Higher Structures

Vertical Forces

$\Sigma F\uparrow = \Sigma F\downarrow$

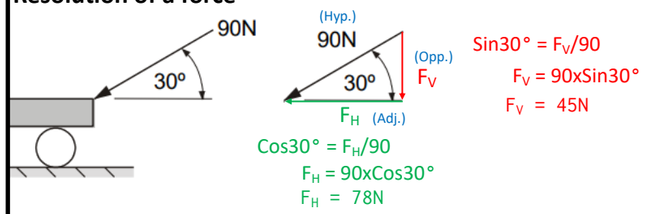
Horizontal Forces

$\Sigma F\rightarrow = \Sigma F\leftarrow$

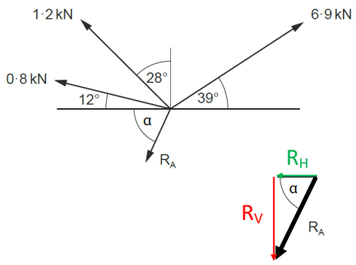
Moments

$\Sigma CWM = \Sigma ACWM$

Resolution of a force



Resolution of forces on a point



1 - Resolve all forces

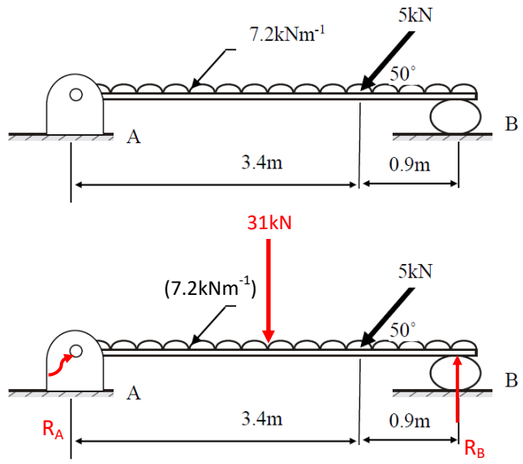
2 - $\Sigma F\uparrow = \Sigma F\downarrow$ to find R_V

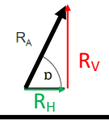
3 - $\Sigma F\rightarrow = \Sigma F\leftarrow$ to find R_H

4 - Pythagoras to find R_A

5 - Find the angle ($\text{Tan}\ \alpha = R_V/R_{H)}$

Uniformly Distributed Loads (UDLs)





1 - Calculate the UDL (Force x distance)

2 - Resolve 5kN force to find vertical component

2 - $\Sigma CWM = \Sigma ACWM$ taking moments about R_A to find R_B

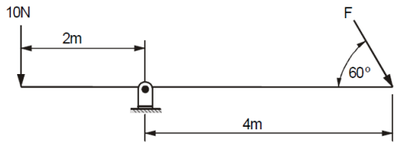
3 - $\Sigma F\uparrow = \Sigma F\downarrow$ to find R_{AV}

4 - $\Sigma F\rightarrow = \Sigma F\leftarrow$ to find R_{AH}

5 - Pythagoras to find R_A

6 - Find the angle ($\text{Tan}\ \alpha = R_V/R_{H)}$

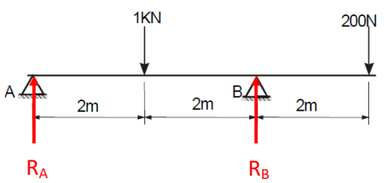
Moments with a force at an angle



1 - Resolve F to find vertical component

2 - $\Sigma CWM = \Sigma ACWM$

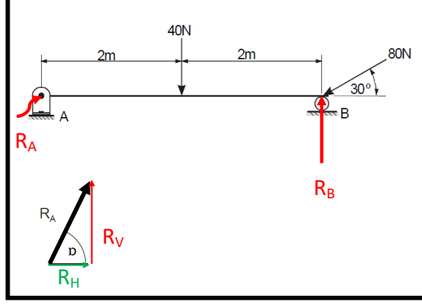
Simple supports



1 - $\Sigma CWM = \Sigma ACWM$ taking moments about R_A to find R_B

2 - $\Sigma F\uparrow = \Sigma F\downarrow$ to find R_A

Hinge & Roller



1 - Resolve 80N force to find vertical component

2 - $\Sigma CWM = \Sigma ACWM$ taking moments about R_A to find R_B

3 - $\Sigma F\uparrow = \Sigma F\downarrow$ to find R_{AV}

4 - $\Sigma F\rightarrow = \Sigma F\leftarrow$ to find R_{AH}

5 - Pythagoras to find R_A

6 - Find the angle ($\text{Tan}\ \alpha = R_V/R_{H)}$

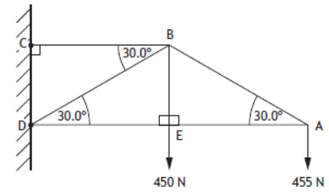
Strut

Members that are in compression, due to external forces trying to compress them, are known as Struts.

