ANSWERS

TORQUE (2)

1.In general, if you want to easily rotate an object about an axis, you want a large lever arm **d** and a large (preferably) perpendicular force **F**.

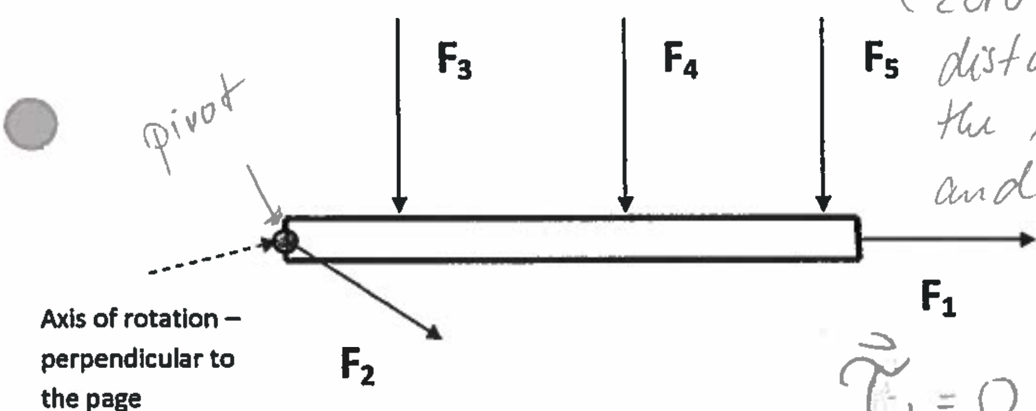
Forces F_1 to F_5 have the same magnitude.

a) Order the 5 different possibilities to apply force (1-5) according to decreasing magnitude of torque produced.

F_5, F_4, F_3, $F_2 = F_1$

b) Find the exact value of torque for F_1 and F_2. Support your answer.

$\vec{\tau}_1 = 0$ N·m [CCW]
because $d = 0$ m
(zero perpendicular distance between the line of action and the pivot point)



$\vec{\tau}_2 = 0$ N·m [CCW]
because $d = 0$ m

2. State the three quantities that affect the magnitude of torque:

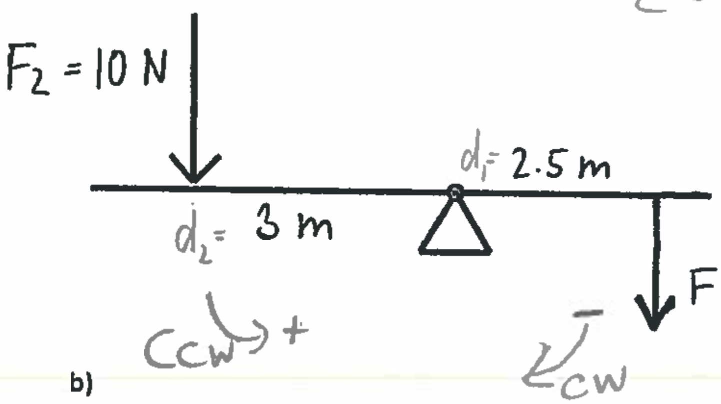
- magnitude of the applied force
- direction at which $\vec{F}_{app}$ acts
- distance between the pivot point and the point $\vec{F}_{app}$ acts

An object is in a rotational equilibrium when all torques add to zero ⇒ $\sum \vec{\tau} = 0 \ N{\cdot}m = \tau_{net} = 0 \ N{\cdot}m$

Torque and Rotational Equilibrium

1. Find the missing magnitude of force needed to ensure the rotational equilibrium $\sum \vec{\tau} = 0$

a)



$\sum \vec{\tau} = 0 \Rightarrow \vec{\tau}_1 + \vec{\tau}_2 = 0$

$-F_1 d_1 + F_2 d_2 = 0$

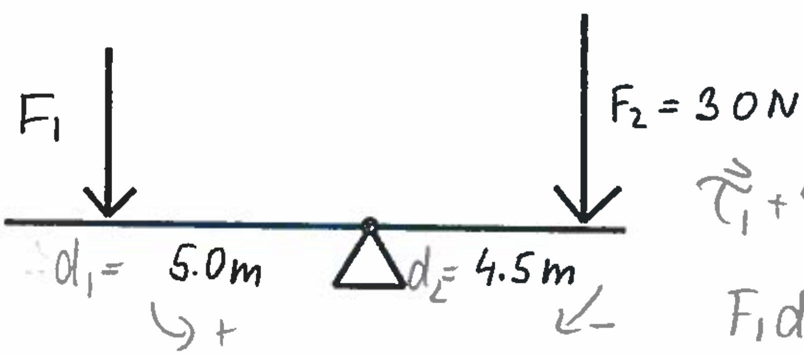
$-F_1 d_1 = -F_2 d_2$

$F_1 = \frac{-F_2 d_2}{-d_1}$

$F_1 = \frac{(10)(3)}{2.5}$

$F_1 = 12 \ N$

b)



