PHYSICS 534

ANSWERS

EXERCISE-17 Moments

ONNES

Heike Onnes was awarded the Nobel prize for physics in 1913 for his investigations into matter at very low temperatures.

The moment of a force (also known as the torque) is the tendency of the force to produce rotation. The point about which rotation takes place is called the ***fulcrum***. By definition, a fulcrum is an ***immovable*** reference point usually designated by a solid triangle (▲). The rotation of a moment is specified as either clock-wise or counter-clock-wise with reference to the fulcrum. Study the diagram below illustrating a force producing a counter-clockwise moment and clockwise moment. Note that the point of application of the force (left or right of the fulcrum) determines the rotation (clock-wise or counter-clock wise) of the moment.

The formula for the moment of a force is:

$$M = Fd_{\perp}$$

where: M is the moment (in newton-meters)
F is the force (in newtons)
$d_{\perp}$ is the perpendicular distance from the force to the fulcrum (in meters)

The Law of Moments says that:

"When a system is in equilibrium, the ***sum*** of all the moments rotating a system clockwise equals the ***sum*** of all the moments rotating the system counter-clock wise." Or, mathematically:

Σ clockwise moments = Σ counter-clockwise moments

or Σ cwm = Σ ccwm

↳ ***Important***: Whenever a system is in equilibrium, the Law of Moments applies about any fulcrum (point) in the system regardless of the location of the fulcrum.

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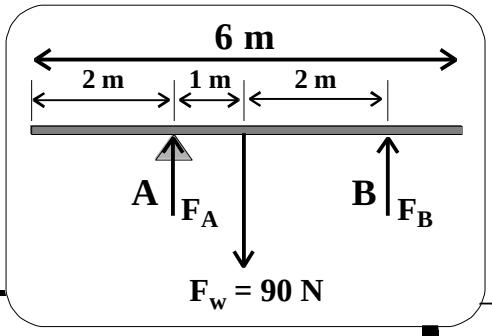
1. Define in your own words "the moment of a force".

The tendency of a force to produce rotation.

2. Two men, A and B, support a ***uniform*** plank on their shoulders. The plank is 6 m long and has a mass of 9 kg. Calculate how much of the weight each man carries if the plank extends 2 m beyond A's shoulder and 1 m beyond B's shoulder. [60 N] [30 N]



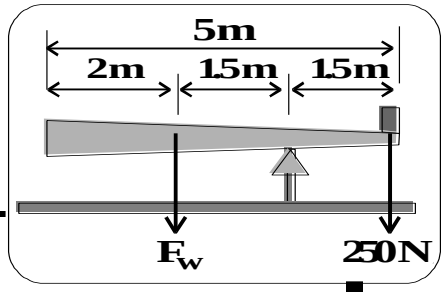
Take moments at point A.

$\because \ \Sigma \text{ cwm} = \Sigma \text{ ccwm}$

$$(90\text{ N})(1\text{ m}) = F_B(3\text{ m}) \quad \text{or} \quad F_B = \frac{(90\text{ N})(1\text{ m})}{3\text{ m}} = 30\text{ N}$$

$\therefore \ F_A = 90\text{ N} - 30\text{ N} = 60\text{ N}$

3. A ***tapered*** plank which is 5 m long has its center of gravity 2 m from the thick end. It is balanced horizontally on a block 1.5 m from the thin end when a weight of 250 N is placed at the thin end. What is the weight of the plank? [250 N]



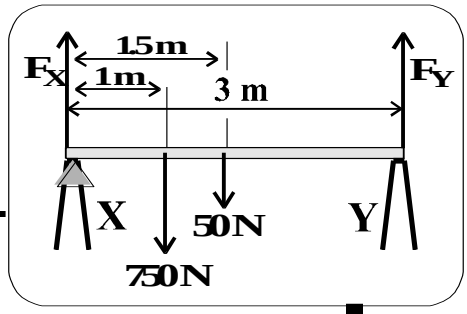
Take moments about point of balance.

$\because \ \Sigma \text{ cwm} = \Sigma \text{ ccwm}$

$\therefore \ (250\text{ N})(1.5\text{ m}) = F_w(1.5\text{ m})$

$$F_w = \frac{(250\text{ N})(1.5\text{ m})}{1.5\text{ m}} = 250\text{ N}$$

4. A worker weighing 750 N stands on a ***uniform*** plank 3 m long that is supported by two step-ladders X and Y. The plank weighs 50 N. If the worker stands 1 m from one end of the plank, what force is supported by each step ladder. [525 N] [275 N]



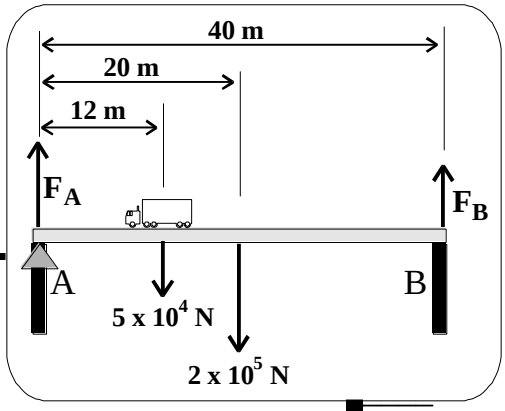
Take moments about point X.

