# مراجعة الدرس الرابع Torque من الوحدة العاشرة منهج انسباير



| المزيد من الملفات بحسب الصف الحادي عشر المتقدم والمادة فيزياء في الفصل الثالث | |
|---|---|
| 1 | مراجعة الدرسين الأول والثاني Inertia of Moment of Calculation and Rotation of Energy Kinetic من الوحدة العاشرة منهج انسباير |
| 2 | مراجعة الدرس السابع Motion Circular for Examples More من الوحدة التاسعة منهج انسباير |
| 3 | مراجعة الدرس السادس Motion Linear and Circular من الوحدة التاسعة منهج انسباير |
| 4 | مراجعة الدرس الخامس Force Centripetal من الوحدة التاسعة منهج انسباير |
| 5 | حل تجميعة مراجعة نهائية وفق الهيكل الوزاري منهج بريدج |

# Unit 10 Rotation

## Section 10.4

## Torque

| | | | |
|---|---|---|---|
| (14) | Describe that a torque ($\vec{\tau}$) on a body involves a force ($\vec{F}$) and a position vector ($\vec{r}$), which extends from a rotation axis to the point where the force is applied. | Student Book | 297~298 |
| (15) | Identify that torque is a vector quantity, measured in the SI units of Nm. | Student Book | 297~298 |

| | | | | |
|---|---|---|---|---|
| [18] | 2nd Part | ↳ Identify the moment arm as the perpendicular distance from the line of action of the force to the axis of rotation.<br>↳ Calculate the torque due to a force on a particle by taking the cross product of the particle's position vector and the force vector.<br>$\vec{\tau} = \vec{r} \times \vec{F}$ ,, $\tau = rF\sin(\theta)$ | Student Book<br>Concept Check 10.4<br>Q.10.48<br>Q.10.49(a) | 297-298<br>298<br>318<br>319 |

Learning Objectives

# Section 10.4

## Torque

By the end of this section, you will be able to:

| | |
|---|---|
| (14) | Describe that a torque ($\vec{\tau}$) on a body involves a force ($\vec{F}$) and a position vector ($\vec{r}$), which extends from a rotation axis to the point where the force is applied. |
| (15) | Identify that torque is a vector quantity, measured in the SI units of Nm. |

**2nd Part**

- Identify the moment arm as the perpendicular distance from the line of action of the force to the axis of rotation.
- Calculate the torque due to a force on a particle by taking the cross product of the particle's position vector and the force vector.

$$\vec{\tau} = \vec{r} \times \vec{F} \quad ,, \quad \tau = rF\sin(\theta)$$

- In physics, the concept of torque refers to the force that causes objects to rotate or change direction.

- For example, when using a wrench, which is the tool used to tighten screws, a torque is generated.

- A force can be exerted at a point far from its center of mass, which may cause the body to rotate as well as move linearly.

- **In the adjacent figures, a person is trying to use a wrench to loosen the screw (bolt) shown in the figure using his hand.**

- **In which shape would it be easier to twist a screw?**


**FIGURE 10.16** (a)–(c) Three ways to use a wrench to loosen a bolt. (d) The force $\vec{F}$ and moment arm $r$, with the angle $\theta$ between them.

**Obviously, it would be easier to turn the screw in figure c , a little more difficult in figure b , and completely impossible in figure a .**

