

مراجعة نهاية الفصل الدراسي الثالث - فيزياء



تم تحميل هذا الملف من موقع المناهج الإماراتية

موقع المناهج ← المناهج الإماراتية ← الصف الحادي عشر المتقدم ← فيزياء ← الفصل الثالث ← ملفات متنوعة ← الملف

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منهج انجليزي | ملخصات وتقارير | مذكرات وبنوك | الامتحان النهائي | للمدرس

المزيد من مادة
فيزياء:

إعداد: أحمد جمال حفناوي

التواصل الاجتماعي بحسب الصف الحادي عشر المتقدم



صفحة المناهج
الإماراتية على
فيسبوك

الرياضيات

اللغة الانجليزية

اللغة العربية

التربية الاسلامية

المواد على تلغرام

المزيد من الملفات بحسب الصف الحادي عشر المتقدم والمادة فيزياء في الفصل الثالث

مراجعة هيكل الامتحان كراسة تدريبية

1

Einstein_AE PHYSICS END OF TERM 3 COVERAGE

2

هيكل اختبار الفيزياء

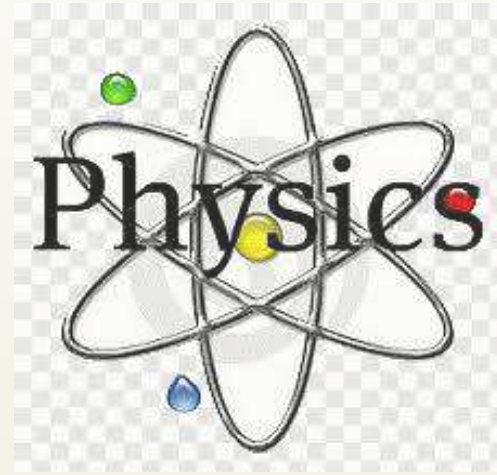
3

مسائل تطبيقية في الحركة الدائرية

4

ملزمة الوحدة التاسعة Conservation Its and Momentum الدرسين الأول والثاني منهج انسباير

5



BE READY

END OF TERM 3 REVISION - ANSWERS PHYSICS GRADE 11 ADV

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حمدة العامري

1	- Define a radian and convert degrees to radians and vice-versa. - Identify that counterclockwise motion is in the positive direction and clockwise motion is in the negative direction.	Student Book Get It?	66~67 67
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Get It?

Identify the angle that Earth rotates in 48 h.

$$\Theta = 360^\circ = 2\pi \text{ rad} \longrightarrow 24 \text{ h}$$

$$\Theta = ?? \longrightarrow 48 \text{ h}$$

$$\Theta = \frac{48 \times 2\pi}{24} = 4\pi \text{ rad.}$$

1. What is a radian?

A. The SI unit of force

B. The SI unit of angular displacement

C. The SI unit of frequency

D. The SI unit of velocity

2. Which of the following is equal to 180° ?

A. $2\pi \text{ rad}$

B. $\frac{\pi}{2} \text{ rad}$

C. $\pi \text{ rad}$

D. $\frac{\pi}{4} \text{ rad}$

$$\Theta (\text{rad}) = \Theta^\circ \times \frac{\pi}{180} = 180 \times \frac{\pi}{180} = \pi \text{ rad.}$$

3. A wheel rotates 270° clockwise. Which of the following correctly represents its angular displacement?

A. $+270^\circ$

B. -270°

C. $+\frac{3\pi}{2} \text{ rad}$

D. -90°

4. A student converts an angle of $\frac{3\pi}{2} \text{ rad}$ into degrees. What is the correct answer?

A. 90°

B. 180°

C. 270°

D. 360°

$$\Theta^\circ = \Theta_{\text{rad}} \times \frac{180}{\pi}$$

$$= \frac{3\pi}{2} \times \frac{180}{\pi} = 270^\circ$$

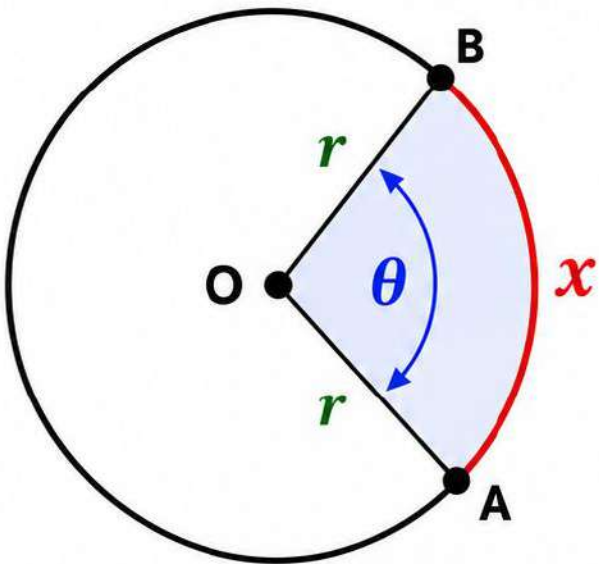
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2	Relate the arc length (x) to the angular displacement (θ) and the distance (r) from the axis of rotation.	Student Book	67
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When an object rotates, it moves along a circular path called an **arc**.

The distance traveled along the arc (**arc length**) depends on:

- Angular displacement (θ) in radians
- Radius (r) of the circular path



FORMULA

$$x = r\theta$$

Where:

- x = Arc length (m)
- r = Distance from the axis of rotation (radius) (m)
- θ = Angular displacement (rad)

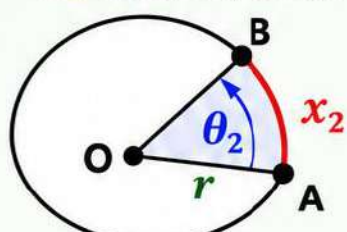


Note: θ must be in **radians** when using the formula.

KEY RELATIONSHIPS

1) SAME r , DIFFERENT θ

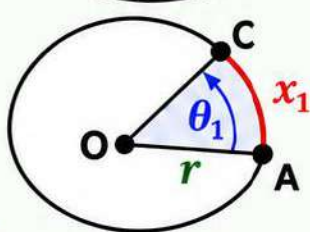
If θ increases, the arc length (x) increases.



$$\theta_1 < \theta_2$$

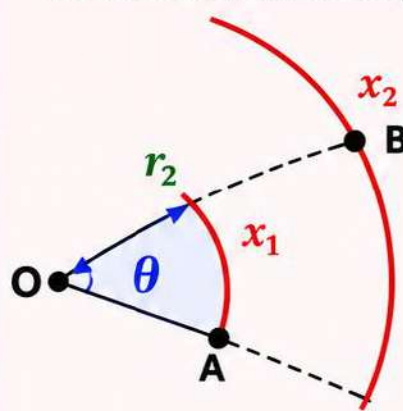
(same r)

$$\Rightarrow x_1 < x_2$$



2) SAME θ , DIFFERENT r

If r increases, the arc length (x) increases.



$$r_1 < r_2$$

(same θ)

$$\Rightarrow x_1 < x_2$$

1. A point on a rotating wheel is 0.8 m from the axis of rotation. Another point is 1.6 m from the axis. Both rotate through the same angular displacement. Which point travels the greater arc length?

- A. The point at 0.8 m
- B. The point at 1.6 m

$\sqrt{r_1 = r_2}$
 $\theta_1 = \theta_2$

~~$x = r\theta$~~
 $x \propto r$

- C. Both travel the same arc length
- D. Cannot be determined

2. Two points are located at the same radius from the center of a rotating disk. Point A rotates through 1 rad, while Point B rotates through 3 rad. Which statement is correct?

- A. Point A travels a greater arc length.
- B. Point B travels a greater arc length.

$r_1 = r_2$

$\theta_B = 3 \text{ rad}$

$\theta_A = 1 \text{ rad}$
 ~~$x = r\theta$~~
 $x \propto \theta$

- C. Both travel the same arc length.
- D. Arc length does not depend on angular displacement.

3	- Apply the relationship between average angular velocity (ω), angular displacement ($\Delta\theta$), and the time interval (Δt) for that displacement. - Solve problems related to rotational variables.	Student Book PRACTICE Pro. Q (2) Check Your Prog. Q (6,7)	67-68 69 69
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2. A rotating toy above a crib makes one complete counterclockwise rotation in 1 min.
- What is its angular displacement in 3 min?
 - What is the toy's angular velocity in rad/min?
 - If the toy is turned off, does it have positive or negative angular acceleration? Explain.

c/ $-\alpha$ because $\omega_2 < \omega_1$
 $\alpha = \frac{\omega_2 - \omega_1}{\Delta t}$

$\theta = 1 \text{ rotation} \times 2\pi = 2\pi \text{ rad.}$

$t = 1 \text{ min} \times 60 = 60 \text{ s}$

$\therefore \theta_{3 \text{ min}} = 1 \times 3 = 3 \text{ rotations}$
 $= 6\pi \text{ rad.}$

b/ $\omega = \frac{\theta}{t} = \frac{2\pi}{1} = 2\pi \text{ rad/min}$

6. **Angular Velocity** The Moon ($r = 1.74 \times 10^6 \text{ m}$) rotates once on its axis in 27.3 days.
- What is its period of rotation in seconds?
 - What is the frequency of its rotation in rad/s?
 - A rock sits on the surface at the Moon's equator. What is its linear speed due to the Moon's rotation?
 - Compare this speed with that of a person at the equator due to Earth's rotation.

