Exercise 13

MECHANICS

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1. Give the definition of a beam.

A beam is a single rigid length of material that is supported horizontally and used to carry or support vertical masses.

2. Give the definition of a cantilever.

A cantilever is a single beam which is attached at one end while the other end can move.

3. Give the definition of a simply supported beam.

A simply supported beam is a beam that rests on two supports and is free to bend under the influence of a force.

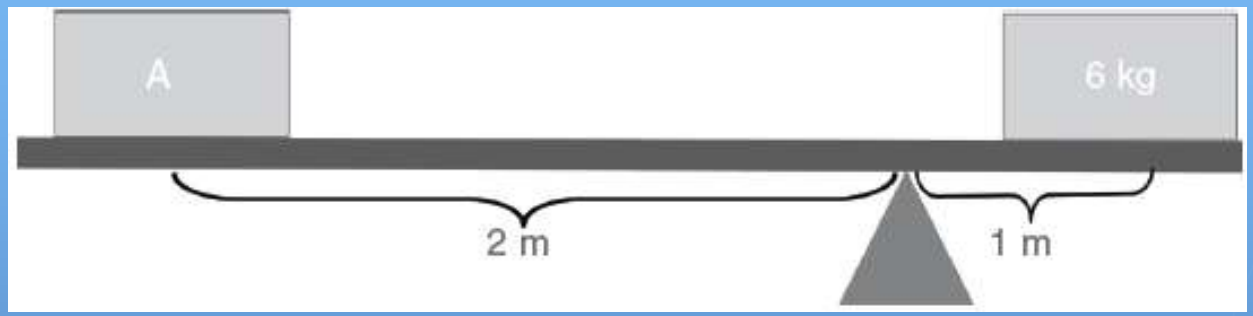
4. Give the definition of a shear force.

A shear force is the algebraic sum of all the perpendicular external forces on a beam on one side of a section of the beam.

5. Give the definition of torque.

Torque is the turning effect of a force around a point.

6 In the sketch is a balanced see-saw:

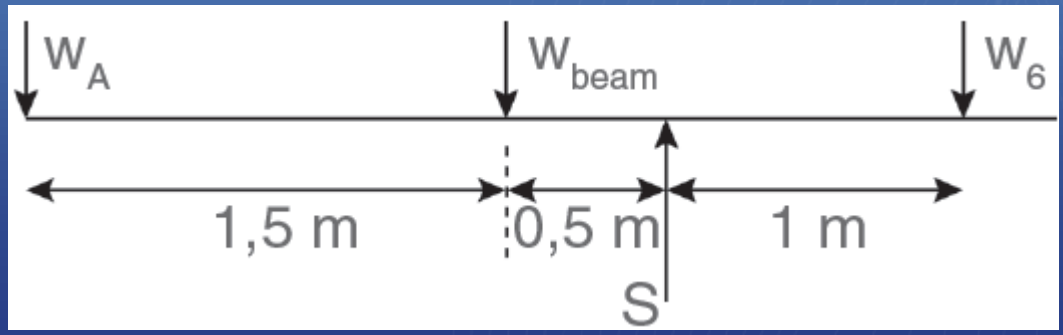


6.1 Calculate the clockwise moment.

$\tau = F \cdot r_{\perp}$

$\tau = (6 \times 9{,}8)(1)$

$\tau = 58{,}8$ N·m kloksgewys



6.2 Calculate the mass of A if the bar of the see-saw has a mass of 4 kg.

The see-saw is in equilibrium, therefore:

