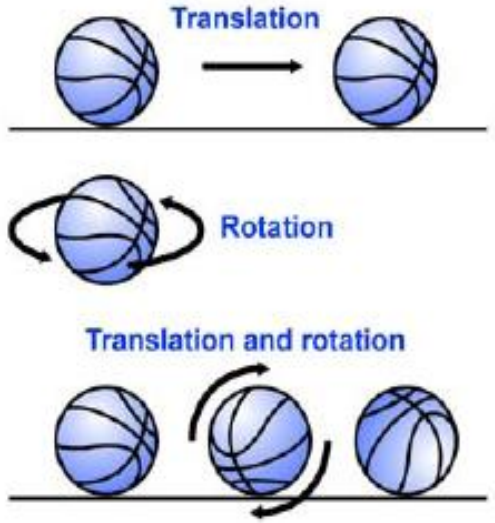
Chapter 11
Rotational Dynamics and Static Equilibrium

Units of Chapter 11

11-1 Torque

❖ Force is the action that creates changes **in a linear motion.**

❖ For **rotational motion**, the same force can cause different results.



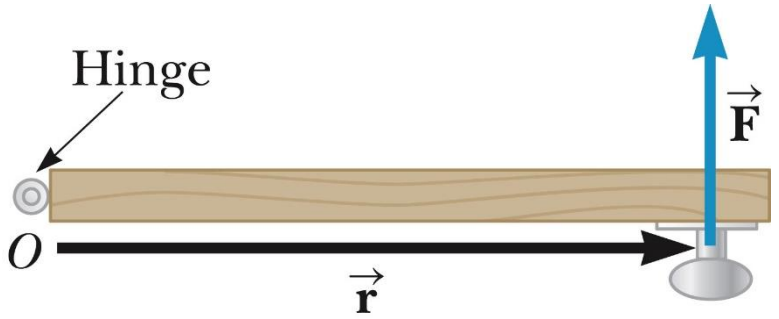
❖ A torque is an action that causes objects to **rotate**.

❖ A **torque** is required to **rotate** an object, just as a **force** is required to move an object in a linear motion.

11-1 Torque

Torque is created by **force**, but it also depends on where the **force i**s applied and the point about which the object **rotates.**

For example, a door pushed at its handle will easily turn and open, but a door pushed near its hinges will not move as easily. The force may be the same, but **the torque** is quite different.



Center of rotation

- **The point or line** about which an object turns is its **center of rotation**.

For example, a door's center of rotation is at its **hinges.**

- A force applied far from the center of rotation produces **a greater torque** than a force **applied close to the center of rotation**.

11-1 Torque

Calculation of Torque:

The torque (τ) created by a force is equal to the lever arm (*r*) times the magnitude of the force (*F*):

$$\boldsymbol{\tau = r \times F}$$

× : vector product

τ: torque , r: Level arm (m), F: Force (N)

Units: N.m

General Definition of Torque:

$$\boldsymbol{\tau = r(F \sin \theta)}$$

Exercise

To open the door, a tangential force F is applied at a distance r from the axis of rotation. If the minimum torque required to open the door is 3.1 N.m , what force must be applied if r is:

(a) 0.94 m? Answer: 3.3 N

(b) 0.35 m? Answer: 8.9 N

11-3 Zero Torque and Static Equilibrium

Static equilibrium occurs when an object is at rest – neither rotating nor translating.

