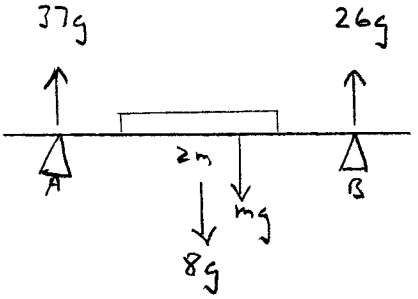
$193 = 2X$

$\Rightarrow X = 96.5\ N$

$Y = 235 - 96.5$

$Y = 138.5\ N$

6)



6 cont) i) $37g + 26g = 8g + mg$

$mg = 55g$

$m = 55$ kg

ii) Taking moments about A

$2 \times 26g = 1 \times 8g + d \times 55g$

$52g = 8g + 55dg$

$52 = 8 + 55d$

$44 = 55d$

$\Rightarrow d = \frac{44}{55} = 0.8$ m

Centre of Karen's mass is 0.8m from A

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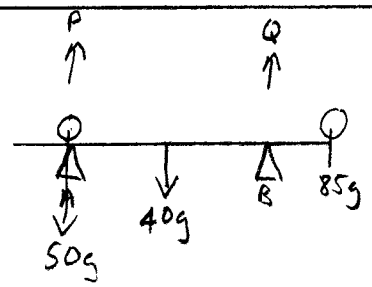
7) i)



Resolving vertically

$P + Q = 50g + 40g + 85g$

$P + Q = 175g$

Taking moments about A

$Q \times 1 = 40g \times 0.5 + 85g \times 1.5$

$Q = 147.5g$ N

$\Rightarrow P = 175g - 147.5g = 27.5g$ N

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7 ii) Again moments about A

$Q \times 1 = 40g \times 0.5 + 50g \times 0.5 + 85g \times 1.5$

$Q = 172.5g$ N

$\Rightarrow P = 2.5g$ N

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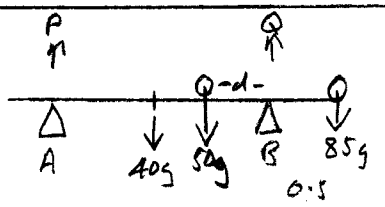
7 iii)



P will be 0N when bench is balanced on the pivot point B

Taking moments about B

$40g \times 0.5 + 50g \times d = 85g \times 0.5$

$20g + 50dg = 42.5g$

$20 + 50d = 42.5$

$50d = 22.5$

$d = \frac{22.5}{50}$

$d = 0.45$ m

P = 0 N when girl is 0.45m from B

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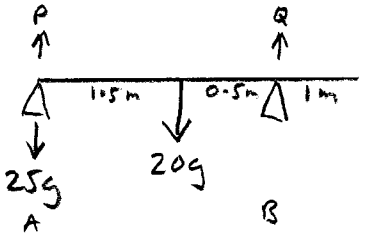
iv) If child leaves bench it will rotate clockwise about B with adult then falling off

8)i)



Resolving vertically

$$P + Q = 20g + 25g$$

$$P + Q = 45g \quad N$$

Take moments about A

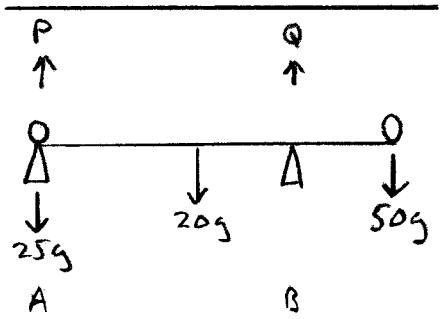
$$20g \times 1.5 = Q \times 2$$

$$30g = 2Q$$

$$\Rightarrow \quad Q = 15g \quad N$$

$$\Rightarrow \quad P = 45g - 15g = 30g \quad N$$

8ii)



$$P + Q = 25g + 20g + 50g$$

$$P + Q = 95g \quad N$$

Take moments about A

$$20g \times 1.5 + 50g \times 3 = Q \times 2$$

$$30g + 150g = 2Q$$

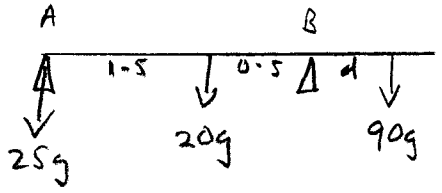
$$2Q = 180g$$

$$Q = 90g \quad N$$

$$\Rightarrow \quad P = 5g \quad N$$

8iii) Reaction at A = 0 N
it board about to tip over

8iv)



