Al-Mustaqbal University / College of Technical Engineering
Department Of Cyber Security Techniques Engineering
Class: 1st
Subject: General Physics / Code (UOMU0208024)
Lecturer: M.Sc. Afyaa Saad
1st/2nd term – Lecture No.4 & Lecture Name (Turning Effect of Forces)

(Turning Effect of Forces)

In previous weeks, we studied forces that cause linear motion (translation). However, a force can also cause an object to rotate. This "turning effect" is called the Moment of a Force or Torque.

Definition: Torque (τ) = is the tendency of a force to rotate an object about some axis.

- The Equation: $\tau = r F \sin\phi$

- r: The distance from the pivot point to the point where the force is applied.
- F: The magnitude of the applied force.
- ϕ: The angle between the force vector and the lever arm.

- SI Unit: Newton-meter (N. m).

Principle of Moments (Momentum Principle in Statics)

For a body to be in rotational equilibrium, the sum of the moments (torques) that try to rotate the body clockwise must equal the sum of the moments that try to rotate it counter-clockwise.

- Clockwise Torques (CW): Usually taken as negative.
- Counter-Clockwise Torques (CCW): Usually taken as positive.
- Principle: $\Sigma\tau = 0$

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Definition

For an object to be in rotational equilibrium about a certain point (Pivot), the following must be true:

The sum of the Counter-Clockwise (CCW) torques must equal the sum of the Clockwise (CW) torques.

Components of the Principle

To understand how this works, we look at three main elements:

1. Pivot (Fulcrum): The point about which the object rotates (e.g., the center of a seesaw).
2. Lever Arm (d): The perpendicular distance from the pivot to the line of action of the force.
3. Force (F): The weight or push applied to the object.

Mathematical Formula:

$\Sigma\tau = 0$

(F1*d1)= (F2*d2)

Imagine a ruler balanced at its center:

- Torque 1 ($\tau 1$) If you place a weight on the left side, it tries to rotate the ruler Counter-Clockwise.
- Torque 2 ($\tau 2$): To prevent this rotation, you must place a weight on the right side to create a Clockwise torque.
- When $\tau 1 = \tau 2$, the ruler stays horizontal and balanced.

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Note:

- The maximum torque is obtained when the force is perpendicular (90°) to the arm.
- If the force passes directly through the fulcrum, the moment equals zero (no matter how large the force is), because the distance (d) equals zero.
- Static equilibrium is not only that the forces cancel each other out (above and below), but that the "rotational tendencies" also cancel each other out.

Conditions of Equilibrium

According to Serway, for a rigid body to be in Static Equilibrium, two conditions must be met:

First Condition (Translational Equilibrium):

The vector sum of all external forces acting on the object must be zero. This means the object does not accelerate linearly.

Equation: $\Sigma F = 0 \quad \Rightarrow \quad \Sigma Fx = 0, \quad \Sigma Fy = 0$

Second Condition (Rotational Equilibrium):

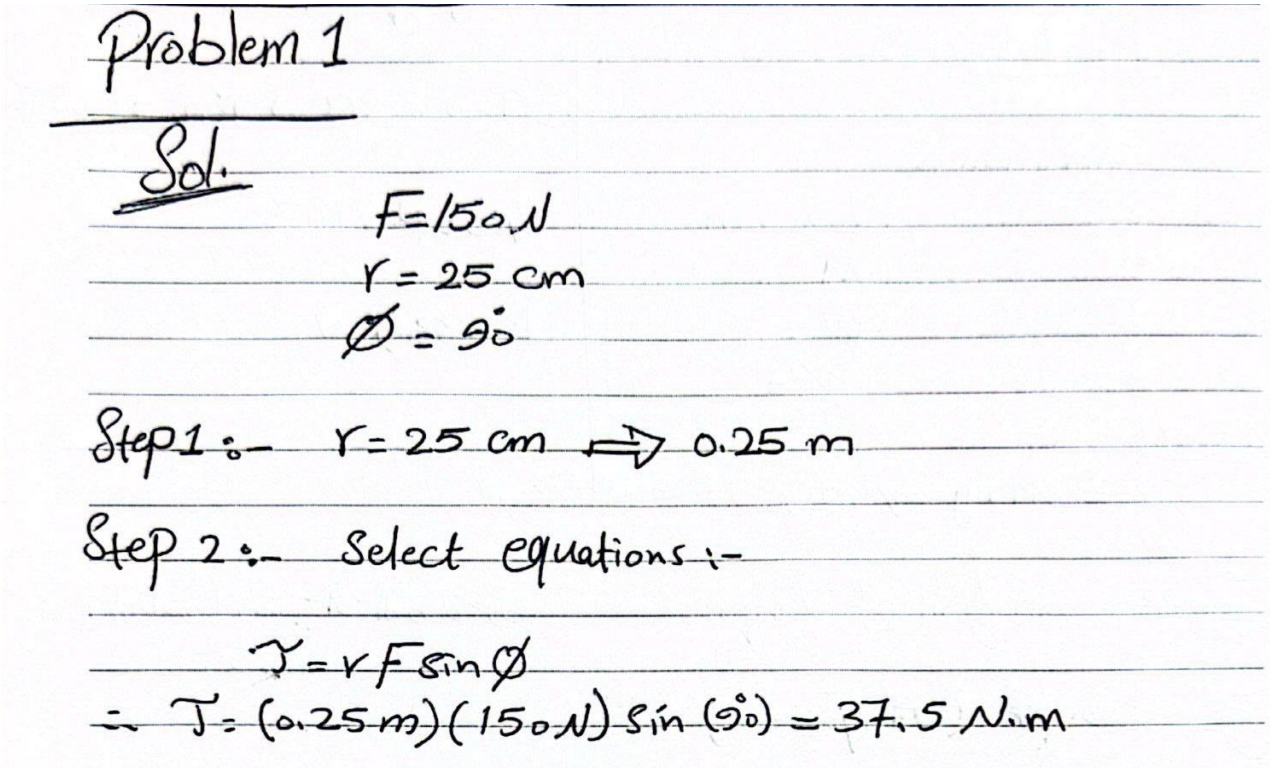
The vector sum of all external torques about any axis must be zero. This means the object does not have angular acceleration.

