Spring 2014

PHYS-2010

Lecture 32

Clicker Question

Room Frequency BA

A space ship is initially rotating on its axis with an angular velocity of ω_0 = 0.5 rad/sec. The Captain creates a maneuver that produces a constant angular acceleration of α = 0.1 rad/sec^2 for 10 sec.

$$\omega = \omega_0 + \alpha t$$
$$= \frac{v}{r} = \frac{2\pi}{\tau} = 2\pi f$$
$$\theta = \theta_0 + \omega_o t + \frac{1}{2}\alpha t^2$$
$$\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$$

1) What is its angular velocity at the end of this maneuver? $\omega = 1.5$ rad/sec

2) At how many rpms is it rotating after the maneuver? $f = \frac{45}{\pi} rpm$

3) How far (in radians) did the space ship rotate while the Captain was applying the angular acceleration?

A) 1 rad B) 5 rad C) 10 rad D) 45 rad

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1) What is its angular velocity at the end of this maneuver? $\omega = 1.5 \text{ rad/sec}$

2) At how many rpms is it rotating after the maneuver? $f = \frac{45}{\pi} rpm$

3) How far (in radians) did the space ship rotate while the Captain was applying the angular acceleration?

A) 1 rad

B) 5 rad

C) 10 rad

D) 45 rad

$$\theta - \theta_0 = \omega_o t + \frac{1}{2}\alpha t^2 = (0.5 \text{ rad/sec})(10 \text{ sec}) + \frac{1}{2}(0.1 \text{ rad/sec}^2)(10 \text{ sec})^2$$

$$= 5 \text{ rad} + 5 \text{ rad} = 10 \text{ rad}$$

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1) What is its angular velocity at the end of this maneuver? $\omega = 1.5 \text{ rad/sec}$

2) At how many rpms is it rotating after the maneuver? $f = \frac{45}{\pi} rpm$

3) How far (in radians) did the space ship rotate while the Captain was applying the angular acceleration? $\theta = 10 \text{ rad}$

4) How many degrees is this?

A) 180°

B) 1800°

C) (1800/π) degrees

D) 360°

$$10\text{rad}\left(\frac{180\deg}{\pi \text{ rad}}\right) = \frac{1800}{\pi}\deg$$

Announcements

- Read Giancoli **Chapter 8 on Rotational Motion**.
- Next CAPA # 11 due April 8.
- Written **Homework # 8** due today at 4 pm.
- Next week: Review Recitation and **missed Lab make-up.**
  - at least 7 labs are required to pass the course;
  - contact your TA to arrange lab makeup ahead of time.
- **Study Session** by Prof. Pollock: Tue, Apr. 8, 5-6pm, G125.
- **Midterm Exam 3** on Thursday, April 10, 7:30 pm.
- Material covered on exam: Giancoli Chapters 5-7

(Gravity, Kepler's laws, Work, Energy, Power, Momentum, Collisions)