$r = 1.74 \times 10^6 \text{ m}$

$\theta = 1 \text{ rotation}$

$= 2\pi \text{ rad}$

$t = 27.3 \text{ d} \times 24 \times 60 \times 60$

$= 2.4 \times 10^6 \text{ s}$

a/ $t_{\text{one rotation}} = 2.4 \times 10^6 \text{ s}$

b/ $f = \frac{\omega}{2\pi} = \frac{\theta/t}{2\pi} = \frac{2\pi/2.4 \times 10^6}{2\pi} = 4.2 \times 10^{-7} \text{ rad/s}$

c/ $v = r\omega = 1.74 \times 10^6 \times \frac{2\pi}{2.4 \times 10^6} = 4.56 \text{ m/s}$

$\rightarrow$ about 100 times faster

7. **Angular Displacement** A movie lasts 2 h. During that time, what is the angular displacement of each of the following?

- the hour hand
- the minute hand
- the second hand

c/ $\theta_{\text{sec}} = ??$ $2\pi \rightarrow 60 \text{ s}$
 $\times \rightarrow 7200 \text{ s}$

$\theta_{\text{sec}} = \frac{7200 \times 2\pi}{60} = 240\pi \text{ rad.}$

a/ $\theta_h = ??$ $2\pi \text{ rad} \rightarrow 12 \text{ h}$
 $\times \text{ rad} \rightarrow 2 \text{ h}$

$\theta_h = \frac{2 \times 2\pi}{12} = \frac{1}{3} \pi \text{ rad.}$

b/ $\theta_{\text{min}} = ??$ $2\pi \text{ rad} \rightarrow 60 \text{ min}$
 $\times \text{ rad} \rightarrow 120 \text{ min}$

$\theta_{\text{min}} = \frac{120 \times 2\pi}{60} = 4\pi \text{ rad.}$

$\rightarrow$ clockwise

1. A bicycle wheel rotates through an angular displacement of 24 rad in 6 s. What is its average angular velocity?

- 2 rad/s
- 4 rad/s
- 6 rad/s
- 12 rad/s

$\omega = \frac{\theta}{t} = \frac{24}{6} = 4 \text{ rad/s}$

$\frac{\theta}{t}$

$\theta = 3 \times 2\pi = 6\pi \text{ rad.}$

t

$\theta = 6\pi \text{ rad.}$

2. A fan rotates at a rate of 3 revolutions per second for 4 s. What is its angular displacement in radians?

- 12 π rad
- 24 π rad
- 6 π rad
- 48 π rad

3. A rotating disk moves through an angular displacement of 90 rad with an average angular velocity of 18 rad/s. How long does the rotation take?

- 3 s
- 4 s
- 5 s
- 6 s

$t = \frac{\theta}{\omega} = \frac{90}{18} = 5 \text{ s}$

- 4 • Relate the linear velocity (v) to the angular velocity (ω) and the distance (r) from the axis of rotation.
 • Solve problems related to rotational variables.

Student Book
 Check Your Prog. Q (10)

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10. **Critical Thinking** A CD-ROM has a spiral track that starts 2.7 cm from the center of the disk and ends 5.5 cm from the center. The disk drive must turn the disk so that the linear velocity of the track is a constant 1.4 m/s. Find the following.

- a. the angular velocity of the disk (in rad/s and rev/min) for the start of the track
 b. the disk's angular velocity at the end of the track
 c. the disk's angular acceleration if the disk is played for 76 min

a./ $\omega_{start} = \frac{v}{r_{start}} = \frac{1.4}{2.7 \times 10^{-2}} = 51.9 \text{ rad/s}$ } $r_{start} = 2.7 \times 10^{-2} \text{ m}$
 $r_{end} = 5.5 \times 10^{-2} \text{ m}$
 $v = 1.4 \text{ m/s}$

$51.9 \text{ rad/s} \times \frac{60}{2\pi} \rightarrow 495.6 \text{ rev/min}$

b./ $\omega_{end} = \frac{v}{r_{end}} = \frac{1.4}{5.5 \times 10^{-2}} = 25.5 \text{ rad/s}$

c./ $\alpha = \frac{\Delta \omega}{\Delta t} = \frac{\omega_{end} - \omega_{start}}{\Delta t} = \frac{25.5 - 51.9}{76 \times 60}$ } $t = 76 \times 60 \text{ s}$

$= -0.006 \text{ rad/s}^2$ ✗

A point on the rim of a rotating wheel is 0.40 m from the axis of rotation. The wheel rotates through an angular displacement of 20 rad in 5 s. What is the linear velocity of the point? ✓ ⊖

- A) 0.8 m/s
 B) 1.6 m/s
 C) 4.0 m/s
 D) 8.0 m/s

$v = r \omega$
 $v = r \frac{\theta}{t} = 0.4 \times \frac{20}{5}$
 $= 1.6 \text{ m/s}$

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5

- Apply the relationship between average angular acceleration (α), change in angular velocity ($\Delta\omega$), and the time interval (Δt) for that change.
- Solve problems related to rotational variables.

Student Book
 Check Your Prog. Q (8)

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8. **Angular Acceleration** In the spin cycle of a clothes washer, the drum turns at 635 rev/min. If the lid is opened, the motor is turned off. If the drum requires 8.0 s to slow to a stop, what is the angular acceleration of the drum?

$$\alpha = \frac{\omega_2 - \omega_1}{\Delta t}$$

$$= \frac{0 - (635 \times \frac{2\pi}{60})}{8}$$

$$= -8.3 \text{ rad/s}^2$$

~~✗~~

$$\omega_1 = 635 \text{ rev/min}$$

$$= 635 \times \frac{2\pi}{60} \text{ rad/s}$$

$$\omega_2 = 0$$

$$\Delta t = 8 \text{ s}$$

$$\alpha = ?$$

A grinding wheel has a radius of 0.50 m. The angular velocity of the wheel increases from 10 rad/s to 30 rad/s in 5 s. What is the tangential acceleration (a) of a point on the rim?

- A) 1 m/s² $\rightarrow t$
 B) 2 m/s²
 C) 4 m/s²
 D) 8 m/s²

$\overline{a} = ?$

$$a = r \alpha$$

$$a = r \left[\frac{\omega_2 - \omega_1}{\Delta t} \right]$$

$$a = 0.5 \times \left(\frac{30 - 10}{5} \right) = 2 \text{ m/s}^2$$

~~✗~~

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6 • Define the term torque. • Identify that a torque on a body involves a force and a lever arm which is the perpendicular distance from the axis of rotation to the point where the force is applied.	Student Book Figure. (5) & Figure. (6)	70~71 70,71
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TORQUE

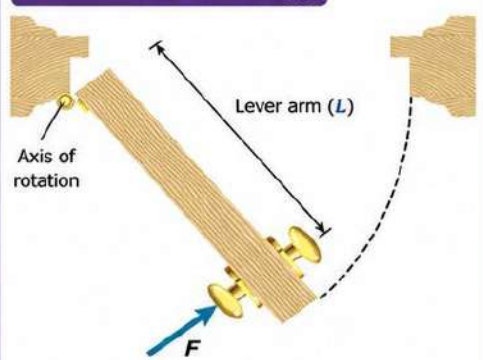
Torque is the turning effect of a force that causes an object to rotate about an axis of rotation.

