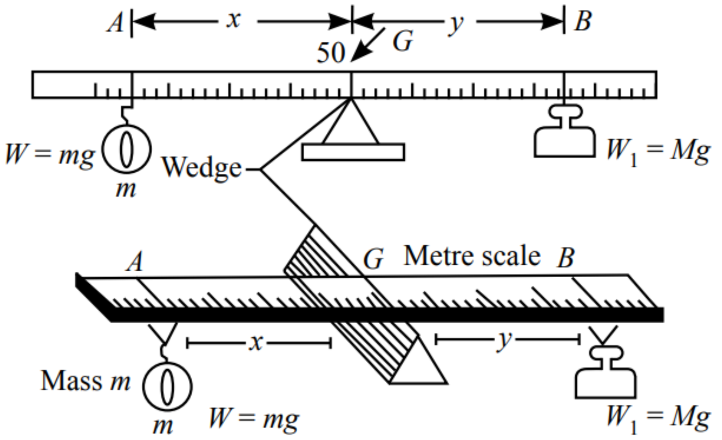
Experiment - 4 : Metre Scale - The mass of a given object by the principle of moments.

Principle

A metre rod is supported at its centre of gravity on a wedge as shown.



An unknown mass m of weight mg is suspended from the left arm at a distance x and a known standard mass M of weight Mg is suspended from the right arm at a distance y. The distances are measured from the knife edge. For equilibrium, the moments of forces about the fulcrum or knife edge are equal, so we have,

$$mg \times x = Mg \times y \Rightarrow m = M\left(\frac{y}{x}\right)$$

Approach

The sharp wedge of a wooden block is placed, so that there is sufficient space below the scale for hanging weights or masses. Then the scale is placed on the wedge with its graduated side facing up.

The position of the scale on the wedge is adjusted such that its length is perpendicular to the edge of the wedge and the scale remains balanced in the horizontal position, when no weights are suspended. This is the position of equilibrium of the scale. This is possible when centre of gravity of the scale is just above the wedge. This position of the scale on the wedge is noted. Two loops of cotton thread are made and with their help the unknown mass m and known mass M are suspended on either side, such that the scale gets balanced again. The position of unknown mass m can be called A and AG = x can have different values such as 10 cm, 20 cm etc., for different observations. The known mass's position for balance can be called GB = y and can be observed.

MCQs Corner

Experiment – 4

17. In the experiment of balancing moments, suppose the fulcrum is at the 40 cm mark, and a known mass of 2 kg is used on the longer arm. The greatest mass of m which can be balanced against 2 kg such that the minimum distance of either of the masses from the fulcrum is atleast 10 cm. (Neglect mass of metre scale)

(a) 4 kg (b) 6 kg (c) 8 kg (d) 12 kg

18. The wedge is kept below the 60 cm mark on the meter scale. Known masses of 1 kg and 2 kg are hung at the 20 cm and 30 cm mark respectively. Where will a 4 kg mass be hung on the metre scale to balance it ? (Neglect mass of metre scale)

(a) 90 cm (b) 70 cm (c) 75 cm (d) 85 cm

19. When a metre scale is balanced above a wedge, 1 kg mass is hung at 10 cm mark and a 2 kg mass is hung at the 85 cm mark. To which mark on the meter scale, the fulcrum be shifted (Neglect mass of metre scale) to balance the scale ?

(a) 50 cm (b) 60 cm (c) 65 cm (d) 70 cm

20. In the scale and wedge experiment, m situated at x from the wedge and M is situated at y from wedge at equilibrium. Now, if $m < M$, then

(a) $x < y$ (b) $x > y$ (c) $x = y$ (d) nothing can be said about x and y unless values of m and M are known.

21. When the 'wedge and scale' experiment is performed at the equator, we get

$$m = M\left(\frac{y_e}{x_e}\right).$$

If the same experiment is performed at the poles, then (R_e and R_p are the equatorial and polar radius of the earth.)

(a) $m = M\left(\frac{y_e}{x_e}\right)\left(\frac{R_p}{R_e}\right)$ (b) $m = M\left(\frac{y_e}{x_e}\right)\cdot\left(\frac{R_p}{R_e}\right)^2$

(c) $m = M\left(\frac{y_e}{x_e}\right)$ (d) $m = M\left(\frac{y_e}{x_e}\right)\cdot\left(\frac{R_e}{R_p}\right)$

Answer Key

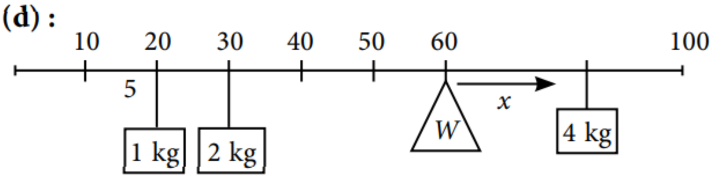
17. (d) 18. (d) 19. (b) 20. (b) 21. (c)

Hints & Explanation

17. (d) : $m = M\left(\frac{y}{x}\right)$, $m_{max} = (2 \text{ kg})\left(\frac{y_{max}}{x_{min}}\right)$

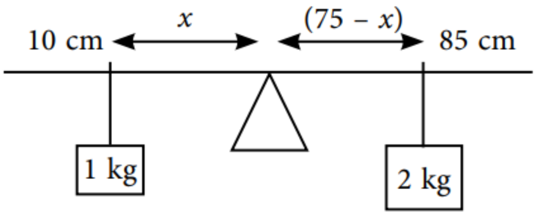
$\Rightarrow m_{max} = (2 \text{ kg})\left(\frac{60 \text{ cm}}{10 \text{ cm}}\right) = 12 \text{ kg}$

18. (d) :



The anti-clockwise moments due to 1 kg and 2 kg are
= (1 kg wt)(60 – 20)cm + (2 kg wt)(60 – 30) cm
= (1 kg wt)(40 cm) + (2 kg wt)(30 cm) = 100 kg wt cm
The clockwise moment due to 4 kg = 4 kg wt × x cm
$\Rightarrow$ 100 = $4x$ or x = 25 cm
So the 4 kg mass must be hung at (60 cm + x) = (60 cm + 25 cm) = 85 cm mark to balance the scale.

19. (b) :



Balancing moments $1x = 2(75 - x) \Rightarrow 3x = 150$ or $x = 50$ cm
$\Rightarrow$ Fulcrum is at 10 cm + 50 cm = 60 cm mark.

20. (b) : $m = M\left(\frac{y}{x}\right)$ as $m < M \Rightarrow y < x$.

21. (c) : When we take moments of force at equilibrium, the terms of g cancel on both sides.

$$mg \cdot x_e = Mg \cdot y_e$$
$$m = M \cdot \left(\frac{y_e}{x_e}\right)$$

The mass is independent of the gravity at that point, so mass at the poles will be same as mass at the equator.