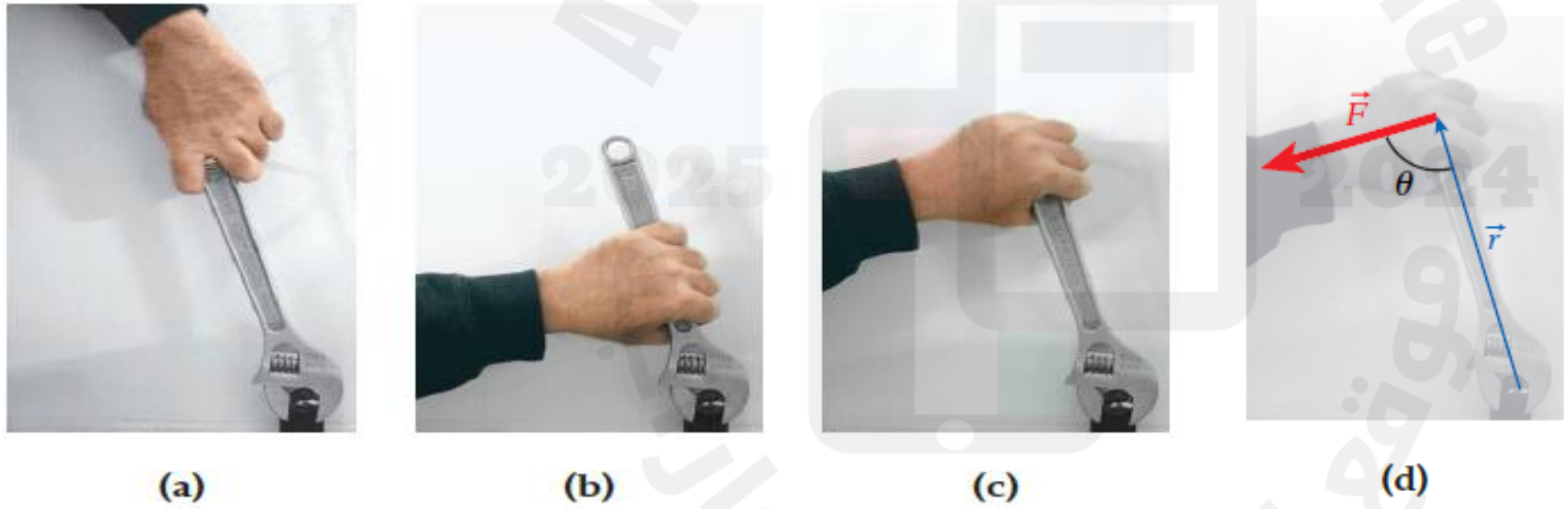



**FIGURE 10.16** (a)–(c) Three ways to use a wrench to loosen a bolt. (d) The force $\vec{F}$ and moment arm $r$, with the angle $\theta$ between them.

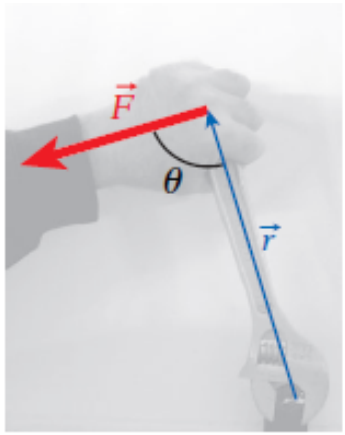
This example shows that the magnitude of the force is not the only relevant quantity.
The perpendicular distance from the line of action of the force to the axis of rotation, called the **moment arm**, is also important.
In addition, the angle at which the force is applied, relative to the moment arm, matters as well.

These considerations are quantified by the concept of torque, $\boldsymbol{\tau}$.

**Torque** (also called ***moment***) is the vector product of the force $\vec{F}$ **and the position vector** $\vec{r}$ .

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

$$\tau = rF \sin\theta$$




(d)

# WS # 25 :

Write the formula to find torque.

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

$$\tau = rF \sin \theta$$

The magnitude of the torque is the product of the magnitude of the force and the distance to the axis of rotation (the magnitude of the position vector, or the moment arm) times the sine of the angle between the force vector and the position vector.

# WS # 25 : (Exercise 1)

**1) What angle between the force and moment arm produces maximum torque?**

→ **90°** (since sin(90°) = 1, this gives maximum torque)

(b) (c)

**2) Why is torque zero when the force is applied directly along the lever arm?**

→ Because **sin(0°) = 0**, so τ = r × F × sin(0°) = 0 → No torque is generated.