KEY IDEA

A torque on a body involves:

- A force (F)
- A lever arm (perpendicular distance from the axis of rotation to the point where the force is applied)

LEVER ARM (L)

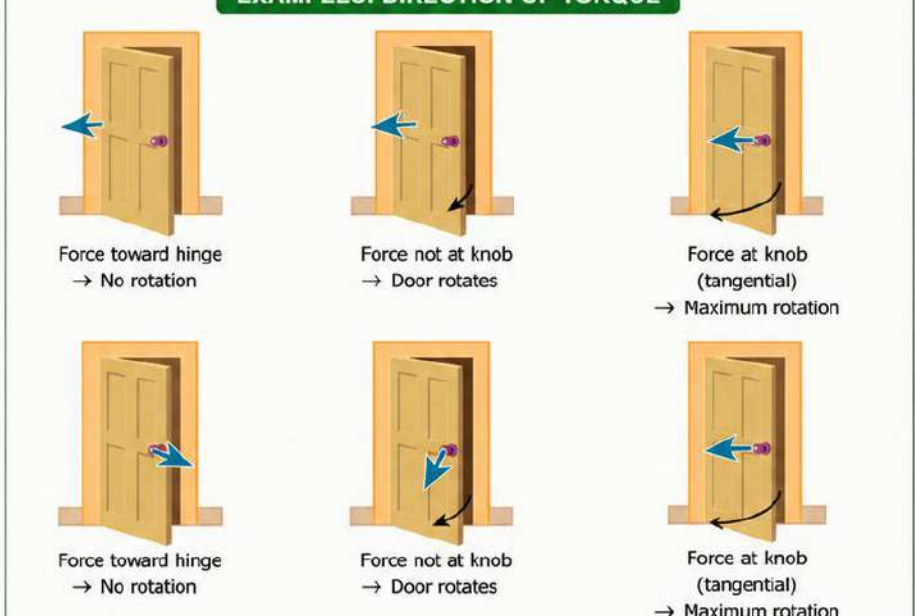


$L = r \sin \theta$

Where:

L = Lever arm (m)
 r = Distance from axis of rotation to the point where the force is applied (m)
 θ = Angle between r and F

EXAMPLES: DIRECTION OF TORQUE



TORQUE FORMULAS

Using lever arm:

$\tau = FL$

Where:

τ = Torque (N·m)
 F = Force (N)
 L = Lever arm (m)

In terms of r and θ :

$\tau = F r \sin \theta$

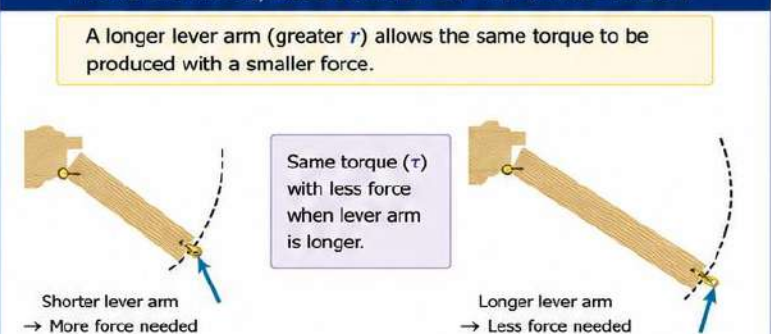
Where:

r = Distance from axis of rotation (m)
 θ = Angle between r and F

- IMPORTANT RELATIONSHIPS**
- ✓ Greater force (F)
→ Greater torque (τ)
 - ✓ Greater distance from the axis (r) → Greater torque (τ)
 - ✓ Torque is maximum when $\theta = 90^\circ$ ($\sin 90^\circ = 1$).
 - ✓ More distance from the axis means the same torque can be produced with less force.

MORE DISTANCE, LESS FORCE FOR THE SAME TORQUE

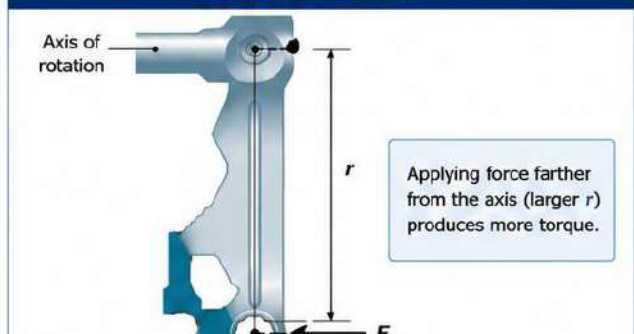
A longer lever arm (greater r) allows the same torque to be produced with a smaller force.



Same torque (τ) with less force when lever arm is longer.

Shorter lever arm → More force needed
 Longer lever arm → Less force needed

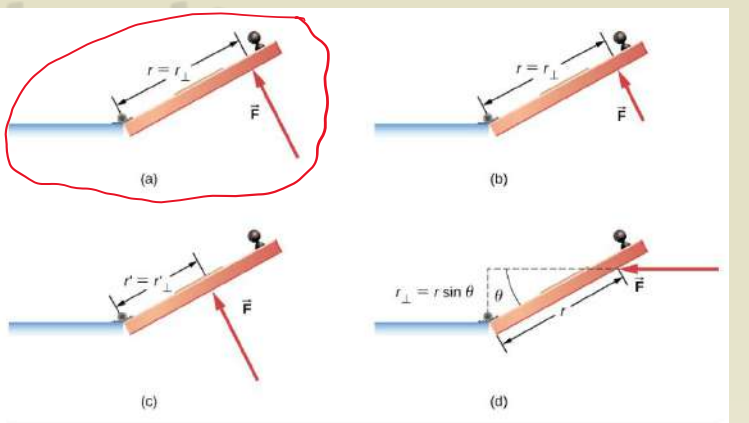
EXAMPLE: WRENCH



Applying force farther from the axis (larger r) produces more torque.

Which diagram in the figure will represent the greater torque?

$F \uparrow \quad r \uparrow \quad \theta = 90^\circ$



(a) (b) (c) (d)

7 • Apply the relation ($\tau = Fr \sin \theta$) to calculate the magnitude of torque (τ) for a force of magnitude (F) where (r) is the distance from the axis of rotation to the point where the force is exerted, and θ is the angle between the force and the radius from the axis of rotation to the point where the force is applied. • Identify that a torque is assigned a positive or negative sign depending on the direction it tends to make the body rotate about a specified rotation axis: "clocks are negative"	Student Book EXAMPLE Pro. Q (1) PRACTICE Pro. Q (11,12,13)	71 72 72
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EXAMPLE Problem 1

LEVER ARM A bolt on a car engine must be tightened with a torque of $35 \text{ N} \cdot \text{m}$. You use a 25-cm -long wrench and pull the end of the wrench at an angle of 60.0° to the handle of the wrench. How long is the lever arm, and how much force must you exert?

$$L = r \sin \theta = 25 \times 10^{-2} \times \sin 60^\circ = 0.22 \text{ m}$$

$$F = \frac{\tau}{r \sin \theta} = \frac{35}{25 \times 10^{-2} \times \sin 60^\circ} = 161.66 \text{ N} \quad \times$$

PRACTICE Problems

ADDITIONAL PRACTICE

11. Consider the wrench in Example Problem 1. What force is needed if it is applied to the wrench pointing perpendicular to the wrench?

$$F = ?? \quad \theta = 90^\circ$$

$$F = \frac{35}{25 \times 10^{-2} \times \sin 90^\circ} = 140 \text{ N}$$

12. If a torque of $55.0 \text{ N} \cdot \text{m}$ is required to turn a bolt and the largest force you can exert is 135 N , how long a lever arm must you use to turn the bolt?

$$\tau = F L$$

$$L = \frac{\tau}{F} = \frac{55}{135} = 0.41 \text{ m}$$

13. You have a 0.234-m -long wrench. A job requires a torque of $32.4 \text{ N} \cdot \text{m}$, and you can exert a force of 232 N .

a. What is the smallest angle, with respect to the handle of the wrench, at which you can pull on the wrench and get the job done?

$$\tau = F r \sin \theta$$

$$32.4 = 232 \times 0.234 \times \sin \theta \Rightarrow \theta = 36.6^\circ$$

b. A friend can exert 275 N . What is the smallest angle she can use to accomplish the job?

$$32.4 = 275 \times 0.234 \times \sin \theta \Rightarrow \theta_{\text{friend}} = 30.2^\circ$$

A mechanic applies a 50 N force to a wrench 0.40 m from the axis of rotation. The angle between the force and the wrench is 90° . What is the magnitude of the torque produced?

$$\tau = ??$$

$$\tau = F r \sin \theta$$

$$= 50 \times 0.4 \times \sin 90^\circ$$

$$= 20 \text{ N} \cdot \text{m} \quad \times$$

- A) $10 \text{ N} \cdot \text{m}$
B) $20 \text{ N} \cdot \text{m}$
C) $50 \text{ N} \cdot \text{m}$
D) $200 \text{ N} \cdot \text{m}$

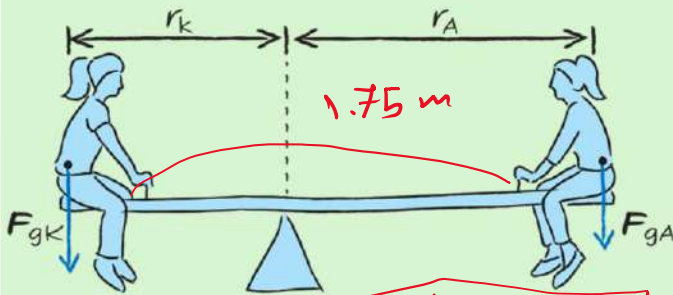
- 8 • Solve problems that involve torque.
• Calculate the net torque when more than one torque acts on a body about a rotation axis.