Rotational Kinematics

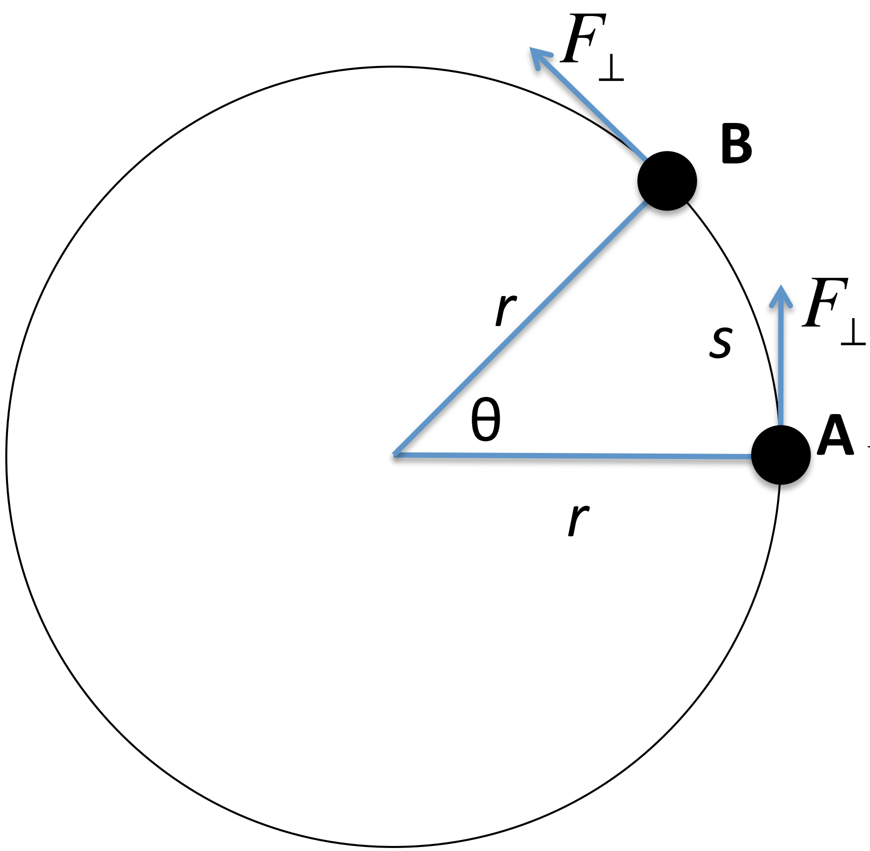
Translation	↔	Rotation	
x	↔	θ	angle of rotation (rads)
$v = \dfrac{\Delta x}{\Delta t}$	↔	$\omega = \dfrac{\Delta\theta}{\Delta t} = \dfrac{v}{r} = \dfrac{2\pi}{\tau} = 2\pi f$	angular velocity (rad/s)
$a = \dfrac{\Delta v}{\Delta t}$	↔	$\alpha = \dfrac{\Delta\omega}{\Delta t} = \dfrac{a_{\tan}}{r}$	angular acceleration (rad/s^2)

Rotational Dynamics

Translation	↔	Rotation	
x	↔	θ	angle of rotation (rads)
$v = \dfrac{\Delta x}{\Delta t}$	↔	$\omega = \dfrac{\Delta\theta}{\Delta t} = \dfrac{v}{r} = \dfrac{2\pi}{\tau} = 2\pi f$	angular velocity (rad/s)
$a = \dfrac{\Delta v}{\Delta t}$	↔	$\alpha = \dfrac{\Delta\omega}{\Delta t} = \dfrac{a_{tan}}{r}$	angular acceleration (rad/s^2)
F	↔	$\tau = r\,F_{\perp}$	torque (N m)
M	↔	$I = \sum m\,r^2$	moment of inertia (kg m^2)
$F_{net} = M\,a$	↔	$\tau_{net} = I\,\alpha$	Newton's 2nd Law

Torque

Rotational Dynamics



Consider the work done by a constant force $F_\perp$ in moving an object from point A to point B on a circle.

W = (Component of force along displacement) x displacement

$$= F_\perp s = F_\perp (r\theta) = (rF_\perp)\theta = \tau\theta$$

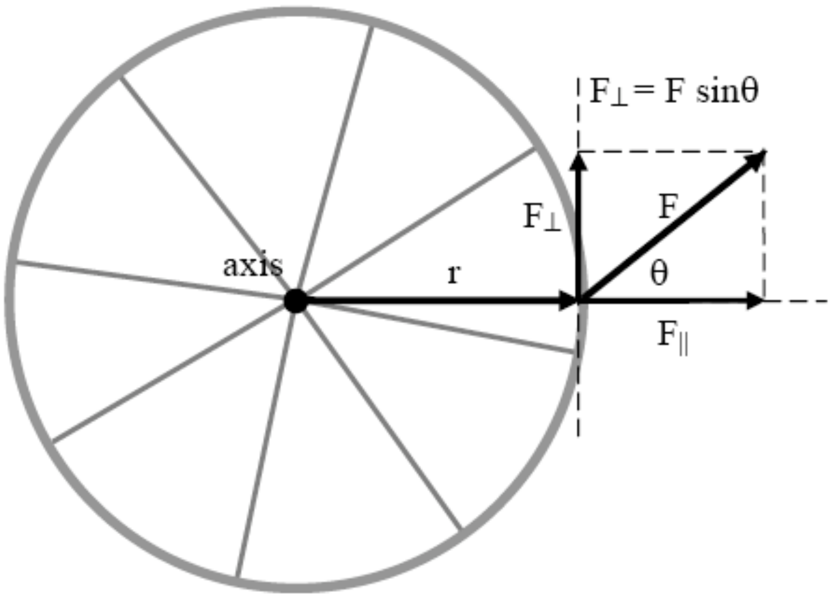
Note: Units of torque are the same as for work/energy (1J = 1 N m), but these are very different quantities!