- **Note:**

**$\tau$=0 At An angle of 180° or 0° (Figure a) will not turn the bolt.**

(a)

# WS # 25 : (Exercise 1)

**3) What is the SI unit of torque?**

$N.m$

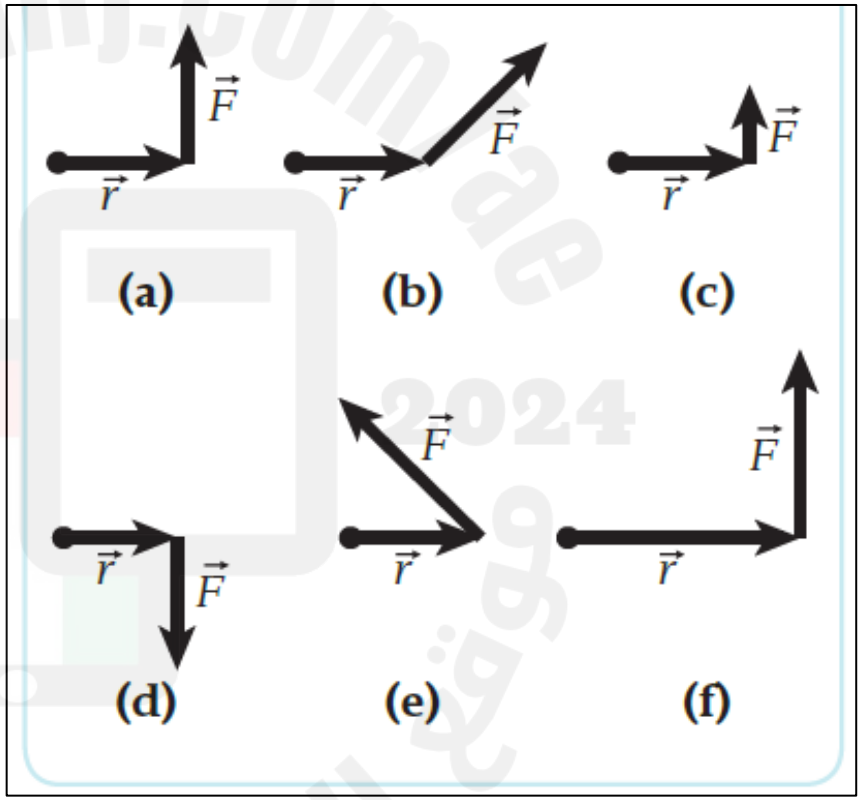
**4) Is torque a vector or a scalar quantity?**

**Torque is a vector quantity**, because it has both magnitude and direction.

# WS # 25 : (Exercise 2)

## Concept Check 10.4

Choose the combination of position vector, $\vec{r}$, and force vector, $\vec{F}$, that produces the torque of highest magnitude around the point indicated by the black dot.




Answer:

f

# WS # 25 : (Exercise 3)

$\tau = ?$

What is the torque on the screw produced by a force of 15 N acting perpendicular to a wrench 25 cm long , as shown in the figure?

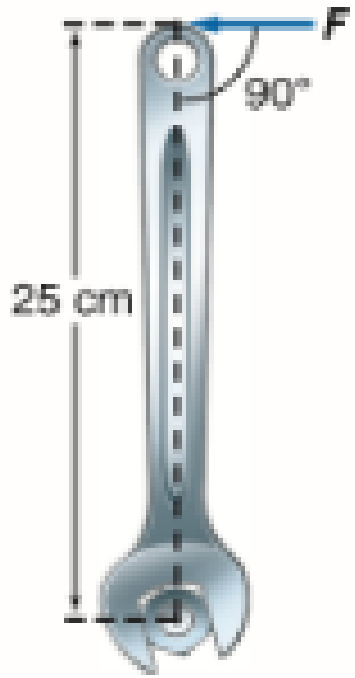
F

$\theta = 90^\circ$ $\quad r = 0.25\,m$

$$\tau = rF\sin\theta$$

$$= (0.25)(15)\sin 90^\circ$$

$$= 3.75\,N.m$$



# WS # 25 : (Exercise 4)

A screw to be tightened with a torque of 8.0 N.m , If you have a wrench that is 0.35 m long , what is the minimum amount of force you must exert?