Student Book
EXAMPLE Pro. Q (2)
PRACTICE Pro. Q (16,18)

73
75
75

EXAMPLE Problem 2

BALANCING TORQUES Karienn (56 kg) and Aysha (43 kg) want to balance on a 1.75-m-long seesaw. Where should they place the pivot point of the seesaw? Assume that the seesaw is massless.



$$m_K = 56 \text{ kg}$$

$$m_A = 43 \text{ kg}$$

$$r_A + r_K = 1.75 \quad (1)$$

$$m_A r_A = m_K r_K$$

$$\frac{43}{56} r_A = \frac{56}{43} r_K$$

$$r_A = \frac{56}{43} r_K = 1.3 r_K \quad (2)$$

From (2) to (1)

$$1.3 r_K + r_K = 1.75$$

$$2.3 r_K = 1.75$$

$$r_K = \frac{1.75}{2.3} = 0.76 \text{ m}$$

$$r_A = 1.75 - r_K$$

$$= 1.75 - 0.76$$

$$= 0.99 \text{ m}$$

16. Ashok, whose mass is 43 kg, sits 1.8 m from a pivot at the center of a seesaw. Steve, whose mass is 52 kg, wants to seesaw with Ashok. How far from the center of the seesaw should Steve sit?

$$m_A = 43 \text{ kg}, r_A = 1.8 \text{ m}$$

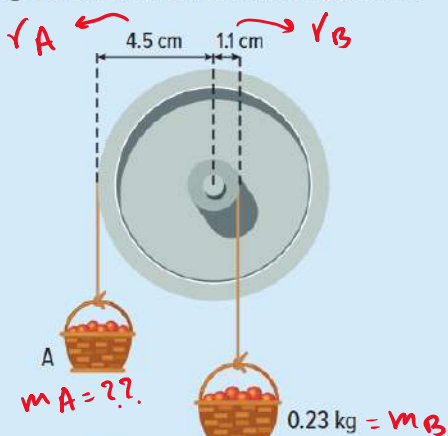
$$m_S = 52 \text{ kg}, r_S = ??$$

$$m_A r_A = m_S r_S$$

$$43 \times 1.8 = 52 \times r_S$$

$$r_S = \frac{43 \times 1.8}{52} = 1.49 \text{ m}$$

18. Two stationary baskets of fruit hang from strings on pulleys of different diameters, as shown in Figure 10. What is the mass of basket A?



$$m_A r_A = m_B r_B$$

$$m_A \times 4.5 = 0.23 \times 1.1$$

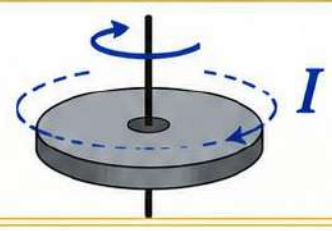
$$m_A = \frac{0.23 \times 1.1}{4.5} = 0.056 \text{ kg}$$

9	Define moment of inertia as the resistance to rotation.	Student Book	75
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MOMENT OF INERTIA (I)

Moment of Inertia is the **resistance of an object to changes in its rotational motion.**

It is the **rotational equivalent of mass** in linear motion.



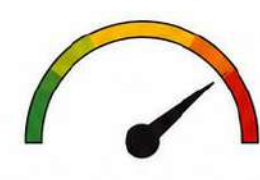
KEY IDEAS



A larger moment of inertia means it is **harder** to start, stop, or change the rotation of an object.



The **farther** the mass is from the axis of rotation, the **greater** the moment of inertia.



The same torque produces **less angular acceleration** for an object with a larger moment of inertia.

- 1. Moment of inertia is best defined as:**
- A) The force that causes an object to rotate.
 - B) The resistance of an object to changes in its rotational motion.**
 - C) The rate at which an object rotates.
 - D) The energy stored in a rotating object.
- 2. Which object has the greater moment of inertia about its center if both have the same mass?**
- A) A solid disk
 - B) A bicycle wheel (mass concentrated near the rim)**
 - C) Both have the same moment of inertia
 - D) It depends only on their angular velocity
- 3. A figure skater is spinning with her arms extended. She then pulls her arms inward. What happens to her moment of inertia?**
- A) It increases
 - B) It remains constant
 - C) It decreases**
 - D) It becomes zero
- 4. Two objects have the same mass. Object A has most of its mass near the axis of rotation, while Object B has most of its mass far from the axis. Which statement is correct?**
- A) Object A has the larger moment of inertia.
 - B) Both objects have the same moment of inertia.
 - C) Object B has the larger moment of inertia and is harder to rotate.**
 - D) Object B has the smaller moment of inertia because it is farther from the axis.

- 11 • Demonstrate how the moment of inertia of an extended object depends on the location and direction of the rotational axis.
• Determine the moment of inertia of extended objects like, solid **uniform cylinder**, **uniform sphere**, **long uniform rod**.

Student Book
Table 2

76
76

1-A solid uniform cylinder and a uniform sphere have the same mass m and radius r . Which object has the greater moment of inertia about its center?
A) Uniform sphere
B) Solid uniform cylinder
C) Both have the same moment of inertia
D) Cannot be determined

2- A long uniform rod of length L is rotated about an axis through its center. If the axis is moved to one end of the rod, the moment of inertia becomes:

- A) $\frac{1}{6} mL^2$
B) $\frac{1}{4} mL^2$
C) $\frac{1}{3} mL^2$
D) $\frac{1}{12} mL^2$

3- Two identical point masses are placed at distances r and $2r$ from the axis of rotation. Compared to the first mass, the moment of inertia of the second mass is:
A) 2 times larger
B) 4 times larger
C) 8 times larger
D) 16 times larger

The moment of inertia (I) is the resistance of an object to changes in its rotational motion.

For extended objects, I depends on:



Mass of the object



Shape of the object



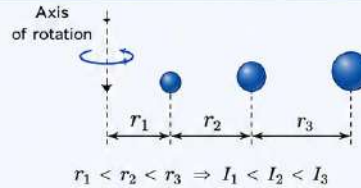
Location of the axis of rotation



Direction of the axis of rotation

KEY IDEA

The farther the mass is from the axis of rotation, the greater the moment of inertia.



General formula:

$$I = \sum mr^2$$

where r is the perpendicular distance from each mass element to the axis.

MOMENT OF INERTIA OF COMMON EXTENDED OBJECTS

Object	Location of Axis	Diagram	Moment of Inertia (I)
Thin hoop of radius r	through central diameter		mr^2
Solid, uniform cylinder of radius r	through center		$\left(\frac{1}{2}\right)mr^2$
Uniform sphere of radius r	through center		$\left(\frac{2}{5}\right)mr^2$
Long, uniform rod of length l	through center (perpendicular to rod)		$\left(\frac{1}{12}\right)ml^2$
Long, uniform rod of length l	through end (perpendicular to rod)		$\left(\frac{1}{3}\right)ml^2$
Thin, rectangular plate of length l and width w	through center (perpendicular to plate)		$\left(\frac{1}{12}\right)m(l^2 + w^2)$

EFFECT OF AXIS LOCATION & DIRECTION

- Changing the location of the axis changes the moment of inertia.
- For the same object, rotating about an axis farther from the mass distribution $\rightarrow$ larger I .

Rod about center



$$I = \left(\frac{1}{12}\right)ml^2$$

Same rod about end



$$I = \left(\frac{1}{3}\right)ml^2 = 4\left(\frac{1}{12}\right)ml^2$$

So, $I_{\text{end}} = 4I_{\text{center}}$
(axis farther from mass $\rightarrow$ greater inertia)

SUMMARY

- ✓ Moment of inertia depends on mass, shape, axis location, and axis direction.
- ✓ The farther the mass is from the axis, the greater the moment of inertia.
- ✓ Different axes on the same object usually give different values of I .
- ✓ Larger I means more resistance to changes in rotational motion.