Taking moments about B if board on point of tipping

$$25g \times 2 + 20g \times 0.5 = 90g \times d$$

$$50g + 10g = 90dg$$

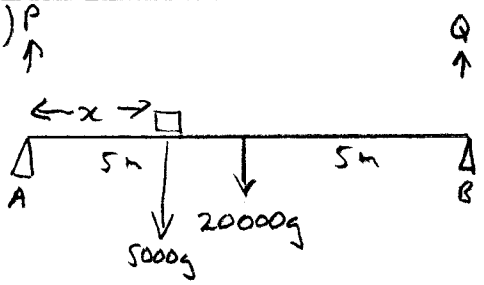
$$60g = 90dg$$

$$60 = 90d$$

$$d = \frac{60}{90} = \frac{2}{3} \text{ m}$$

Boy can walk $\frac{2}{3}$ m from B towards end of board before it is on the point of tipping

9)i)



$$P + Q = 5000g + 20000g$$

$$P + Q = 25000g$$

Take moments about A

$$Q \times 10 = 20000g \times 5 + 5000g \times x$$

9i) cont) $10Q = 100000g + 5000xg$

$Q = 500g(20+x)$ N

$\Rightarrow P = 25000g - 500g(20+x)$

$P = 500g(50-(20+x))$

$P = 500g(30-x)$ N

9ii) Its centre of mass

9iii) For this situation

$P+Q = 5000g + 5000g + 20000g$ N

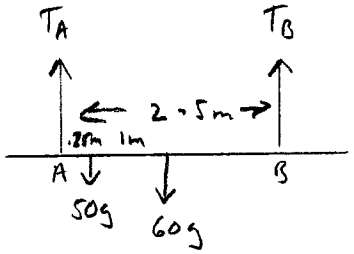
$P+Q = 30000g$ N

Symmetry of situation $\Rightarrow$

$P = Q = 15000g$ N

at all times

10) i)



$T_A + T_B = 50g + 60g$

$T_A + T_B = 110g$ N

Taking moments about A

$50g \times 0.25 + 60g \times 1.25 = T_B \times 2.5$

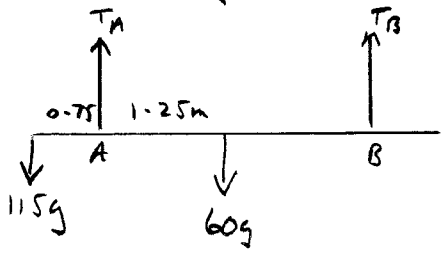
$12.5g + 75g = 2.5T_B$ N

$87.5g = 2.5T_B$

$T_B = \frac{87.5g}{2.5} = 35g$ N

$\Rightarrow T_A = 110g - 35g = 75g$ N

10ii) Could not tip unless couple were outside the supports, so test when couple are at very end of bridge



Take moments about A

$115g \times 0.75 + 2.5T_B = 60g \times 1.25$

$86.25g + 2.5T_B = 75g$

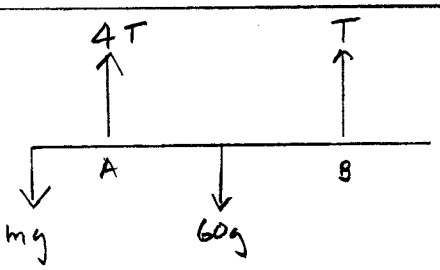
$2.5T_B = 75g - 86.25g$

$2.5T_B = -11.25g$

$\Rightarrow T_B < 0$ but T_B must be ≥ 0 for couple to walk safely.

Bridge would tip when they first stepped onto it.