$\tau$

$F = ?$

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

$$8 = (0.35) F \sin 90^\circ$$

$$F = 22.9\ N$$

# WS # 25 : (Exercise 5)

A person exerts a horizontal force of 42 N on the end of a door 0.70 m wide. What is the magnitude of the torque if the force is exerted perpendicular to the door?

يبذل شخص قوة أفقية مقدارها 42 N عند نهاية باب بعرض (0.70 m). ما مقدار عزم الدوران إذا تم بذل القوة عموديا على الباب؟

a. 0 N.m

b. 29.4 N.m

c. 60 N.m

d. 14.7 N.m

$\tau = rF\sin\theta$

$= (0.70)(42)\sin 90^\circ$

$\tau = 29.4\ \text{N.m}$

$|\vec{\tau}| = \sqrt{(-12)^2 + (8)^2 + (4)^2} = 14.9\ \text{N.m}$ magnitude of torque or $\vec{\tau} = (-12, 8, 4)\ \text{N.m}$

## WS # 25 : (Exercise 6)

$F_x$ $F_y$

**10.48** A force, $\vec{F} = (2\hat{x} + 3\hat{y})$ N, is applied to an object at a point whose position vector with respect to the pivot point is $\vec{r} = (4\hat{x} + 4\hat{y} + 4\hat{z})$ m. Calculate the torque created by the force about that pivot point.

$r_x$ $r_y$ $r_z$

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

$$\tau_x = r_y F_z - r_z F_y = (4 \times 0) - (4 \times 3) = -12$$

$$\tau_y = r_z F_x - r_x F_z = (4 \times 2) - (4 \times 0) = 8$$

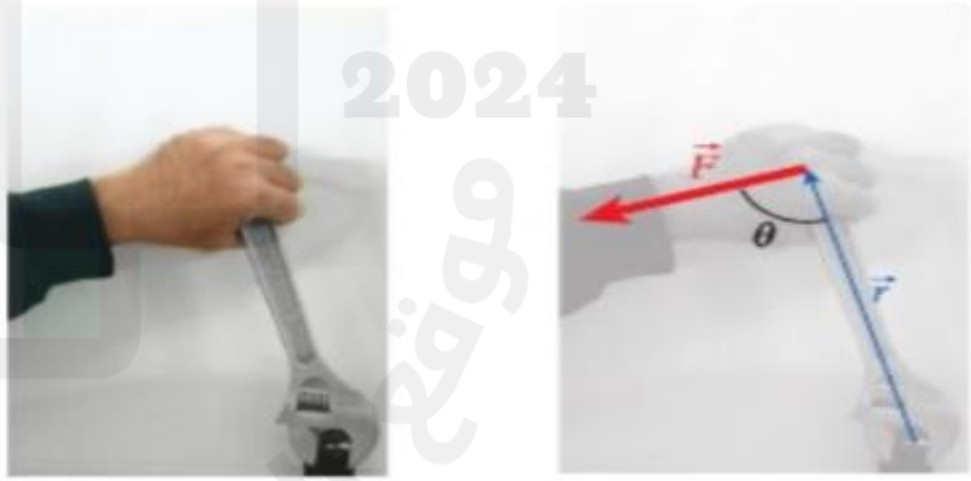
$$\tau_z = r_x F_y - r_y F_x = (4 \times 3) - (4 \times 2) = 4$$

$$\vec{\tau} = (-12\hat{x} + 8\hat{y} + 4\hat{z})\ \text{N.m}$$

**The rotation of the object about any fixed axis may be clockwise or counterclockwise.**

**In the adjacent figure, in which direction will the torque generated by the hand pulling the wrench be directed?**

**It will be counterclockwise.**



Torques around any fixed axis of rotation can be clockwise or counterclockwise. The net torque is defined as the difference between the sum of all clockwise torques and the sum of all counterclockwise torque

$$\tau_{\text{net}} = \sum_i \tau_{\text{counterclockwise},i} - \sum_j \tau_{\text{clockwise},j}$$

# WS # 26 :

- The right-hand rule is used to determine the direction of the torque vector.