UNITS

The SI unit of moment of inertia is $\text{kg} \cdot \text{m}^2$.
(Same as mass $\times$ distance²)

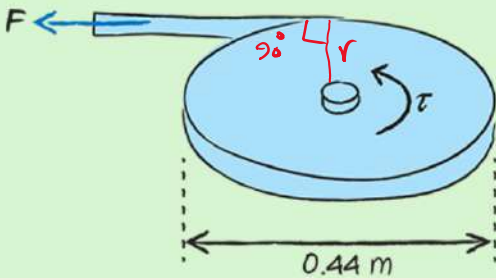
12	- State Newton's second law for rotational motion which relates the net torque (τ_{net}) on a body to the body's moment of inertia (I) and rotational acceleration (α), all calculated relative to a specified axis of rotation. - Apply Newton's second law for rotation to solve problems.	Student Book EXAMPLE Pro. Q (4) Check Your Prog. Q (35)	78 79 80
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EXAMPLE Problem 4

TORQUE A solid steel wheel is free to rotate about a motionless central axis. It has a mass of 15 kg and a diameter of 0.44 m and starts at rest. You want to increase this wheel's rotation about its central axis to 8.0 rev/s in 15 s .

a. What torque must be applied to the wheel?

b. If you apply the torque by wrapping a strap around the outside of the wheel, how much force should you exert on the strap?



$$\alpha = \frac{\tau}{I}$$

$$\tau = I \alpha$$

$$\frac{1}{2} m r^2 \quad \omega_f - \omega_i$$

$$\tau = \frac{1}{2} m r^2 \times \frac{\omega_f - \omega_i}{\Delta t}$$

$$\tau = \frac{1}{2} \times 15 \times (0.22)^2 \times \frac{(8 \times 2\pi) - 0}{15} = 1.22 \text{ N.m}$$

$$b) \quad F = \frac{\tau}{r \sin \theta} = \frac{1.22}{0.22 \times \sin 90} = 5.55 \text{ N}$$

35. **Newton's Second Law for Rotational Motion** A rope is wrapped around a pulley and pulled with a force of 13.0 N . The pulley's radius is 0.150 m . The pulley's rotational speed increases from 0.0 to 14.0 rev/min in 4.50 s . What is the moment of inertia of the pulley?

$$\alpha = \frac{\tau}{I}$$

$$I = \frac{\tau}{\alpha} \rightarrow \frac{F r \sin \theta}{\frac{\omega_f - \omega_i}{\Delta t}}$$

$$I = \frac{F r \sin \theta}{\left[\frac{\omega_f - \omega_i}{\Delta t} \right]} = \frac{13 \times 0.15 \times \sin 90}{\left[\frac{(14 \times \frac{2\pi}{60}) - 0}{4.5} \right]} = 5.99 \text{ kg m}^2$$

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13	• Explain the meaning of center of mass. • Locate experimentally the center of mass of an object by suspending it from different points.	Student Book Check Your Prog. Q (42,44,45)	81~83 87
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42. Location of Center of Mass Can the center of mass of an object be located in an area where the object has no mass? Explain.

Yes. The center of mass can be located in an empty region of an object if the mass is distributed symmetrically around that region.
Examples: A ring, hula hoop, or roll of tape has its center of mass at the geometric center, even though there is no material there.

- 44. Center of Mass** Where is the center of mass on a roll of masking tape?
- 45. Center of Mass** Describe how you would find the center of mass of this textbook.

44- At the center of the roll (the center of the hole).

45- Make three small holes near the edge of the textbook at different locations.
Suspend the textbook freely from the first hole.
Hang a plumb line (string with a weight) from the same hole and allow it to come to rest. Draw a straight line along the direction of the plumb line on the textbook.
Repeat the process by suspending the textbook from the second hole and draw a second line.
Repeat again for the third hole and draw a third line.
The point where all three lines intersect is the center of mass of the textbook.

14	State the conditions for an object to be in static equilibrium- both translational and rotational equilibrium.	Student Book Get It? Check Your Prog. Q (41)	83 83 87
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 **Get It?**

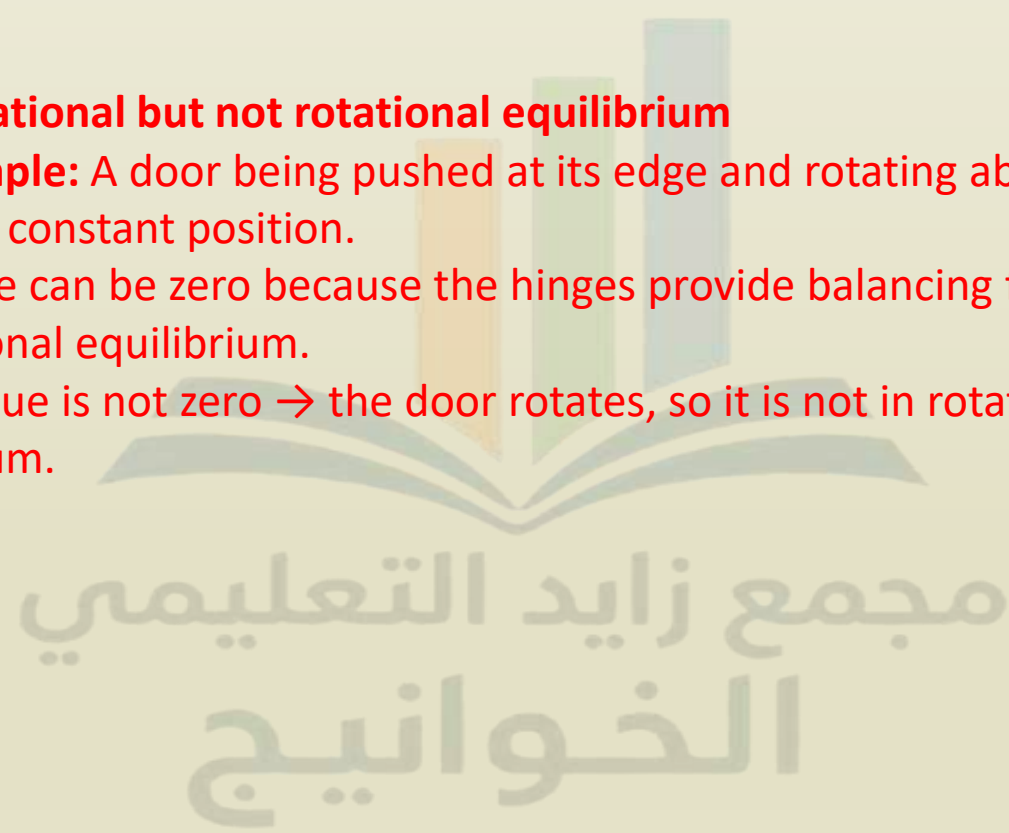
Describe when an object is the most stable.

An object is most stable when it has a low center of mass and a wide base of support.

41. **Equilibrium** Give an example of an object for each of the following conditions.

- a. rotational but not translational equilibrium
- b. translational but not rotational equilibrium

- a. Rotational but not translational equilibrium**
- ✓ **Example:** A ball falling straight downward without spinning.
- No net torque → rotational equilibrium.
 - Net force (gravity) acts downward → not translational equilibrium.
- b. Translational but not rotational equilibrium**
- ✓ **Example:** A door being pushed at its edge and rotating about its hinges at constant position.
- Net force can be zero because the hinges provide balancing forces → translational equilibrium.
 - Net torque is not zero → the door rotates, so it is not in rotational equilibrium.



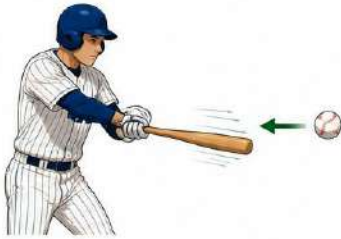
15	Explain what happens when a player hits a ball in terms of the acting forces and their effects on the colliding objects before, during, and after collision.	Student Book	93
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A Baseball Player Hitting a Baseball

When a baseball player hits a baseball with a bat, forces act between the bat and the ball during the short time of collision. These forces change the motion of both objects.

1. BEFORE COLLISION

- The baseball is approaching the bat (or may be at rest).
- The bat is moving toward the baseball.
- There is no contact force between the bat and the ball yet.



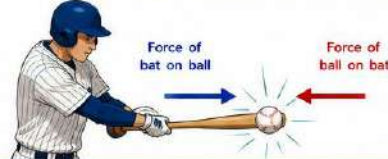
No contact force

2. DURING COLLISION

- The bat exerts a force on the baseball.
- The baseball exerts an equal and opposite force on the bat.

$$F_{\text{bat on ball}} = -F_{\text{ball on bat}}$$

(Newton's Third Law)



- The forces increase from zero to a maximum value and then decrease back to zero as the ball leaves.
- These forces act for a very short time, producing an impulse ($F\Delta t$).
- The baseball's momentum changes.
- The baseball accelerates and changes its velocity direction.
- The bat experiences an equal and opposite force, causing a slight change in its motion and vibration.

3. AFTER COLLISION

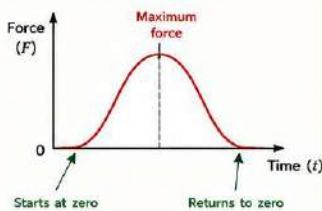
- The baseball leaves the bat and moves away with a new velocity.
- The ball usually moves faster and in the opposite direction.
- The bat continues its swing with slightly less speed.
- The contact force is zero again because the bat and ball are no longer in contact.



No contact force

FORCE vs. TIME DURING COLLISION

The force starts at zero, rises to a maximum, and returns to zero as the ball leaves.