Torque

$$\tau \equiv rF_\perp$$

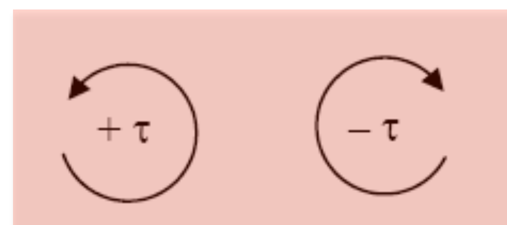
Units: N m

Torque



∴ Torques are related to $F_{\perp}$

∴ The amount of work done by $F_{\perp}$ increases linearly with both *r* and $F_{\perp}$.



<u>Torque:</u>

$$\tau \equiv rF_{\perp}$$

= (lever arm) x (Component of force perpendicular to lever arm)

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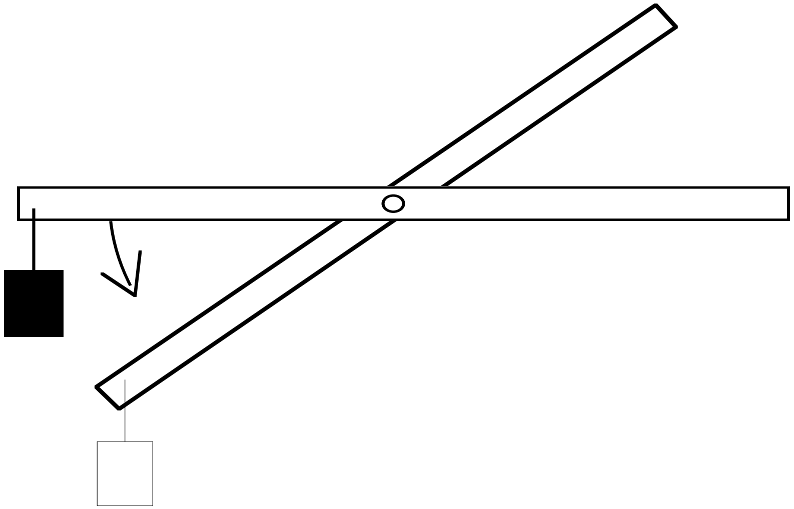
A mass is hanging from the end of a horizontal bar which pivots about an axis through it center, but it being held stationary. The bar is released and begins to rotate. As the bar rotates from horizontal to vertical, the magnitude of the torque on the bar..



$$\tau \equiv rF_{\perp}$$

A) increases

B) decreases

C) stays constant

Both the lever arm and the magnitude of the force of gravity stay constant but the angle between them decreases!

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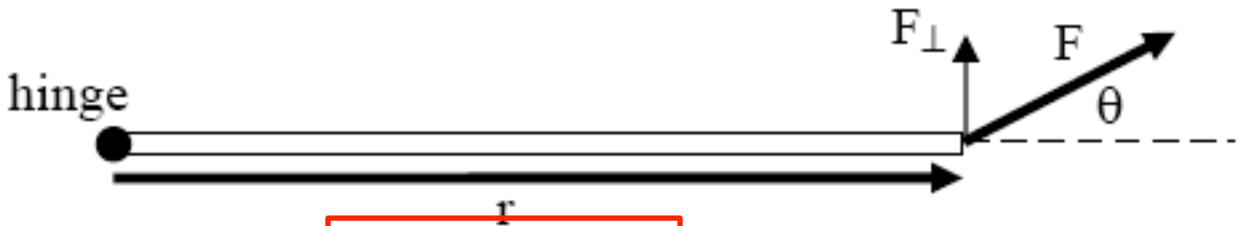
Torque

$$\tau \equiv rF_{\perp}$$

You pull on a door handle a distance *r* = 1m from the hinge with a force of magnitude 20 N at an angle θ =30° from the plane of the door.