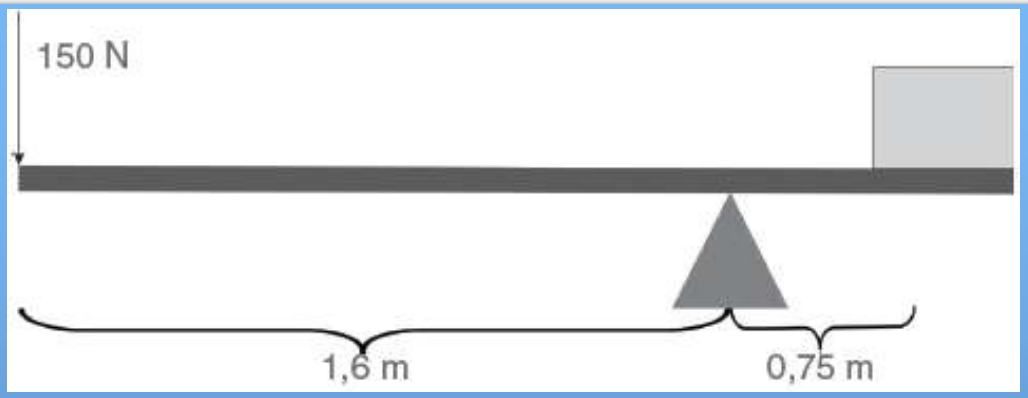
$$\Sigma\tau_{clockwise} = \Sigma\tau_{anticlockwise}$$

$$\therefore \tau_A + \tau_W = 58,8$$

$$(m \times 9,8)(2) + (4 \times 9,8)(0,5) = 58,8$$

$$m = 2 \text{ kg}$$

7. Mandla lifts a crate with the help of a lever, as indicated in the sketch. He uses a downward force of 150 N. The mass of the lever is 2,5 kg.



Calculate the mass of the crate.

$$\Sigma\tau_{clockwise} = \Sigma\tau_{anticlockwise}$$

$$\tau_W + \tau_{150} = \tau_{crate}$$

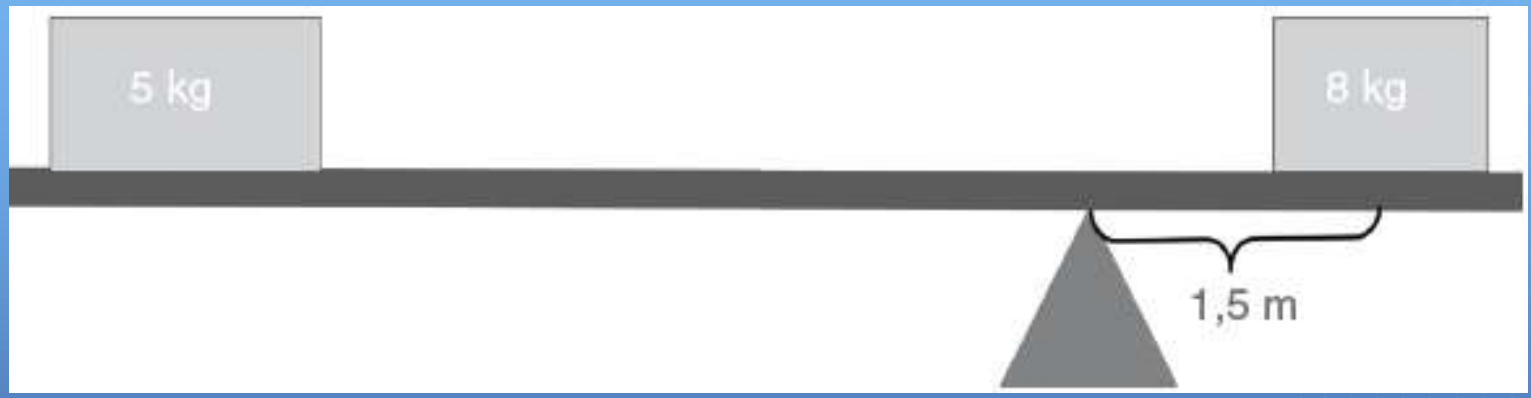
$$F_W \cdot r_\perp + F_{150} \cdot r_\perp = F_{crate} \cdot r_\perp$$

$$(2{,}5 \times 9{,}8)(0{,}425) + 150 \times 1{,}6 = (m \times 9{,}8) \times 0{,}75$$

$$m = \frac{240 + 10{,}41}{7{,}35}$$

$$m = 34{,}07 \text{ kg}$$

8 In the sketch is a balanced scale:



8.1 Calculate the mass of the crate.

$\tau = F \cdot r_{\perp}$

$\tau = (8 \times 9{,}8)(1{,}5)$

$\tau = 117{,}6$ N·m clockwise

8.2 Ignore the mass of the balance beam and calculate how far the 5 kg crate is from the fulcrum.

The scale is in equilibrium, therefore:

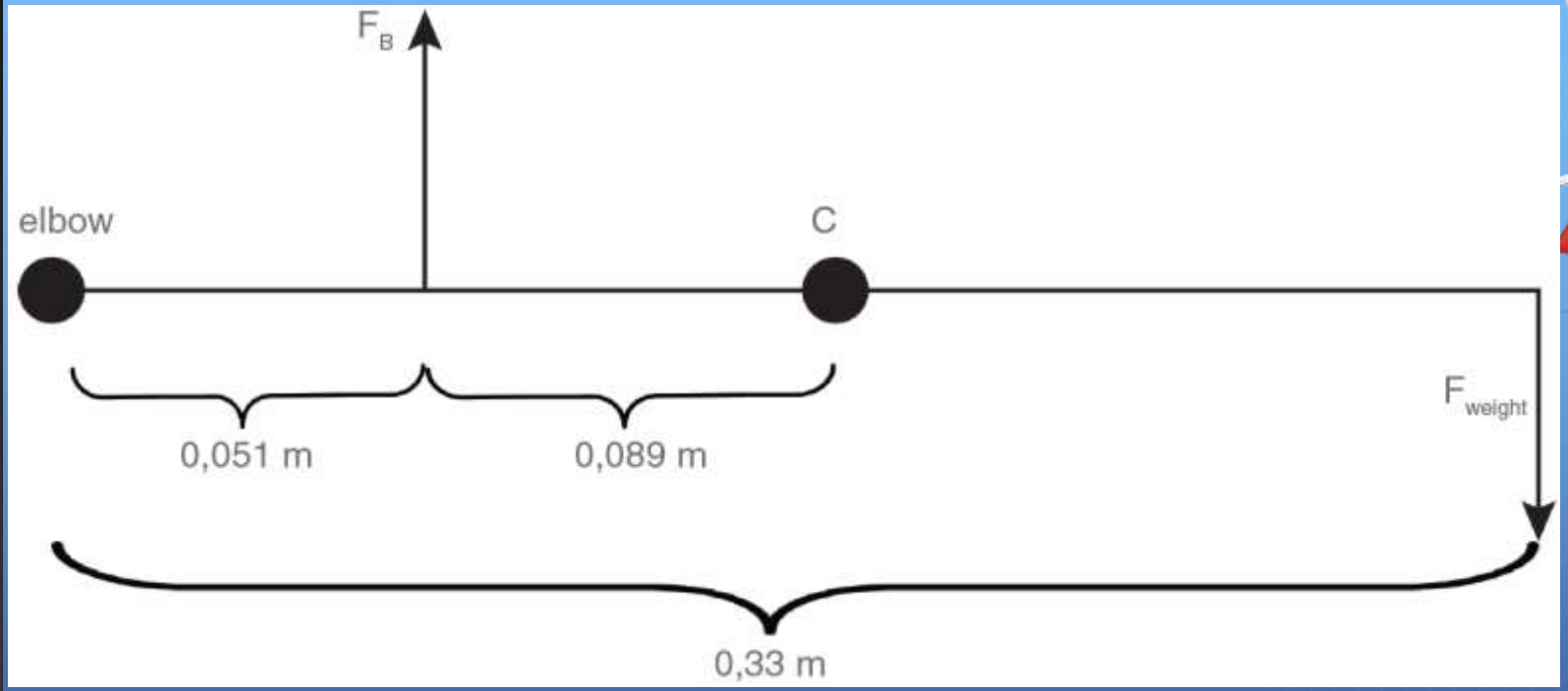
$$\Sigma\tau_{clockwise} = \Sigma\tau_{anticlockwise}$$

$$\therefore F \cdot r_{\perp} = 117,6$$

$$(5 \times 9,8)r = 117,6$$

$$r = 2,4 \text{ m}$$

9 An athlete prepares for a fitness competition. In order to develop the upper arm muscles, she starts with an exercise program. The program involves holding a 175 N weight in the palm of her hand for a few minutes at a time. The forearm weighs 24 N. In the diagram the elbow joint is the fulcrum. The weight of the forearm works through point C. The maximum force that is exerted due to the weight in the upper arm muscles, is represented by F_B.



9.1 What do you understand by the term moment of a force?

The moment of a force is the turning effect of the force around a specific point.