KEY IDEAS

- During collision, the forces on the bat and ball are equal in magnitude and opposite in direction at every instant.
- The impulses on the two objects are equal and opposite.
- The momentum of both objects changes.
- If we neglect external forces, the total momentum of the bat-ball system is conserved.

SUMMARY

Before collision:
No contact force.

During collision:
Force increases from zero to maximum and decreases back to zero; velocities change (ball reverses direction).

After collision:
The ball leaves with a new velocity in the opposite direction; the bat continues its motion.

1- When a baseball bat hits a baseball, which statement is correct during the collision?

- A) The bat exerts a force on the ball, but the ball exerts no force on the bat.
 B) The ball exerts a force on the bat, but the bat exerts no force on the ball.
 C) The bat and ball exert equal and opposite forces on each other.
 D) The bat exerts a larger force on the ball than the ball exerts on the bat.

2- The graph of force versus time during the collision between a baseball bat and a baseball is best described as:

- A) The force is maximum before contact and decreases to zero during collision.
 B) The force remains constant throughout the collision.
 C) The force increases from zero to a maximum value and then decreases back to zero as the ball leaves the bat.
 D) The force starts at a maximum value and continuously decreases to zero.

3- What happens to the baseball's velocity during the collision with the bat?

- A) Its speed changes, but its direction remains the same.
 B) Its direction changes, and it usually moves away in the opposite direction after the collision.
 C) Its velocity becomes zero and remains zero.
 D) Its momentum does not change.

16	- Define impulse as the product of average force on an object and the time interval over which it acts. - Derive impulse expression from Newton's Second Law of motion and specify its unit.	Student Book	93
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IMPULSE (J)

DEFINITION

Impulse is the product of the **average force** acting on an object and the **time interval** over which the force acts.

$$J = F_{avg} \Delta t$$

DERIVATION FROM NEWTON'S SECOND LAW

$$F = ma \quad (\text{Newton's Second Law})$$

$$F = m \frac{\Delta v}{\Delta t} \quad (a = \frac{\Delta v}{\Delta t})$$

$$F \Delta t = m \Delta v \quad (\text{Multiply both sides by } \Delta t)$$

$$F \Delta t = m (v_f - v_i) \quad (\Delta v = v_f - v_i)$$

$$F \Delta t = mv_f - mv_i$$

$$F \Delta t = p_f - p_i \quad (p = mv)$$

$$F \Delta t = \Delta p$$

Therefore, $J = \Delta p$

1- Which statement best defines impulse?

- A) The product of mass and velocity
- B) The product of average force and the time interval over which it acts**
- C) The rate of change of momentum
- D) The product of force and acceleration

2- According to the derivation of impulse from Newton's Second Law, impulse is equal to:

- A) Velocity
- B) Acceleration
- C) Change in momentum**
- D) Kinetic energy

UNIT OF IMPULSE

Unit of impulse = $N \cdot s$
 Since $1 N = 1 kg \cdot m/s^2$
 Therefore,
 $1 N \cdot s = 1 kg \cdot m/s$

KEY IDEAS

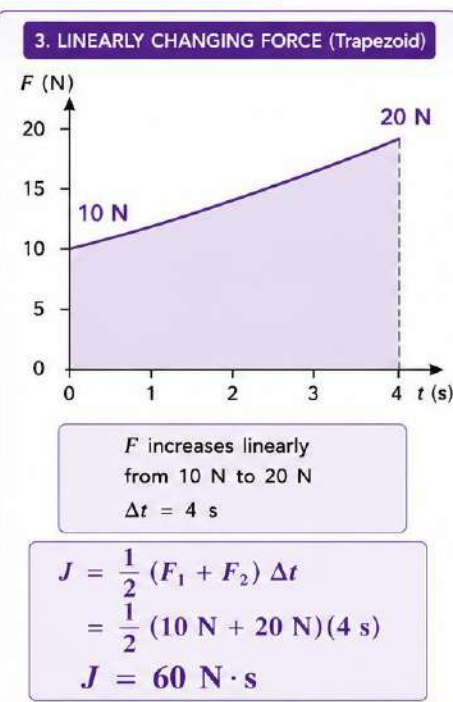
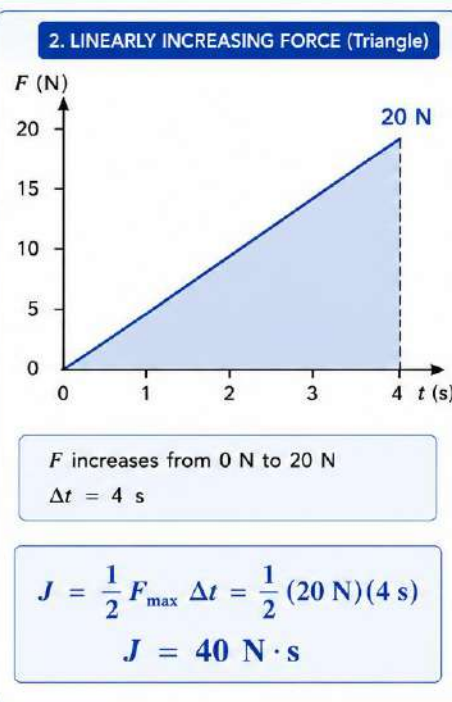
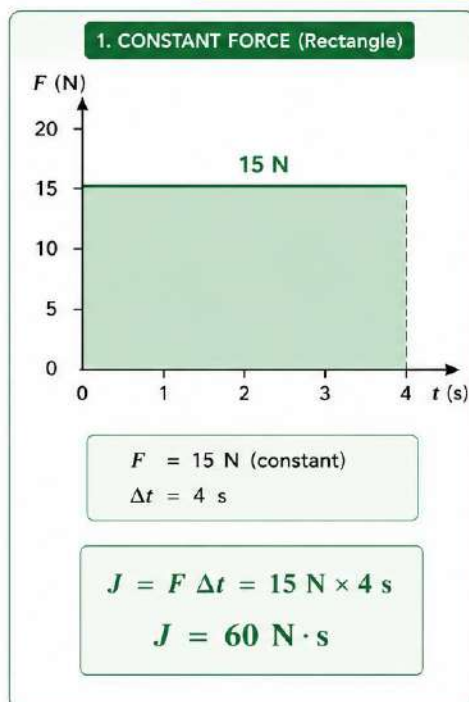
- ✓ Greater force → Greater impulse
- ✓ Longer time interval → Greater impulse
- ✓ Impulse changes an object's momentum

$$\text{IMPULSE} = \text{FORCE} \times \text{TIME} = \text{CHANGE IN MOMENTUM}$$

17 Calculate the impulse in case of a constant force and in case when the force is not constant by using the average force multiplied by the time interval over which it acts or by finding the area under a force-time graph.

Student Book
 PRACTICE Pro. Q (3,4)

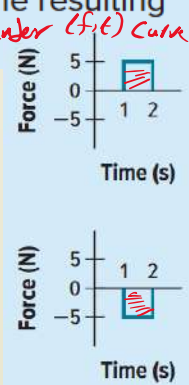
93~94
 95



3. A 7.0-kg object, moving at 2.0 m/s , receives two impulses (one after the other) along the direction of its motion. Both of these impulses are illustrated in **Figure 2**. Find the resulting speed and direction of motion of the object after each impulse.

$J_1 = 5 \times (2 - 1) = 5 \text{ Ns}$
 $J = m(v_f - v_i)$
 $5 = 7 \times (v_f - 2)$
 $v_f = 2.7 \text{ m/s}$
 same direction of motion v_i
 (+)

$J_2 = -5 \times (2 - 1) = -5 \text{ Ns}$
 $-5 = 7 \times (v_f - 2)$
 $v_f = 1.29 \text{ m/s}$
 Same direction of motion v_i
 (+)



4. The driver accelerates a 240.0-kg snowmobile, which results in a force being exerted that speeds up the snowmobile from 6.00 m/s to 28.0 m/s over a time interval of 60.0 s .