Equation: $\Sigma\tau = 0$

Mathematical problems

Problem 1:

A mechanic tightens a nut using a wrench that is 25 cm long. He exerts a force of 150 N perpendicular to the wrench. Calculate the torque applied to the nut.



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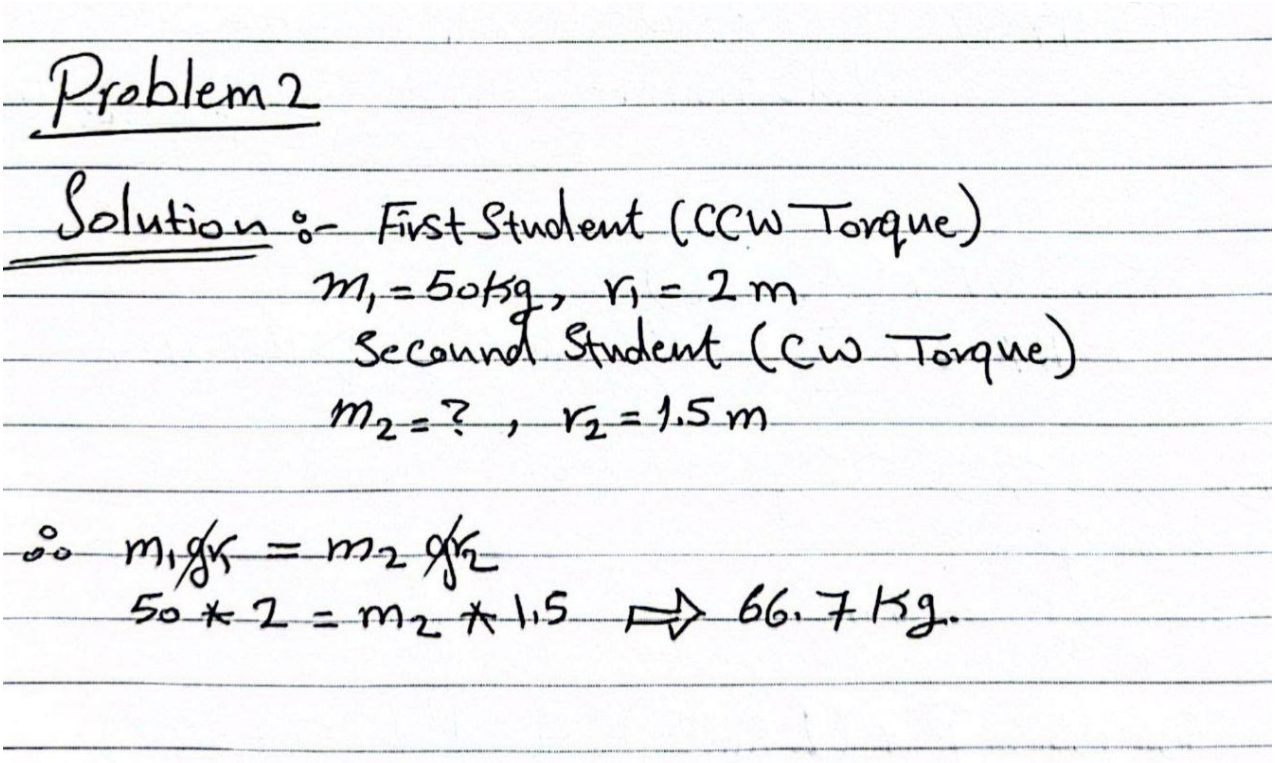
Problem 2

A 50 student sits at one end of a 4.0 m long uniform seesaw, which is pivoted at its center. A second student sits on the other side, 1.5 m from the pivot, and the seesaw is balanced. What is the mass of the second student?



Problem 3

A 5.0m long ladder of mass 12 kg leans against a smooth vertical wall, making an angle of 60° with the ground. Calculate the magnitude of the normal force exerted by the wall on the ladder.

Problem 3

Solution :-

L = 5m
M = 12 kg
W = ?
$\phi = 60^\circ$

Step1

$W = M * g \Rightarrow 12 * 9.8 = 117.6\ N$

Step2 analysis of Torque

Applying Equilibrium

$\Sigma T = 0 \Rightarrow$ CCW Torq. = CW To

$4.33P = 147$

$P = 33.9\ N$

(a) عزم الدوران (Tourque CW)

F = 117.6N.

المسافة من القاعدة الى المتوسط = 2.5 m

ذراع القوة (المسافة العمودية) بما ان الوزن شاقولي
نستأخذ المسافة الافقية

$T_{CW} = W * (\frac{1}{2} \cos 60^\circ)$
$= 117.6 * \frac{1}{2} (2.5)(\cos 60^\circ) \Rightarrow 147\ N.m$

(b) عزم قوة الجدار Tourque CCW :-

قوة الجدار P = ?

المسافة من القاعدة الى الجدار = 5 m

ذراع القوة $T_{CCW} = P * (L \sin\theta) \Rightarrow P * (5 * 0.866)$

$T_{CCW} \Rightarrow 4.33P$

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