Tie

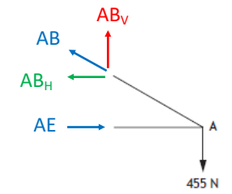
Members that are in tension, due to external forces trying to pull them apart, are known as Ties.

Nodal analysis

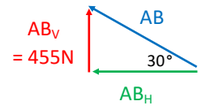


1 - Analyse the first node to break down any forces at an angle into horizontal and vertical components.

2 - As we know a vertical force at A and only have one unknown vertical AB_V, we start with $\Sigma F\uparrow = \Sigma F\downarrow$ to find AB_V.

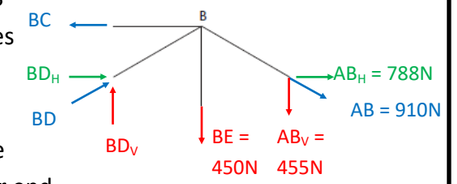


3 - We can now draw AB as a triangle of forces to use trigonometry and Pythagoras to solve AB and AB_H.



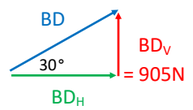
4 - Once we know AB_H, we can find AE using $\Sigma F\rightarrow = \Sigma F\leftarrow$.

5 - Now using node B we can add the values we already know, remembering that they act the opposite direction at the other end.



6 - Start with $\Sigma F\uparrow = \Sigma F\downarrow$ to find BD_V.

7 - We can now draw BD as a triangle of forces to use trigonometry and Pythagoras to solve BD and BD_H.



8 - Once we know BD_H, we can find BC using $\Sigma F\rightarrow = \Sigma F\leftarrow$.

9 - We then complete the table and state whether the member is a Strut (in compression) or a Tie (in tension).

Member	Magnitude	Nature
AB	910 N	Tie
AE	790 N	Strut
BD	1800 N	Strut
BC	2300 N	Tie

Simultaneous Equations

8. (continued) MARKS

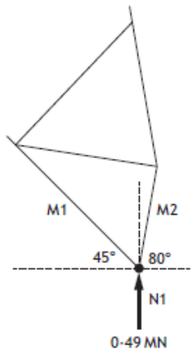
During the design phase a structural engineering company produced detailed information about the internal structure of the Kelpies.

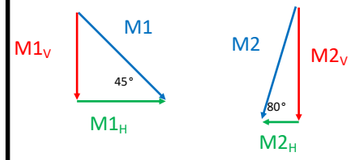
Detail from a proposed design for one of the Kelpies' steel support legs is shown.

Node N1 is in static equilibrium.

M2 is a strut.

(b) Calculate, using simultaneous equations, the magnitude of the forces in members M1 and M2, and state the nature of the internal force acting on M1. **5**





$$Sin45° = \frac{M1_V}{M1} \qquad Sin80° = \frac{M2_V}{M2}$$
$$M1_V = M1 \times Sin45° \qquad M2_V = M2 \times Sin80°$$
$$M1_V = M1 \times 0.707 \qquad M2_V = M2 \times 0.984$$

$$Cos45° = \frac{M1_H}{M1} \qquad Cos80° = \frac{M2_H}{M2}$$
$$M1_H = M1 \times Cos45° \qquad M2_H = M2 \times Cos80°$$
$$M1_H = M1 \times 0.707 \qquad M2_H = M2 \times 0.173$$

$\Sigma F\uparrow = \Sigma F\downarrow$

$$0.49 = (M_1 \times 0.707) + (M_2 \times 0.984)$$

$\Sigma F\rightarrow = \Sigma F\leftarrow$

$$(M_1 \times 0.707) = (M_2 \times 0.173)$$

Find the common factor, in this case (M_1 x 0.707) and substitute the value into one of the equations to solve M2.

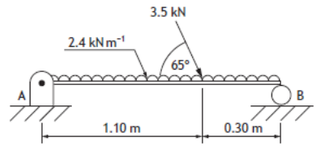
$$0.49 = (M_2 \times 0.173) + (M_2 \times 0.984)$$
$$0.49 = M_2(0.173 + 0.984)$$
$$0.49 = M_2 \times 1.157$$
$$\frac{0.49}{1.157} = M_2$$
$$M_2 = 0.42MN$$

Now subsititue the value of M2 into one of the equations to solve for M1.

$$(M_1 \times 0.707) = (0.42 \times 0.173)$$
$$M_1 \times 0.707 = 0.07266$$
$$M_1 = \frac{0.07266}{0.707}$$
$$M_1 = 0.1MN$$

7. Viewing platforms are commonplace in sports academies to allow for filming of training and games.

A beam used in the construction of the viewing platform is shown.



(a) (i) Calculate the magnitude of the reaction at B. **3**

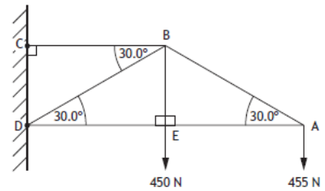
7. (a) (continued)

(ii) Calculate the magnitude and direction of the reaction at A. **4**

8. (continued)

Due to the rapid expansion of the construction site, additional floodlights are to be installed.

The diagram below shows part of the design for the frame that supports the floodlights.