$\because \ \Sigma \text{ cwm} = \Sigma \text{ ccwm}$

$\therefore \ (750\text{ N})(1\text{ m}) + (50\text{ N})(1.5\text{ m}) = F_Y(3\text{ m})$

$$F_Y = \frac{825\text{ N}\cdot\text{m}}{3\text{ m}} = 275\text{ N} \quad \therefore \ F_X = 800\text{ N} - 275\text{ N} = 525\text{ N}$$

5. A bridge is supported by two columns, A and B. The bridge is 40 m long and weighs 2 x 10^5 N. A truck weighing 5 x 10^4 N is 12 m from column-A. Calculate the upward force exerted by each column. [1.35 x 10^5 N] [1.15 x 10^5 N]



Take moments about point A.

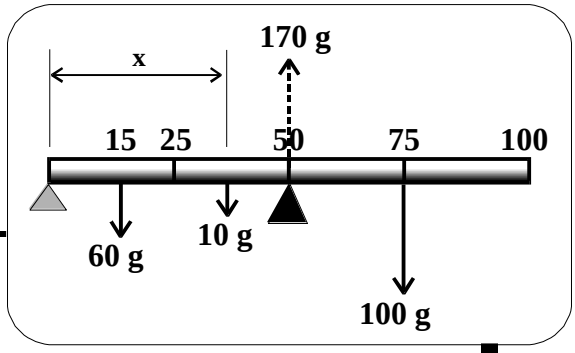
$\because \Sigma \text{ cwm} = \Sigma \text{ ccwm}$

$\therefore\ (5\times10^4\text{ N})(12\text{ m}) + (2\times10^5\text{ N})(20\text{ m}) = F_B(40\text{ m})$

$$F_B = \frac{(5\times10^4\text{ N})(12\text{ m}) + (2\times10^5\text{ N})(20\text{ m})}{40\text{ m}} = 1.15\times10^5\text{ N}$$

$$F_A = 2.5\times10^5\text{ N} - 1.15\times10^5\text{ N} = 1.35\times10^5\text{ N}$$

6. A uniform meter stick is supported at its center. A load of 60 g hangs at the 15 cm point and a load of 100 g hangs at the 75 cm mark. Where should a 10 g mass be hung so as to produce equilibrium? [10 cm]



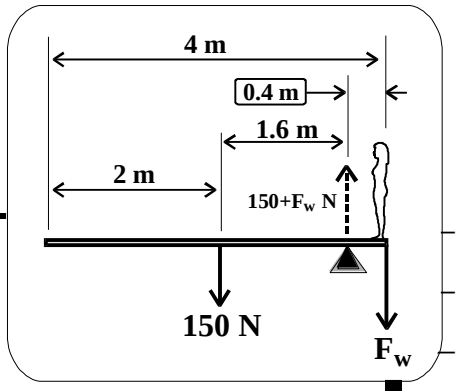
Take moments from the zero point and treat the grams as forces.

$\because\ \Sigma \text{ cwm} = \Sigma \text{ ccwm}$

$\therefore\ (60\text{ g})(15\text{ cm}) + (10\text{ g})(x) + (100\text{ g})(75\text{ cm}) = (170\text{ g})(50\text{ cm})$

$$x = \frac{(170\text{ g})(50\text{ cm}) - (60\text{ g})(15\text{ cm}) - (100\text{ g})(75\text{ cm})}{10\text{ g}} = 10\text{ cm}$$

7. A ***uniform*** plank 4 m long has a mass of 15 kg. A girl finds that the plank will balance if supported by a fulcrum 40 cm from ***her*** end. Find the weight of the girl. [600 N]



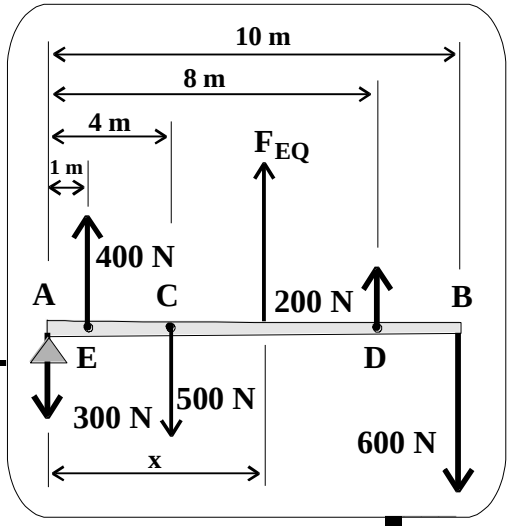
Take moments about the point of balance.