9.2 Calculate the force F_B that was exerted by the upper arm muscle and the reaction force F_E that the elbow joint exerts. Assume that the force F_E works downwards.

Choose clockwise as positive.

Also choose upward and to the right as positive.

$$\Sigma\tau_{clockwise} = \Sigma\tau_{anticlockwise}$$

$$\tau_{arm} + \tau_{weight} = \tau_B$$

$$F \cdot r_{\perp} + F \cdot r_{\perp} = F \cdot r_{\perp}$$

$$24 \times (0{,}051 + 0{,}089) + 175 \times 0{,}33 = FB \times 0{,}051$$

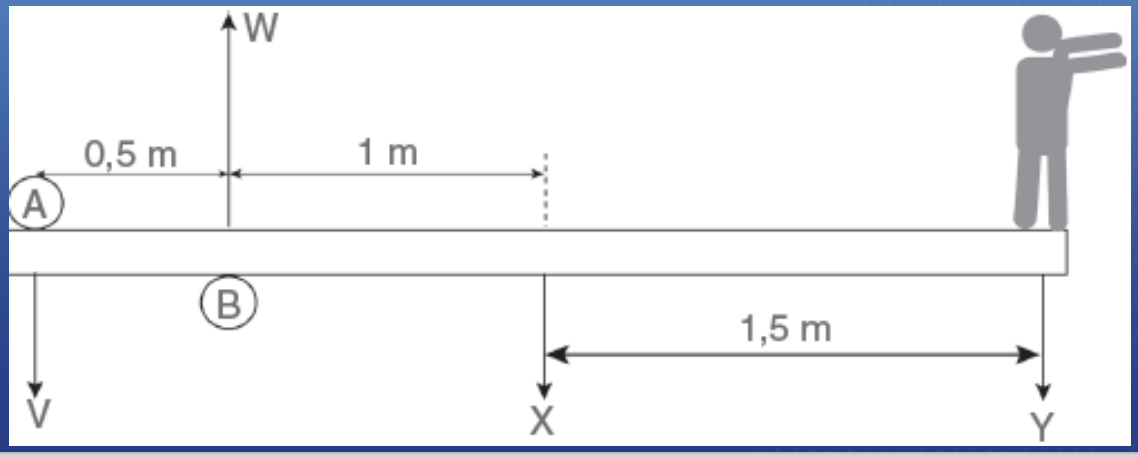
$$F_B = \frac{61{,}11}{0{,}051}$$

$F_B = 1\,198{,}24$ N downward

9.3 Is the direction assigned to the force on the elbow joint correct? Give a reason for your answer.

Yes, for equilibrium the net force of the system must be zero. The force exerted by the elbow is a reaction force to the other forces acting on the forearm.

10. A diver with a weight of 650 N stands at the end of a diving board with a length of 3 m. The diving board itself has a weight of 200 N. The diving board is attached with bolts at point A in the sketch and can rotate at point A. Furthermore, the diving board is supported by a fulcrum B. The forces acting on the diving board, are indicated in the sketch as V, W, X and Y.



10.2 Name the forces V, W, X and Y.

V: downward force of the bolts at A

W: upward force of the fulcrum at B

X: weight of the diving board 200 N

Y: weight of the diver 650 N

10.2 Calculate the magnitude of force W.

Choose the pivot as A.

Choose clockwise as positive.

Also choose upward and to the right as positive.

$$\Sigma\tau_{clockwise} = \Sigma\tau_{anticlockwise}$$

$$\tau_{650} + \tau_{200} = \tau_{W}$$

$$F \cdot r_{\perp} + F \cdot r_{\perp} = F \cdot r_{\perp}$$

$$650 \times 3 + 200 \times 1,5 = W \times 0,5$$

$$W = \frac{2\ 250}{0,5}$$

$$W = 4\ 500 \text{ N upward}$$

10.3 Subsequently, calculate the magnitude of force V.

Choose the fulcrum as B.

Choose clockwise as positive.