What's the torque you exerted on the door? (Note: sin 30° = 1/2)



A) 8 Nm

B) 10 Nm

C) 12 Nm

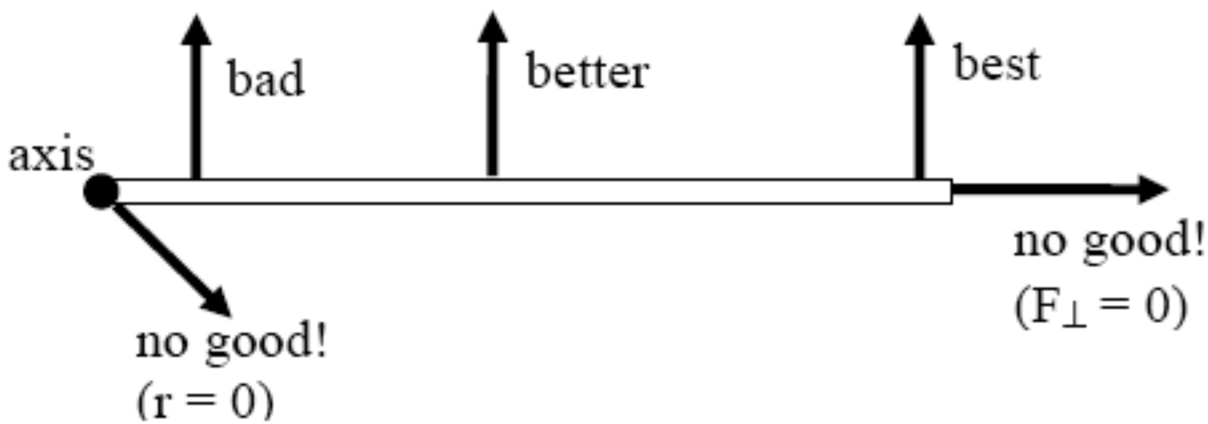
D) 20 Nm

$$\tau = rF_{\perp} = rF\sin\theta = (1m)(20N)(1/2) = 10Nm$$

Torque

$$\tau \equiv rF_{\perp}$$

Therefore, to easily rotate an object about an axis, you want a large lever arm *r* and a large ***perpendicular*** force $F_{\perp}$:



Torque

$$\tau \equiv rF_{\perp}$$

Therefore, to easily rotate an object about an axis, you want a large lever arm *r* and a large *perpendicular* force $F_{\perp}$:

(a) (b)

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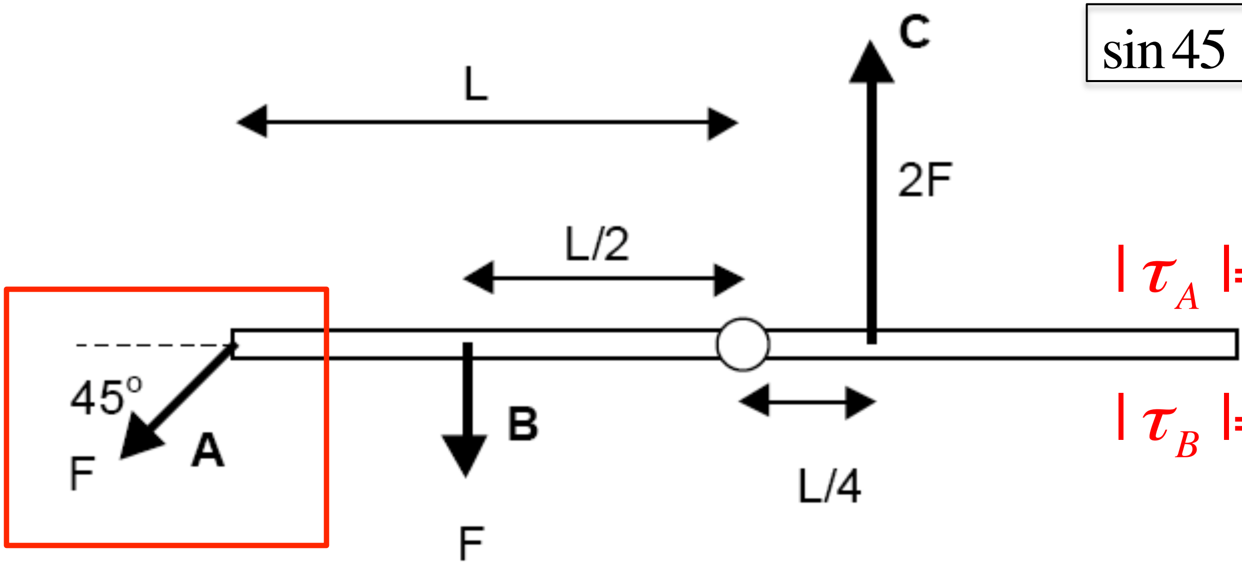
Torque

$$\tau \equiv rF_{\perp}$$

Three forces labeled A, B, and C are applied to a rod which pivots on an axis through its center.