10iii)



Let person have mass m and tensions be 4T and T as shown

10iii cont) Resolving vertically

$$4T + T = mg + 60g$$

$$5T = g(m + 60) \quad (1)$$

Taking moments about A

$$mg \times 0.75 + T \times 2.5 = 60g \times 1.25$$

$$0.75mg + 2.5T = 75g$$

$$2.5T = 75g - 0.75mg$$

$$\Rightarrow 5T = 150g - 1.5mg \quad (2)$$

From (1) and (2)

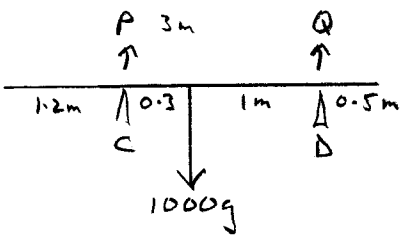
$$mg + 60g = 150g - 1.5mg$$

$$2.5mg = 90g$$

$$m = \frac{90}{2.5}$$

$$m = 36 \text{ kg}$$

11) i)



$$P + Q = 1000g$$

Taking moments about C

$$1000g \times 0.3 = Q \times 1.3$$

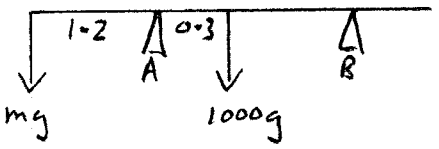
$$\Rightarrow Q = \frac{300g}{1.3}$$

$$\Rightarrow Q = 2262 \text{ N}$$

$$\Rightarrow P = 1000g - 2262$$

$$P = 7538 \text{ N}$$

11 ii)



On point of tipping when

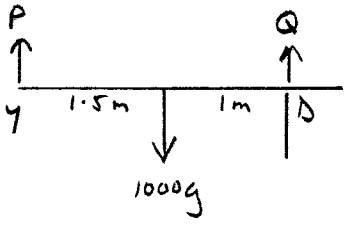
$$mg \times 1.2 = 1000g \times 0.3$$

$$mg = 1000g \times \frac{0.3}{1.2}$$

$$m = 250 \text{ kg}$$

∴ 5 children of mass 50 kg standing on end would have stone on point of tipping. ∴ 6 would cause it to tip

11 iii) Find upward force required at Y



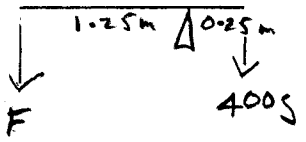
$$P + Q = 1000g$$

Take moments about D

$$1000g \times 1 = P \times 2.5$$

$$\Rightarrow P = 400g \text{ N}$$

11(iii) cont) $\therefore$ reaction down on lever $= 400g$ N



Downward force F required is given by

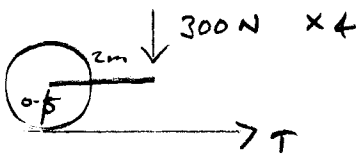
$$F \times 1.25 = 400g \times 0.25$$

$$F = 400g \times \frac{0.25}{1.25}$$

$$F = 80g \text{ N}$$

$$F = 784 \text{ N}$$

12) i)



Turning effect of seamen

$= 4 \times 300 \times 2$

$= 2400$ Nm

Steady angular speed $\therefore$

turning effect of tension T also 2400 Nm in opposite direction

$$T \times 0.5 = 2400$$

$$T = 4800 \text{ N}$$

12 ii) Horizontal component of Tension

$= T\cos 20^\circ$

$= 4800 \cos 20^\circ$

Using $F = ma$ N2L

$$4800 \cos 20^\circ = 2000{,}000\, a$$

$$a = \frac{4800 \cos 20^\circ}{2 \times 10^6}$$

$$a = 2.255 \times 10^{-3} \text{ ms}^{-2}$$

$$a = 0.0023 \text{ ms}^{-2}$$

12 iii) Actual $a = 0.0015$ ms^{-2}

$\therefore F = 2 \times 10^6 \times 0.0015$

$F = 3000$ N

Resultant horizontal force on ship

$= 3000$ N

Turning effect of seamen less 300Nm resistance $= 2100$ Nm

$\therefore T \times 0.5 = 2100$ Nm

$T = 4200$ N

Horizontal component $= 4200 \cos 20^\circ$
$= 3947$ N

Resistance R due to water

$R = 3947 - 3000 = 947$ N