Also choose upward and to the right as positive.

$$\Sigma\tau_{clockwise} = \Sigma\tau_{anticlockwise}$$

$$\tau_{650} + \tau_{200} = \tau_{v}$$

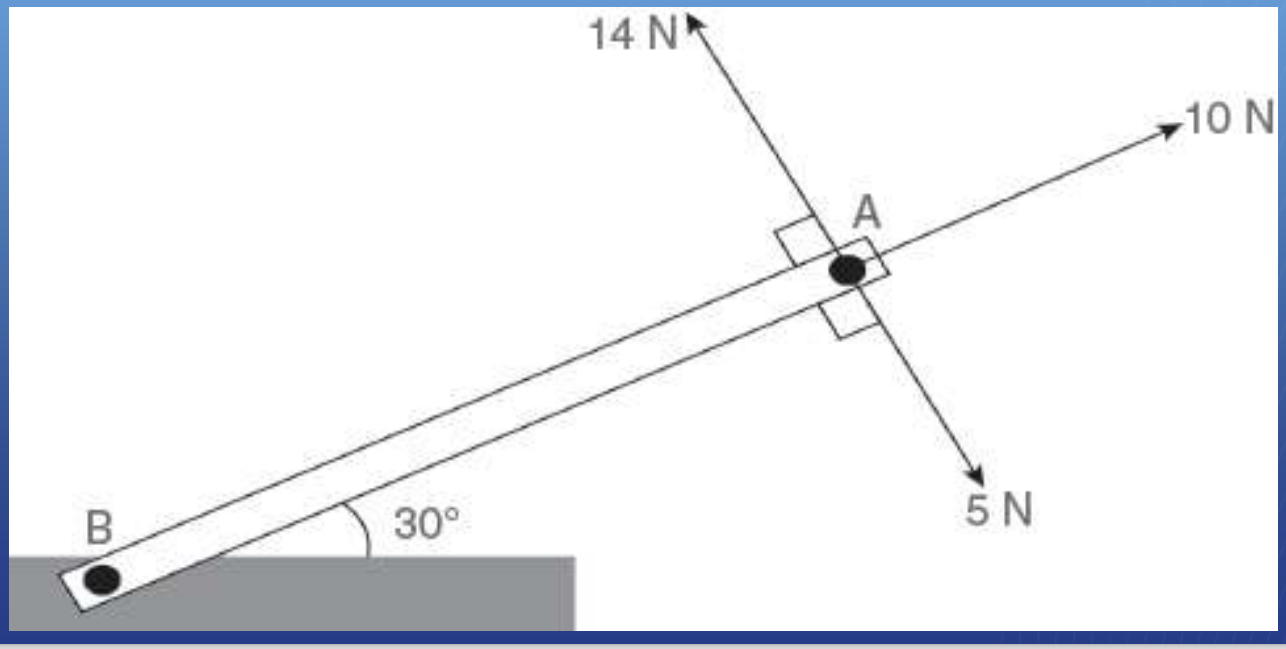
$$F \cdot r_{\perp} + F \cdot r_{\perp} = F \cdot r_{\perp}$$

$$650 \times 2{,}5 + 200 \times 1 = V \times 0{,}5$$

$$V = \frac{1\,825}{0{,}5}$$

$$V = 3\,650 \text{ N downward}$$

11 A pole with a length of 2,9 m is firmly anchored to the ground at position B as indicated in the diagram. Three forces with magnitudes and directions as shown in the diagram are exerted on the pole at position A.



11.1 What is the magnitude of the angle between the:

11.1.1 5 N force and the moment arm r of this force

90°

11.1.2 10 N force and the moment arm r of this force

0°

11.1.3 14 N force and the moment arm r of this force?

90°

11.2 Calculate the moment of each of the following forces:

11.2.1 5 N

5 N

$\tau = F \cdot r$

$\tau = 5 \times 2,9$

$\tau = 14,5$ N·m clockwise

11.2.2 10 N;

10 N; $\tau = 0$ N·m since the force is is not perpendicular to the moment arm r.

11.2.3 14 N

14 N

$\tau = \mathbf{F \cdot r}$

$\tau = \mathbf{14 \times 2,9}$

$\tau = \mathbf{40,6\ N \cdot m\ anticlockwise}$

11.3 Calculate the net torque of the lever.

$\Sigma\tau = \mathbf{14,5 + 0 + (-40,6)}$

$= \mathbf{-26,1\ N \cdot m \therefore 26,1\ N \cdot m\ anticlockwise}$