Which force causes the largest size torque?

$$\sin 45 = \cos 45 = 1/\sqrt{2} = 0.707$$



$$|\tau_A| = LF\sin 45 = 0.707\,LF$$

$$|\tau_B| = \frac{L}{2}F = 0.5\,LF$$

$$|\tau_C| = \frac{L}{4}(2F) = 0.5\,LF$$

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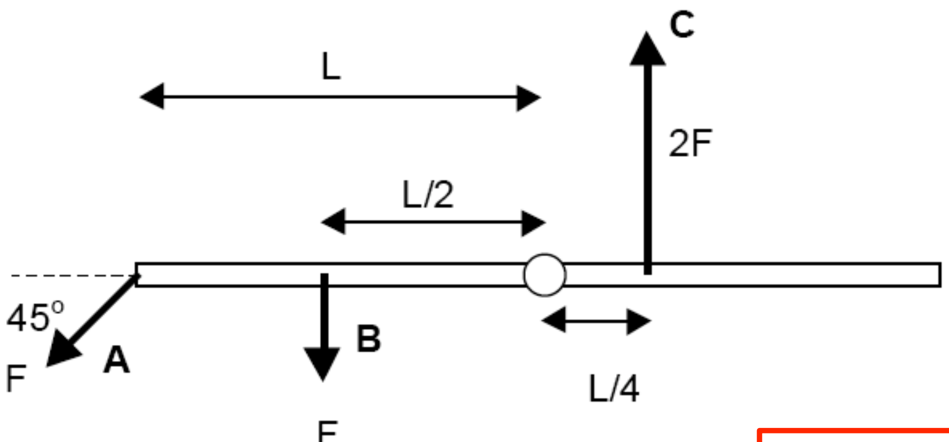
Room Frequency BA

Torque

$$\tau \equiv rF_{\perp}$$

Three forces labeled A, B, and C are applied to a rod which pivots on an axis through its center.

What is the net torque on the rod?



$$\tau_A = LF\sin 45 = 0.707\,LF$$

$$\tau_B = \frac{L}{2}F = 0.5\,LF$$

$$\tau_C = \frac{L}{4}(2F) = 0.5\,LF$$

$$\tau_{net} = (0.707 + 0.5 + 0.5)LF$$

$$= 1.707\,LF$$

A) 0.707 LF B) -0.707 LF **C) 1.707 LF**

D) -1.707 LF E) Zero

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Torque

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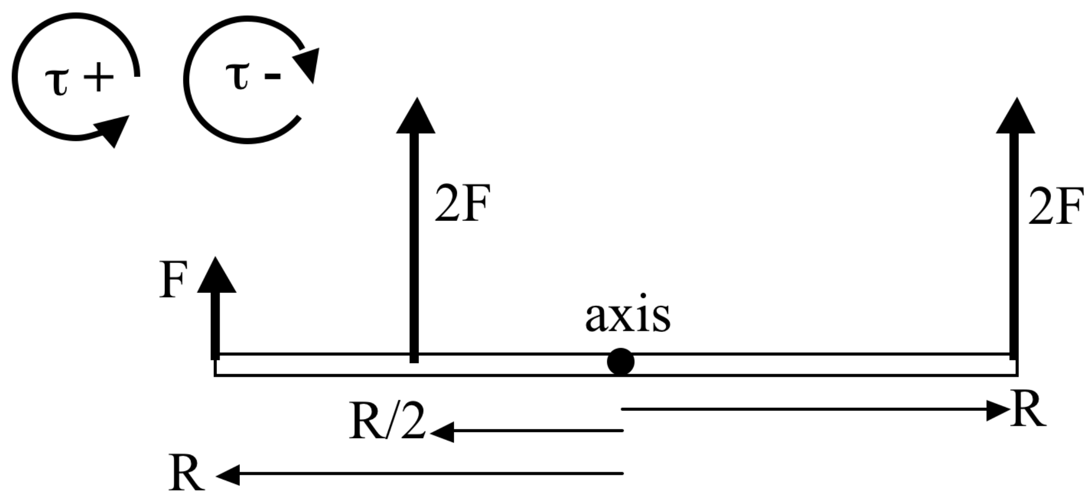
Three forces are applied to a rod which rotates about the center. What is the **net torque** about the axis? Recall the sign convention.

$$\tau \equiv rF_{\perp}$$



A) +RF

B) -RF

C) zero

D) +3RF

E) -3RF

Total Torque:

$\tau_{tot} = +(2F)\times R - (2F)\times(R/2) - F\times R = 0$