Conditions for Static Equilibrium

For an extended object to be in static equilibrium, the following two conditions must be met:

(i) The net force acting on the object must be zero,

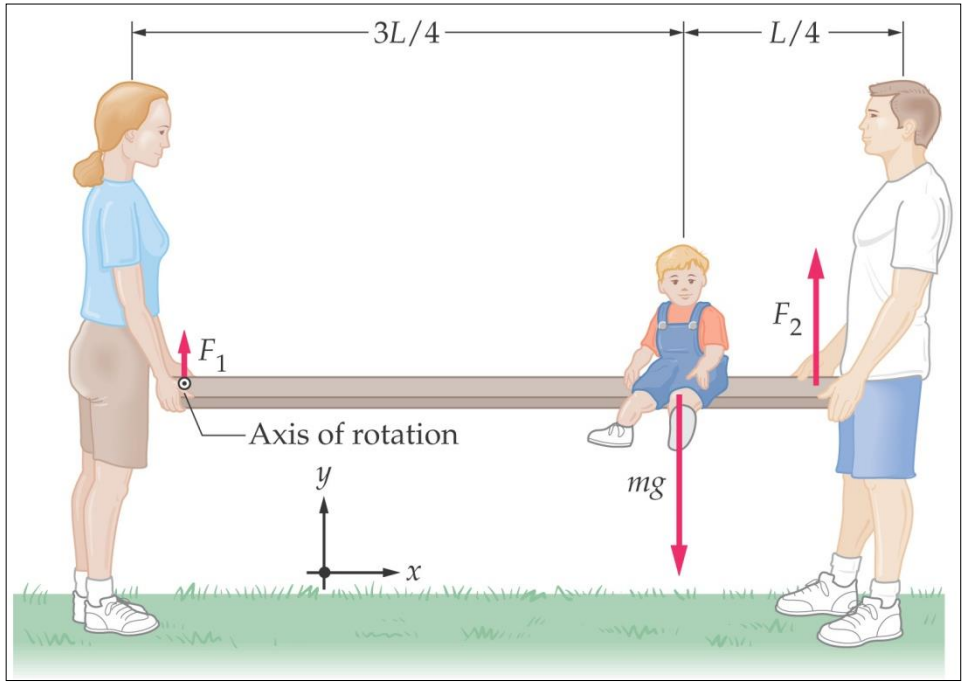
$$\sum F_x = 0, \sum F_y = 0 \qquad \text{11–5}$$

(ii) The net torque acting on the object must be zero,

$$\sum \tau = 0 \qquad \text{11–6}$$

11-3 Zero Torque and Static Equilibrium

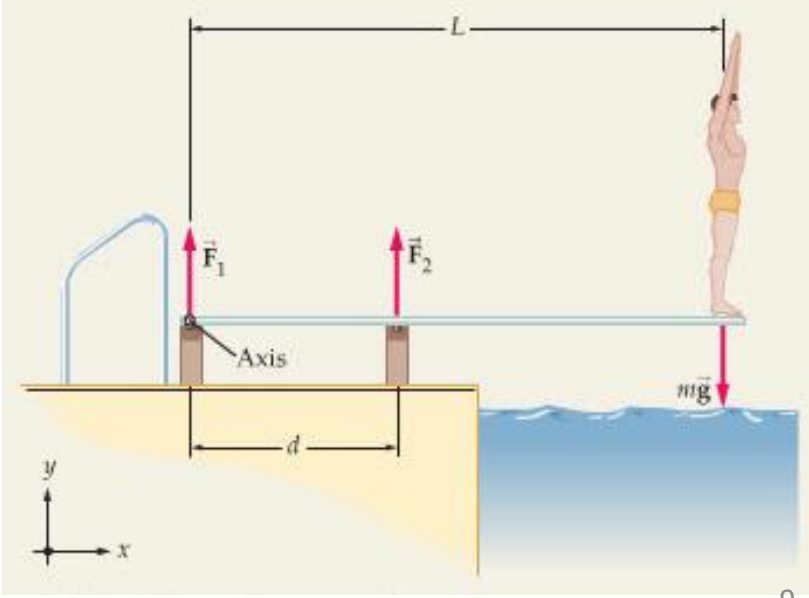
If the net torque is zero, it doesn't matter which axis we consider rotation to be around; we are free to choose the one that makes our calculations easiest.



