

Exercise walk-through

5.3

Torque

AP Physics C: Mechanics

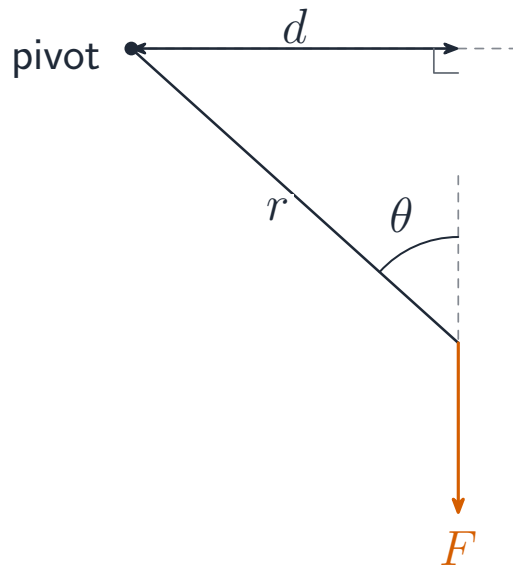
Torque about a chosen axis

$$\vec{\tau} = \vec{r} \times \vec{F}, \quad |\tau| = rF \sin \phi = Fr_{\perp}$$

Torque is a **vector product**. The **moment arm** is the perpendicular distance to the force's line of action.

The **right-hand rule** points perpendicular to the plane: out of the page for counterclockwise torque, into it for clockwise. Units are N m; torque is not scalar work.

Locate the line of action



A force through the axis gives zero torque about that axis. It can still cause translation.

Angled lever: original attempt

A 20 N force acts 0.30 m from an axis, at 30° to the radius. It tends to turn the lever counterclockwise.

Find the signed torque and perpendicular moment arm. Compare with a perpendicular 10 N force at the same point.

Why is the distance to the application point not always the moment arm?

Angled lever: two equivalent calculations

$$\tau = rF \sin \phi$$

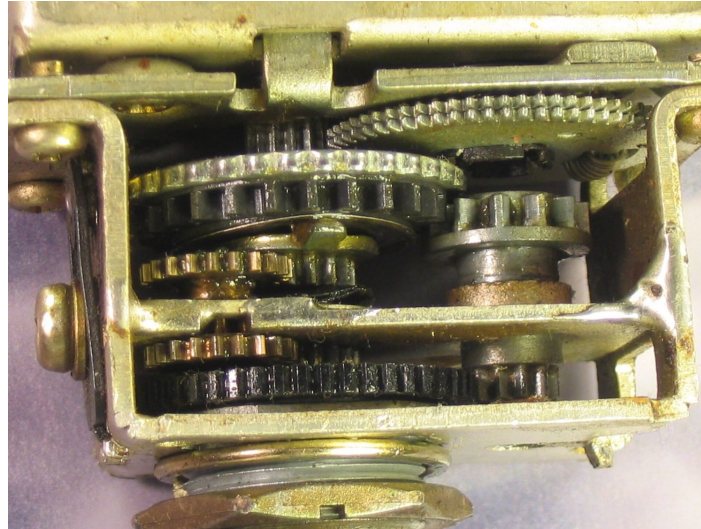
$$\tau = (0.30 \text{ m})(20 \text{ N}) \sin 30^\circ = +3.0 \text{ N m}$$

$$r_\perp = r \sin \phi = (0.30 \text{ m}) \sin 30^\circ = 0.15 \text{ m}$$

$$\tau = Fr_\perp = (20 \text{ N})(0.15 \text{ m}) = +3.0 \text{ N m}$$

A perpendicular 10 N force gives $(0.30 \text{ m})(10 \text{ N}) = 3.0 \text{ N m}$ too. Geometry and force both matter.

Gears: what the photo can establish



Visible geometry suggests different angular speeds. It supplies neither torque values nor inertias, efficiency or friction losses.

Exercises 2.1-2.3

2.1 A 20 N force acts perpendicular to a spanner 0.3 m from the bolt. Find the torque.[2]

2.2 State the torque when a force acts straight along the line toward the axis. [1]

2.3 Define the lever arm. [1]

Exercises 2.1-2.3

2.1 A 20 N force acts perpendicular to a spanner 0.3 m from the bolt. Find the torque.[2]

2.1

- $\tau = rF = 0.3 \times 20 = 6 \text{ N m}$

2.2 State the torque when a force acts straight along the line toward the axis. [1]

2.2

- Zero (the lever arm is zero)

2.3 Define the lever arm. [1]

2.3

- The perpendicular distance from the axis to the line of the force

Exercises 2.4·3.1

2.4 A 50 N force acts at 30° to a 0.4 m arm. Find the torque.

[2]

3.1 The torque of a force is greatest when the force acts

[1]

☐

A along the arm toward the axis

B perpendicular to the arm

C at 45° to the arm

D at the axis

Exercises 2.4·3.1

2.4 A 50 N force acts at 30° to a 0.4 m arm. Find the torque. [2]

2.4

- $\tau = rF \sin \theta = 0.4 \times 50 \times \sin 30^\circ = 10 \text{ N m}$

3.1 The torque of a force is greatest when the force acts [1]

☐

A along the arm toward the axis

B perpendicular to the arm

C at 45° to the arm

D at the axis

3.1 B

- perpendicular gives the maximum torque

Exercise 3.2

3.2 A force of 8 N acts at 0.25 m, perpendicular to the arm. The torque is [1]

☐

A 2 N m

B 32 N m

C 0.03 N m

D 8 N m

Exercise 3.2

3.2 A force of 8 N acts at 0.25 m, perpendicular to the arm. The torque is [1]

☐

A 2 N m

B 32 N m

C 0.03 N m

D 8 N m

3.2 A

- $\tau = 0.25 \times 8 = 2 \text{ N m}$

Exercise 3.3 (a)

3.3 Two children sit on a seesaw. A 300 N child sits 1.5 m from the pivot.

(a) Find the torque this child produces.

[2]

Exercise 3.3 (a)

3.3 Two children sit on a seesaw. A 300 N child sits 1.5 m from the pivot.

(a) Find the torque this child produces.

[2]

(a)

- $\tau = 1.5 \times 300 = 450 \text{ N m}$

Exercise 3.3 (b)

3.3 Two children sit on a seesaw. A 300 N child sits 1.5 m from the pivot.

(b) State where a 450 N child must sit on the other side to balance it.

[2]

Exercise 3.3 (b)

3.3 Two children sit on a seesaw. A 300 N child sits 1.5 m from the pivot.

(b) State where a 450 N child must sit on the other side to balance it. [2]

(b)

- $450 = 300 \times d \Rightarrow d = 1.5 \text{ m from the pivot}$

Exercise 3.4 (a)

3.4 A 40 N force is applied to a door 0.8 m from the hinge, at 60° to the door.

(a) Find the torque about the hinge.

[2]

Exercise 3.4 (a)

3.4 A 40 N force is applied to a door 0.8 m from the hinge, at 60° to the door.

(a) Find the torque about the hinge.

[2]

(a)

- $\tau = 0.8 \times 40 \times \sin 60^\circ = 27.7 \text{ N m}$

Exercise 3.4 (b)

3.4 A 40 N force is applied to a door 0.8 m from the hinge, at 60° to the door.

(b) State how to increase the torque without changing the force.

[1]

Exercise 3.4 (b)

3.4 A 40 N force is applied to a door 0.8 m from the hinge, at 60° to the door.

(b) State how to increase the torque without changing the force.

[1]

(b)

- Apply it perpendicular to the door (or farther from the hinge)