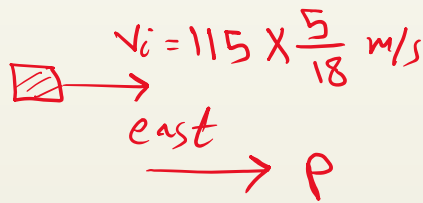
- Sketch the event, showing the initial and final situations.
- What is the snowmobile's change in momentum? What is the impulse on the snowmobile?
- What is the magnitude of the average force that is exerted on the snowmobile?

a. $v_i \rightarrow v_f$
 $J = \Delta p = m(v_f - v_i)$
 $= 240 \times (28 - 6)$
 $= 5280 \text{ N} \cdot \text{s}$
 or
 5280 kg m/s

c. $F = \frac{J}{\Delta t}$
 $= \frac{5280}{60}$
 $= 88 \text{ N}$

18	Apply the linear momentum equation to calculate the linear momentum of different systems.	Student Book PRACTICE Pro. Q (1)	94
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1. A compact car, with mass 725 kg , is moving at 115 km/h toward the east. Sketch the moving car.
- Find the magnitude and direction of its momentum. Draw an arrow on your sketch showing the momentum.
 - A second car, with a mass of 2175 kg , has the same momentum. What is its velocity?



a. $\vec{P} = m \vec{v}$

$$= 725 \times 115 \times \frac{5}{18}$$

$$= 2.3 \times 10^4 \text{ Kg m/s}$$

b.

$$v = \frac{P}{m} = \frac{2.3 \times 10^4}{2175}$$

$$= 10.57 \text{ m/s}$$

$$\left. \begin{array}{l} m_2 = 2175 \text{ Kg} \\ P_2 = P_1 \end{array} \right\}$$



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19	Apply the impulse-momentum theorem to solve relevant problems	Student Book	94
		EXAMPLE Pro. Q (1)	95
		PRACTICE Pro. Q (2)	96

EXAMPLE Problem 1

AVERAGE FORCE A 2200-kg vehicle traveling at 94 km/h (26 m/s) can be stopped in 21 s by gently applying the brakes. It can be stopped in 3.8 s if the driver slams on the brakes, or in 0.22 s if it hits a concrete wall. What is the impulse exerted on the vehicle? What average force is exerted on the vehicle in each of these stops?

$$m = 2200 \text{ Kg}$$

$$v_i = 26 \text{ m/s}$$

$$V_f = 0$$

$$t = 21 \text{ s}$$

applying the brakes

$$f = 3.8 \text{ s}$$

slams on the brakes

$$t = 0.22 \text{ s}$$

Hits a concrete wall

$$J = \Delta p = m(v_f - v_i)$$

$$= 2200 \times (0 - 26) = -5.7 \times 10^4 \text{ N}\cdot\text{s}$$

$$f = \frac{\Delta}{\Delta t} = \frac{-5.7 \times 10^4}{21} = -2.7 \times 10^3 \text{ N}$$

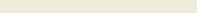
$$F = \frac{-5.7 \times 10^4}{3.8} = -1.5 \times 10^4 \text{ N}$$

$$F = \frac{-5.7 \times 10^4}{0.22} = -2.6 \times 10^5 \text{ N}$$

2. The driver of the compact car in the previous problem suddenly applies the brakes hard for 2.0 s. As a result, an average force of 5.0×10^3 N is exerted on the car to slow it down. $\ominus$ Δt
- a. What is the change in momentum, or equivalently, what is the magnitude and direction of the impulse on the car?
- b. Complete the "before" and "after" sketches, and determine the momentum and the velocity of the car now. $\rightarrow$ *opposite direction to the motion.*

velocity of the car now.

a/ $J = F \Delta t = -5 \times 10^3 \times 2 = -10^4$ N.s = Δp opposite direction to the motion.

b. 

$$\Delta = P_f - P_i$$

$$\rho_f = \gamma + \rho_i = -10^4 + (2.32 \times 10^4) \\ = 1.3 \times 10^4 \text{ kg m/s}$$

$$v_f = \frac{P_f}{m} = \frac{1.3 \times 10^4}{725} = 17.9 \text{ m/s} \approx 18 \text{ m/s}$$

- 1- A 0.5 kg ball changes its velocity from 2 m/s to 8 m/s in the same direction. What is the impulse acting on the ball?

- A) 2 N·s
B) 3 N·s
C) 4 N·s
D) 5 N·s

$$J = \Delta p = m(v_f - v_i)$$

$$= 0.5 \times (8 - 2) = 3 \text{ N.s}$$

- 2- A 2 kg cart initially moves at 3 m/s and comes to rest after a collision. What is the magnitude of the impulse acting on the cart?

- A) 2 N·s
B) 3 N·s
C) 6 N·s
D) 9 N·s

$$J = 2 \times (0 - 3) = -6 \text{ N.s}$$

direction

Magnitude.

20	Define the angular momentum of an object as the product of the object's moment of inertia and the object's angular velocity and write in in equation form ($L = I\omega$) and specify its unit.	Student Book	97
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ANGULAR MOMENTUM (L)

DEFINITION: Angular momentum of an object is the product of the object's moment of inertia and the object's angular velocity.

$$L = I\omega$$

WHERE:

L = Angular momentum
 ($\text{kg} \cdot \text{m}^2/\text{s}$)

I = Moment of inertia
 ($\text{kg} \cdot \text{m}^2$)

ω = Angular velocity
 (rad/s)

UNIT:

$\text{kg} \cdot \text{m}^2/\text{s}$
 (since radian is dimensionless)

KEY POINTS:

- If I increases, L increases.
- If ω increases, L increases.
- If either $I = 0$ or $\omega = 0$, then $L = 0$.

SIMPLE IDEA:



Angular Momentum = Rotational Inertia $\times$ Angular Velocity
 $(L) \qquad \qquad \qquad (I) \qquad \qquad \qquad (\omega)$

1- Which equation correctly represents angular momentum?

- A) $L = mr^2$ B) $L = I\omega$

C) $\tau = I\alpha$

D) $p = mv$

2- What is the SI unit of angular momentum?

A) $\text{kg} \cdot \text{m/s}$

B) $\text{N} \cdot \text{m}$

C) $\text{kg} \cdot \text{m}^2/\text{s}$

D) rad/s

21	- Solve problems involving angular momentum. - Solve problems involving the conservation of angular momentum.	EXAMPLE Pro. Q (2)	99
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EXAMPLE Problem 2

ANGULAR IMPULSE AND CHANGE IN ANGULAR MOMENTUM } At the conclusion of his competition routine, an ice-skater spins in one spot at a rate of 2.5 rotations per second. If you assume that his moment of inertia is 0.50 kg·m², what is his angular momentum? At the conclusion of the spin, the skater slowly and dramatically slows to a stop over 3.0 s by dragging the toe on one skate. What was the value and sign of the angular impulse on the skater? What average torque did the ice exert on the skater?

$$L = I\omega = 0.5 \times 5\pi = 7.85 \text{ Kg m}^2/\text{s}$$

$$\text{angular impulse} = \Delta L = I(\omega_f - \omega_i)$$

$$= 0.5 \times (0 - 5\pi) = -7.85 \text{ N.m.s}$$

$$\omega_f = 0$$

$$\Delta t = 3$$

$$\tau = \frac{\text{angular impulse}}{\Delta t} = \frac{-7.85}{3} = -2.62 \text{ Nm}$$

sign Value

X

I

1- A spinning wheel has a moment of inertia of 2 kg·m² and an angular velocity of 6 rad/s. What is its angular momentum?

A) 3 kg·m²/s ω

B) 8 kg·m²/s

C) 12 kg·m²/s

D) 18 kg·m²/s

$$L = I\omega$$

$$= 2 \times 6 = 12 \text{ Kg m}^2/\text{s}$$

2- A figure skater reduces her moment of inertia from 4 kg·m² to 2 kg·m² while spinning. If her initial angular velocity is 3 rad/s, what is her final angular velocity?

A) 1.5 rad/s $\omega_f = ?$

B) 3 rad/s

C) 6 rad/s

D) 12 rad/s

$$L_i = L_f$$

$$I_i \omega_i = I_f \omega_f$$

$$4 \times 3 = 2 \times \omega_f$$

$$\omega_f = \frac{4 \times 3}{2} = \frac{12}{2} = 6 \text{ rad/s}$$

I_i

I_f

ω_i

22	Discuss the forces and impulses exerted on one another in case of two-particle collision in one dimension.	Student Book Check Your Prog. Q (30,32)	101 110
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30. **Conservation of Momentum** During a tennis serve, the racket of a tennis player continues forward after it hits the ball. Is momentum conserved in the collision between the tennis racket and the ball? Explain, making sure you define the system.

Yes. If the system is defined as the tennis racket and the tennis ball together, the system is considered a closed and isolated system during the short collision. Therefore, the total momentum of the system is conserved because the forces between the racket and the ball are internal, equal, and opposite.

32. **Initial Momentum** During a soccer game, two players come from opposite directions and collide when trying to head the ball. The players come to rest in midair and fall to the ground. Describe their initial momenta.

The two players had equal and opposite initial momenta. Since the system is closed and isolated, momentum is conserved. Their total initial momentum was zero, which is why they came to rest after the collision.

1-During a one-dimensional collision between two objects, the force exerted by object 1 on object 2 is 20 N to the right. What is the force exerted by object 2 on object 1?