$\vec{\tau}_1 + \vec{\tau}_2 = 0$

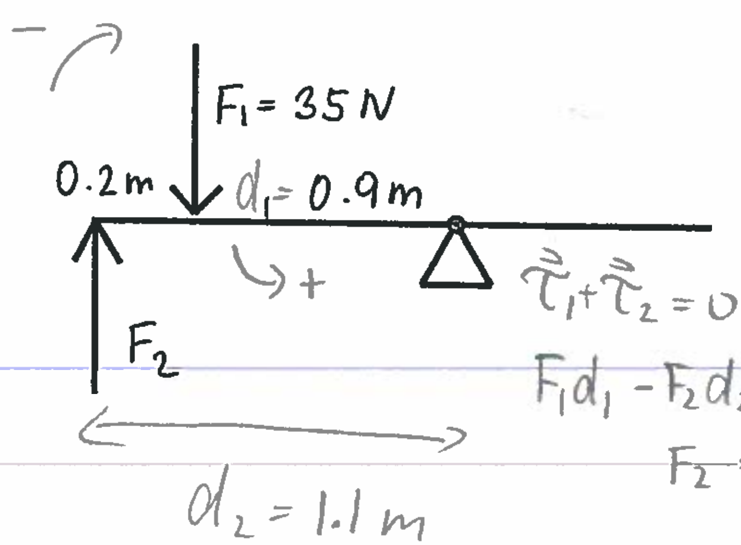
$F_1 d_1 - F_2 d_2 = 0$

$F_1 = \frac{F_2 d_2}{d_1}$

$F_1 = \frac{(30)(4.5)}{5.0}$

$F_1 = 27 \ N$

c)



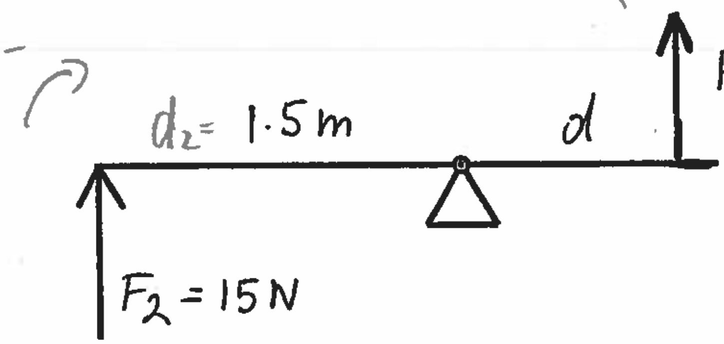
$\vec{\tau}_1 + \vec{\tau}_2 = 0$

$F_1 d_1 - F_2 d_2 = 0$

$F_2 = \frac{+F_1 d_1}{+d_2} = \frac{(35)(0.9)}{1.1} \doteq 29 \ N$

2. **Find the magnitude of lever arm necessary to ensure the rotational equilibrium** $\sum \vec{\tau} = 0$

a) $\vec{\tau}_1 + \vec{\tau}_2 = 0 \longrightarrow F_1 d_1 + (-F_2 d_2) = 0$



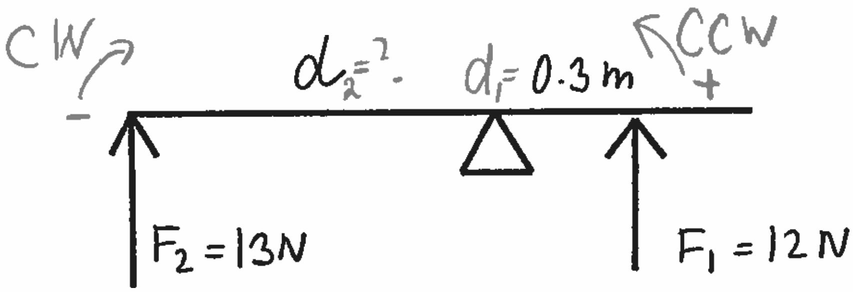
$d_1 = \frac{F_2 d_2}{F_1}$

$d_1 = \frac{(15)(1.5)}{10}$

$d_1 = 2.25\,m$

$\therefore d_1 \doteq 2.3\,m$

b) $\vec{\tau}_1 + \vec{\tau}_2 = 0 \longrightarrow F_1 d_1 + (-F_2 d_2) = 0$



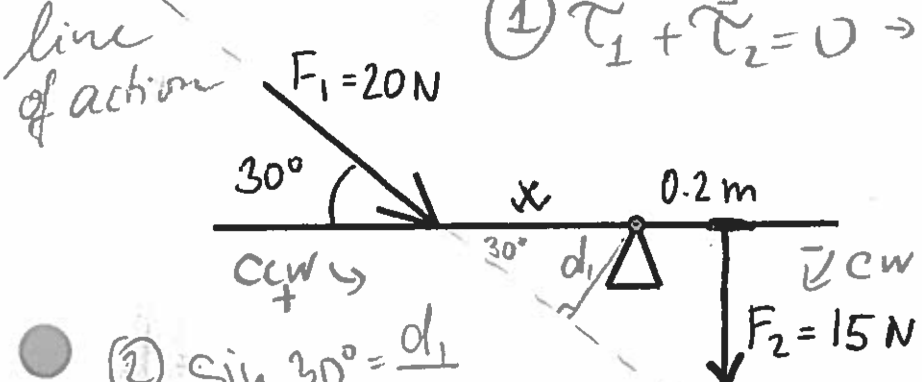
$d_2 = \frac{+F_1 d_1}{+F_2}$

$d_2 = \frac{(12)(0.3)}{13}$

$\therefore d_2 \doteq 0.28\,m$

c) **How far (x) relative to the fulcrum is F_1 applied to maintain the rotational equilibrium?**