Example 11.4

A 5.00 m long diving board of negligible mass is supported by two pillars. One pillar is at the left end of the diving board, as shown below; the other is 1.50 m away. Find the forces exerted by the pillars when a 90.0 kg diver stands at the far end of the board?

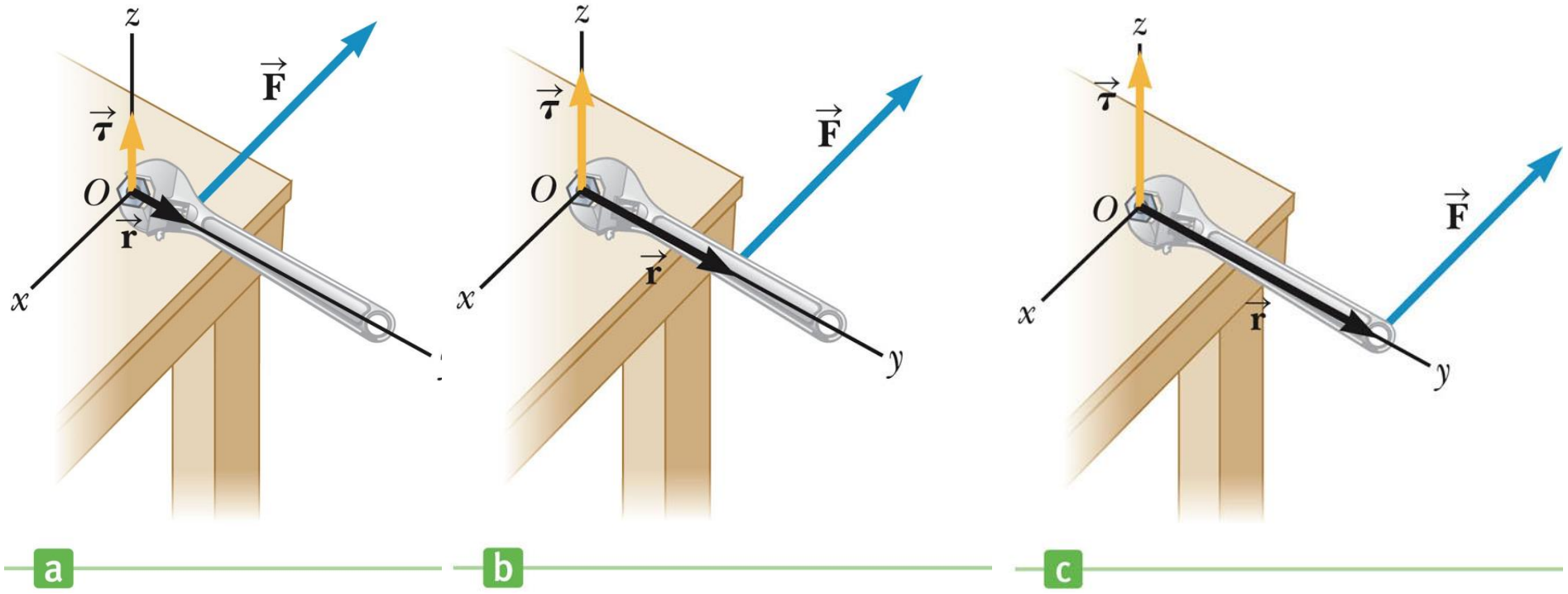
Answers: $F_{2y} = 2940\,N$, $F_{1y} = -2060\,N$



Summary of Chapter 11

- A force applied so as to cause an angular acceleration is said to exert a torque.
- Torque due to a tangential force: $\boldsymbol{\tau = r \times F}$
- Torque in general: $\boldsymbol{\tau = r(F \sin \theta)}$
- In order for an object to be in static equilibrium, the total force and the total torque acting on the object must be zero.

Torque



In which case is the torque greater?

Active Example 11.1

A child of mass m is supported on a light plank by his parents, who exert the forces F1 and F2 as indicated. Find the forces required to keep the plank in static equilibrium. Use the right end of the plank as the axis of rotation?