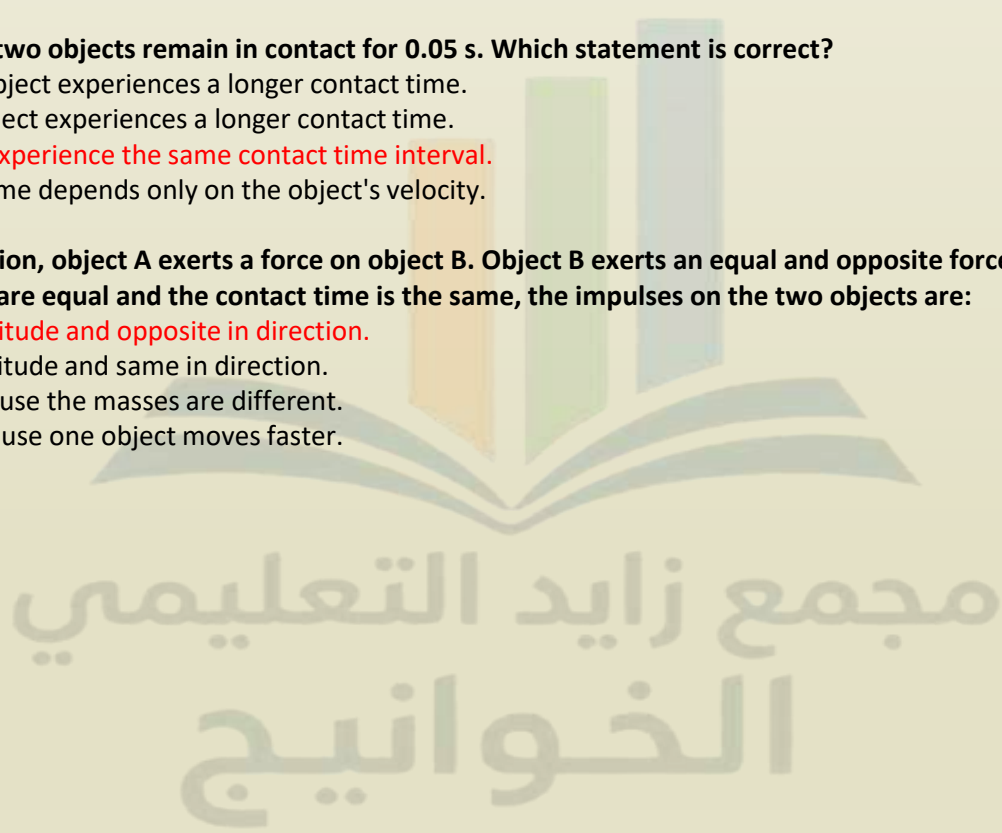
- A) 20 N to the right
- B) 10 N to the left
- C) 20 N to the left
- D) 40 N to the left

2- In a collision, two objects remain in contact for 0.05 s. Which statement is correct?

- A) The heavier object experiences a longer contact time.
- B) The lighter object experiences a longer contact time.
- C) Both objects experience the same contact time interval.
- D) The contact time depends only on the object's velocity.

3- During a collision, object A exerts a force on object B. Object B exerts an equal and opposite force on object A. Since the forces are equal and the contact time is the same, the impulses on the two objects are:

- A) Equal in magnitude and opposite in direction.
- B) Equal in magnitude and same in direction.
- C) Different because the masses are different.
- D) Different because one object moves faster.

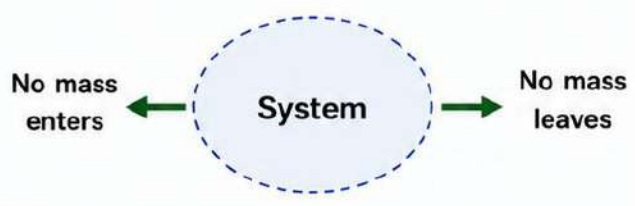


23	- Define a closed system as a system that does not gain or lose mass. - Define an isolated system as a closed system where the net of external forces is zero.	Student Book	102
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CLOSED AND ISOLATED SYSTEMS

CLOSED SYSTEM

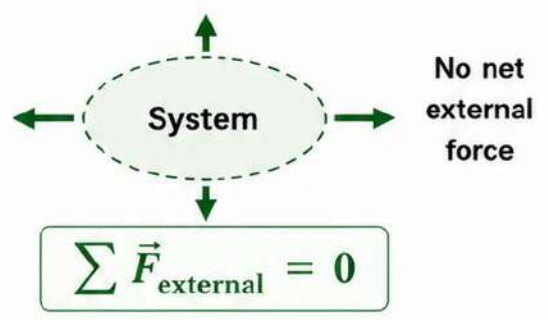
A closed system is a system that does not gain or lose mass.



- Mass remains constant.
(No mass enters or leaves the system)

ISOLATED SYSTEM

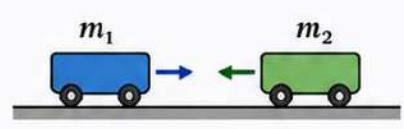
An isolated system is a closed system where the net external force is zero.



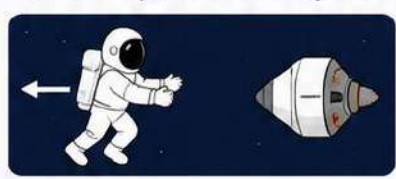
- No mass enters or leaves the system.
- Net external force equals zero.
- Total momentum remains constant.

EXAMPLES

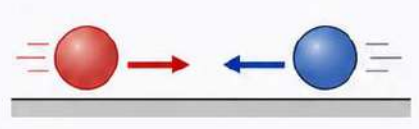
Two carts colliding on a smooth track



An astronaut pushing away from a spacecraft in space



Two balls colliding on a frictionless surface



1- Which statement correctly describes a closed system?

- A) A system where the net external force is zero.
- B) A system that does not gain or lose mass.**
- C) A system with no internal forces.
- D) A system with constant momentum only.

2- Which condition must be satisfied for a system to be considered isolated?

- A) The system must not gain or lose mass only.
- B) The net internal force must be zero.
- C) The system must be closed and the net external force must be zero.**
- D) The total momentum must be increasing.

3- A system does not gain or lose mass, but a net external force acts on it. This system is:

- A) Both closed and isolated.
- B) Neither closed nor isolated.
- C) Isolated but not closed.
- D) Closed but not isolated.**

24	Define the system and apply the law of conservation of linear momentum to different situations in one dimension like recoil, propulsion in space, or others to calculate different physical quantities.	Student Book EXAMPLE Pro. Q (3) EXAMPLE Pro. Q (4)	102~105 103 105
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EXAMPLE Problem 3

SPEED A 1875-kg car going 23 m/s rear-ends a 1025-kg compact car going 17 m/s on ice in the same direction. The two cars stick together. How fast do the two attached cars move immediately after the collision?

$$v_{f1} = v_{f2} = v_f$$

$$\rightarrow +x$$

$$m_1 v_{i1} + m_2 v_{i2} = m_1 v_{f1} + m_2 v_{f2}$$

$$(1875 \times 23) + (1025 \times 17) = (1875 \times v_f) + (1025 \times v_f)$$

$$v_f = 20.88 \text{ m/s} \approx 21 \text{ m/s}$$

~~X~~

EXAMPLE Problem 4

SPEED An astronaut at rest in $\oplus$ direction. space fires a thruster pistol that expels a quick burst of 35 g of hot gas at 875 m/s . The combined mass of the astronaut and pistol is 84 kg . How fast and in what direction is the astronaut moving after firing the pistol?

$$m_1 v_{i1} + m_2 v_{i2} = m_1 v_{f1} + m_2 v_{f2}$$

$$\begin{cases} v_{i1} = 0 \\ v_{i2} = 0 \end{cases}$$

$$0 + 0 = (35 \times 10^{-3} \times 875) + (84 \times v_{f2})$$

$$m_1 = 35 \times 10^{-3} \text{ kg}$$

$$v_{f2} = -0.36 \text{ m/s}$$

opposite direction to the hot gas
~~X~~


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25	- Explain the law of conservation of angular momentum and express it in equation form ($L_f = L_i$) - Discuss different examples that involve the law of conservation of angular momentum like in ice skating, tops, gyroscopes, and others. - Solve problems involving the conservation of angular momentum.	Student Book Figure. (13)	108 108
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A diver rotates at $\overset{\omega_i}{3}$ rad/s with a moment of inertia of $\overset{I_i}{4}$ kg·m². When the diver tucks into a ball, the moment of inertia decreases to 2 kg·m². What is the diver's new angular velocity?

- A) 1.5 rad/s
- B) 3 rad/s
- C) 6 rad/s
- D) 12 rad/s

$$\begin{aligned}
 &L_i = L_f \\
 &I_i \omega_i = I_f \omega_f \\
 &4 \times 3 = 2 \times \omega_f \\
 &\omega_f = \frac{4 \times 3}{2} = \frac{12}{2} = 6 \text{ rad/s}
 \end{aligned}$$