① $\vec{\tau}_1 + \vec{\tau}_2 = 0 \Rightarrow F_1 d_1 + (-F_2 d_2) = 0$



$d_1 = \frac{F_2 d_2}{F_1}$

$d_1 = \frac{(15)(0.2)}{20}$

$d_1 = 0.15\,m$

② $\sin 30° = \frac{d_1}{x}$

$x = \frac{0.15}{\sin 30°} = 0.3\,m$

Find d_1:

$\sin 40° = \frac{d_1}{2.3}$

$d_1 = (2.3)(\sin 40°)$

$d_1 = 1.4784\ m$

Find d_2 using $\sum \vec{\tau} = 0\ N\cdot m$

$\vec{\tau}_1 + \vec{\tau}_2 = 0$

$F_1 d_1 + (-F_2 d_2) = 0$

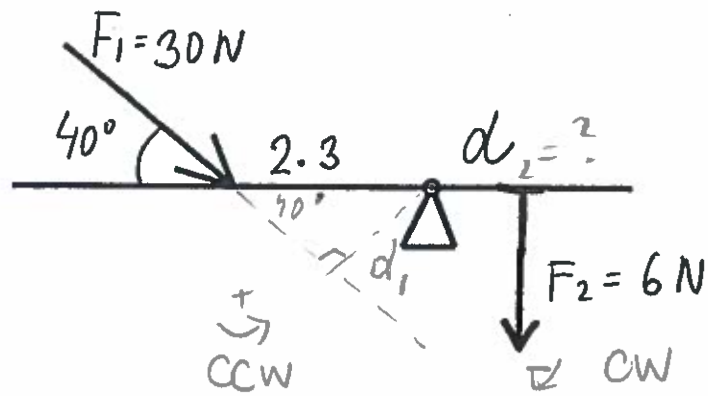
$-F_2 d_2 = -F_1 d_1$

$d_2 = \frac{+F_1 d_1}{+F_2}$

$d_2 = \frac{(30)(1.4784)}{6}$

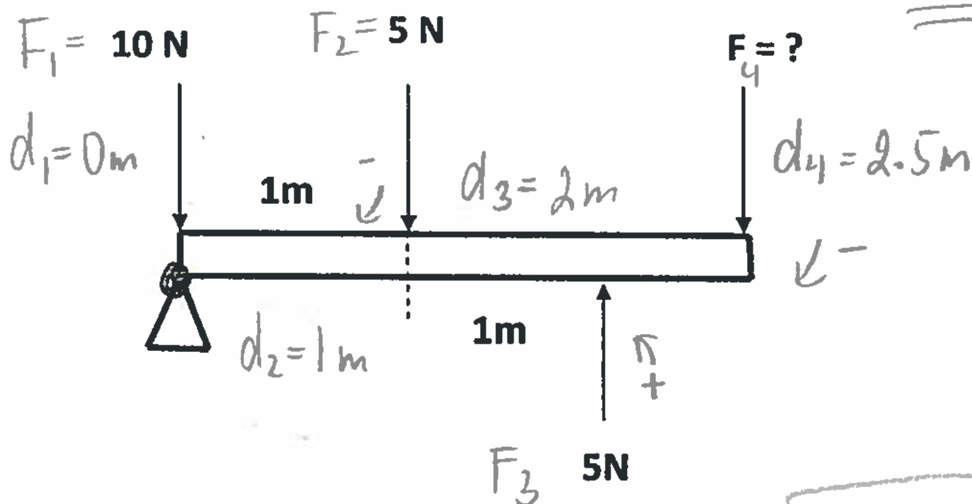
$\therefore d_2 \doteq 7.4\ m$

d)



3. Determine the unknown force to keep the beam in rotational equilibrium. The beam has length of 2.5m and its mass in negligible.

$\sum \vec{\tau} = 0\ N\cdot m$



$\rightarrow F_4 = 2\ N$

$\vec{\tau}_1 + \vec{\tau}_2 + \vec{\tau}_3 + \vec{\tau}_4 + 0$

$F_1 d_1 - F_2 d_2 + F_3 d_3 - F_4 d_4 = 0$

$(10)(0) - (5)(1) + (5)(2) - F_4(2.5) = 0$

$0 - 5 + 10 - 2.5 F_4 = 0$

$\frac{-2.5 F_4}{-2.5} = \frac{-5}{-2.5}$