$\because\ \Sigma \text{ cwm} = \Sigma \text{ ccwm}$

$(F_w)(0.4\text{ m}) = (150\text{ N})(1.6\text{ m})$

$$\therefore\ F_w = \frac{(150\text{ N})(1.6\text{ m})}{0.4\text{ m}} = 600\text{ N}$$

8. A plank, AB, is 10 m long and has a mass of 50 kg. Its center of gravity, C, is 4 m from end A. At A, a force of 300 N acts downward. At end B, a force of 600 N acts downward. At D, 2 m from end B, a force of 200 N acts upward. At E, 1 m from end A, a force of 400 N acts upward. Find:



❶ The force required to produce equilibrium. [800 N

Since the system is at rest, $F_R = 0$

$\therefore$ Σ Forces up $= \Sigma$ Forces down

$400\text{ N} + F_{EQ} + 200\text{ N} = 300\text{ N} + 500\text{ N} + 600\text{ N}$

$\therefore \quad F_{EQ} = 800\text{ N North}$

❷ The point of application of the equilibriant force (from end-A): [7.5 m]

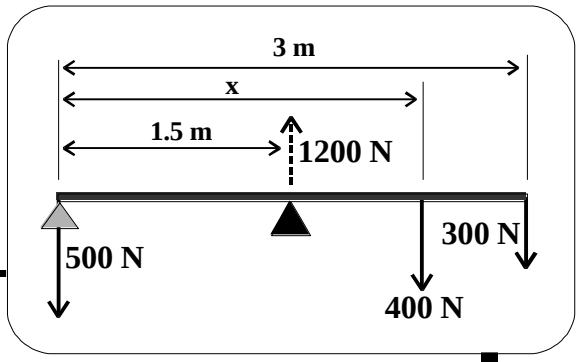
Take moments about point A.

$\because$ Σ cwm $= \Sigma$ ccwm

$\therefore$ $(500\text{ N})(4\text{ m}) + (600\text{ N})(10\text{ m}) = (400)(1\text{ m}) + (800\text{ N})(x) + (200\text{ N})(8\text{ m})$

$(800\text{ N})x = 2800\text{ N}\cdot\text{m} \qquad \therefore \; x = \dfrac{2800\text{ N}\cdot\text{m}}{800\text{ N}} = 7.5\text{ m}$

9. A 30 kg boy and a 50 kg boy sit at opposite ends of a 3 m long seesaw which is pivoted at its center. Where must a 40 kg boy sit, from the 50 kg boy, in order to balance the seesaw? [2.25 m]



Take moments about the 500 N boy.

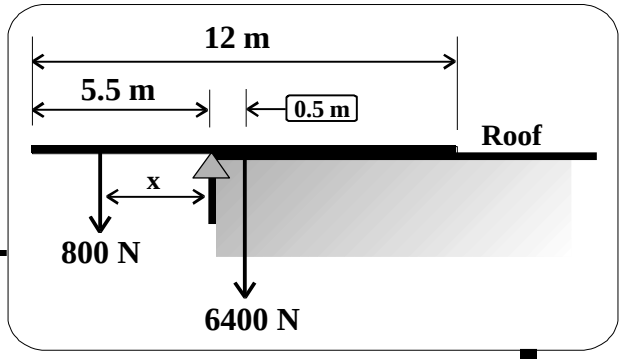
$\because$ Σ cwm $= \Sigma$ ccwm

$(400\text{ N})(x) + (300\text{ N})(3\text{ m}) = (1200\text{ N})(1.5\text{ m})$

$\therefore \quad (400\text{ N})(x) = (1200\text{ N})(1.5\text{ m}) - (300\text{ N})(3\text{ m})$

$$x = \frac{(1200\text{ N})(1.5\text{ m}) - (300\text{ N})(3\text{ m})}{400\text{ N}} = \frac{900\text{ N}\cdot\text{m}}{400\text{ N}} = 2.25\text{ m}$$

10. A 640 kg iron beam, 12 m long, rests on the roof of a building such that one end overhangs the roof by 5.5 m. How far ***from the roof*** can an 80 kg man walk out on the beam without falling? [4 m]



Take moments from edge of roof.

$\because \Sigma \text{ cwm} = \Sigma \text{ ccwm}$

$\therefore \quad (6400 \text{ N})(0.5 \text{ m}) = (800 \text{ N})(x)$

$$x = \frac{(6400 \text{ N})(0.5 \text{ m})}{(800 \text{ N})} = 4 \text{ m}$$

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