(c) Calculate, using nodal analysis at nodes A and B, the magnitude and nature of the forces in members AB, AE, BD, and BC.

Member BE is a 450 N tie.

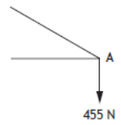
Complete the table below. Show all working and final units. **8**

Member	Magnitude	Nature
AB		tie
AE		strut
BD		
BC		

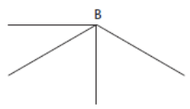
8. (c) (continued)

Space for calculations

node A

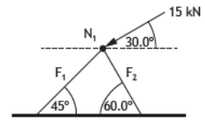


node B



11. (continued)

The structural design for the frame used to support the boom is shown.



Node N_1 is in static equilibrium.

F_1 is a strut, and F_2 is a tie.

(c) (i) Write, in its simplest form, the equation for the vertical forces acting on N_1 (include all forces and their angles). **1**

(ii) Write, in its simplest form, the equation for the horizontal forces acting on N_1 (include all forces and their angles). **1**

11. (c) (continued)

(iii) Calculate the magnitude of the forces in members F_1 and F_2. **3**

(c)	(i)	$\Sigma F_\downarrow = 0$ $F_1\sin45\downarrow = 15\sin30\downarrow + F_2\sin60\downarrow$ $F_1\sin45 - F_2\sin60 = 15\sin30$	1	Any form of presentation of equation shown is acceptable. 1 mark for equation based on vertical force components.
	(ii)	$\Sigma F_\rightarrow = 0$ $F_1\cos45\rightarrow + F_2\cos60\rightarrow = 15\cos30\leftarrow$ $F_1\cos45 + F_2\cos60 = 15\cos30$	1	Any form of presentation of equation shown is acceptable. 1 mark for equation based on horizontal force components.
	(iii)	Vertical components: $F_1\sin45 - F_2\sin60 = 15\sin30$ Horizontal components: $F_1\cos45 + F_2\cos60 = 15\cos30$ Vertical forces - Horizontal forces $F_2 = (-\sin60 - \cos60) =$ $15\sin30 - 15\cos30$ $F_2 = (15\sin30 - 15\cos30) / (-\sin60 - \cos60)$ $F_2 = 4.019237886$ $F_2 = 4.0$ kN (2 sf) $F_1\sin45 - 4.0\sin60 = 15\sin30$ $F_1 = 15.50558\overline{12}$ $F_1 = 16$kN (2 sf)	3	1 mark for appropriate substitution (other correct methods are acceptable). 1 mark for F_2 with correct unit. 1 mark for F_1 with correct unit.

(c)	(i)	$\Sigma F_\downarrow = 0$ $AB\sin30 = 455$ AB = 910 N (2 sf)	1	1 mark for AB.
	(ii)	$\Sigma F_\rightarrow = 0$ $AE = 910\cos30 = 788.0831174$ N AE = 790 N (2 sf)	1	1 mark for AE.
	(iii)	Node A $\Sigma F_\downarrow = 0$ $AB\sin30 = 455$ AB = 910 N (2 sf) $\Sigma F_\rightarrow = 0$ $AE = 910\cos30 = 788.0831174$ N AE = 790 N (2 sf) Node B $\Sigma F_\downarrow = 0$ $BD\sin30 = 910\sin30 + 450$ BD = 1810 N BD = 1800 N (2 sf) BD is a strut $\Sigma F_\rightarrow = 0$ $BC = 1800\cos30 + 910\cos30$ BC = 2346.928844 BC = 2300N (2 sf) BC is a tie	8	1 mark for AB. 1 mark for substitution. 1 mark for BD. 1 mark for nature. 1 mark for substitution. 1 mark for BC. 1 mark for nature.

Member	Magnitude	Nature		
AB	910 N	Tie		
AE	790 N	Strut		
BD	1800 N	Strut		
BC	2300 N	Tie		

7.	(a)	(i)	UDL = 2.4 × 1.4 UDL = 3.36 kN	3	1 mark for UDL point load equivalent (no unit required). 1 mark for substitution. 1 mark for calculating B with correct unit.
			Moments @ A CWM = ACWM (3.36 × 0.7) + (3.5sin65 × 1.1) = B × 1.4 B (vertical) = 4.172346414 = 4.2 kN (2 sf)		
		(ii)	$\Sigma F_\downarrow = 0$ $V_A + 4.2 = 3.5\sin65 + 3.36$ $V_A = 2.332077255$ kN	4	1 mark for calculating V_A (no unit required). 1 mark for calculating H_A (no unit required). 1 mark for calculating R_A with correct unit. 1 mark for calculating direction with correct unit.
			$\Sigma F_\rightarrow = 0$ $3.5\cos65 = H_A = 1.479163916$ $H_A = 1.479163916$ kN $R_A = \sqrt{(2.332077255^2 + 1.479163916^2)}$ $R_A = 2.761613697$ $R_A = 2.8$ kN (2 sf) $\theta = \tan^{-1}(2.332077255 / 1.479163916)$ $\theta = 57.61431725$ $\theta = 58°$ (2 sf)		