  - Thumb pointing towards the position vector.
  - Index finger in the direction of the force vector.
  - The direction of the middle finger indicates the direction of the torque vector.

- **Note that the direction of the torque vector is perpendicular to both the force vector and the position vector.**

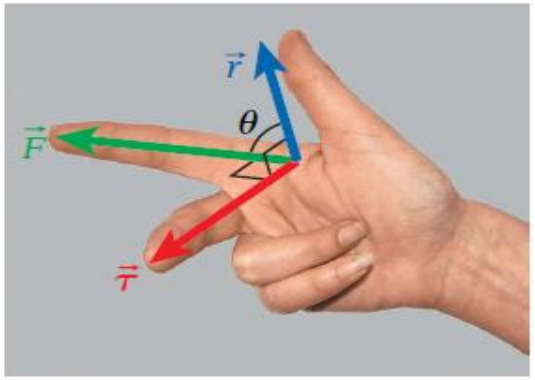



**FIGURE 10.17** Right-hand rule for the direction of the torque for a given force and position vector.

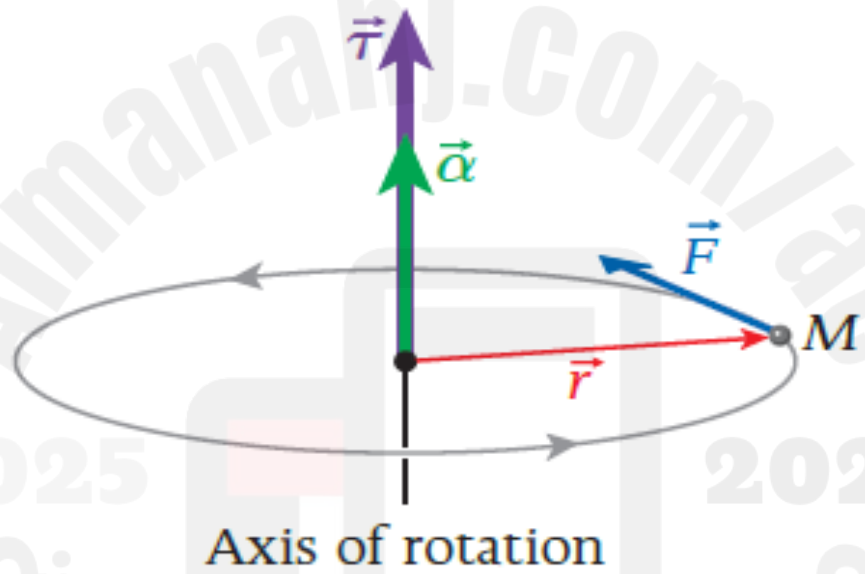
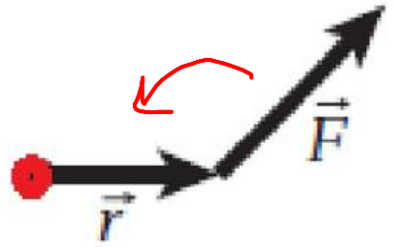



**FIGURE 10.18** A force exerted on a point particle creates a torque.

# WS # 26 : (Exercise 1)

What is the direction of the torque around the red point of the force vector and position vector that lie on the page plane shown in the figure?

ما اتجاه عزم الدوران حول النقطة الحمراء لمتجهي القوة ومتجه الموقع اللذان يقعان على مستوى الصفحة كما يظهر في الشكل؟




- ❑ Into the page. لداخل الصفحة
- ❑ Out of the page. لخارج الصفحة
- ❑ Clockwise. مع عقارب الساعة
- ❑ Counterclockwise. بعكس عقارب الساعة

# WS # 26 : (Exercise 2)

Which of the following is a correct unit of torque?

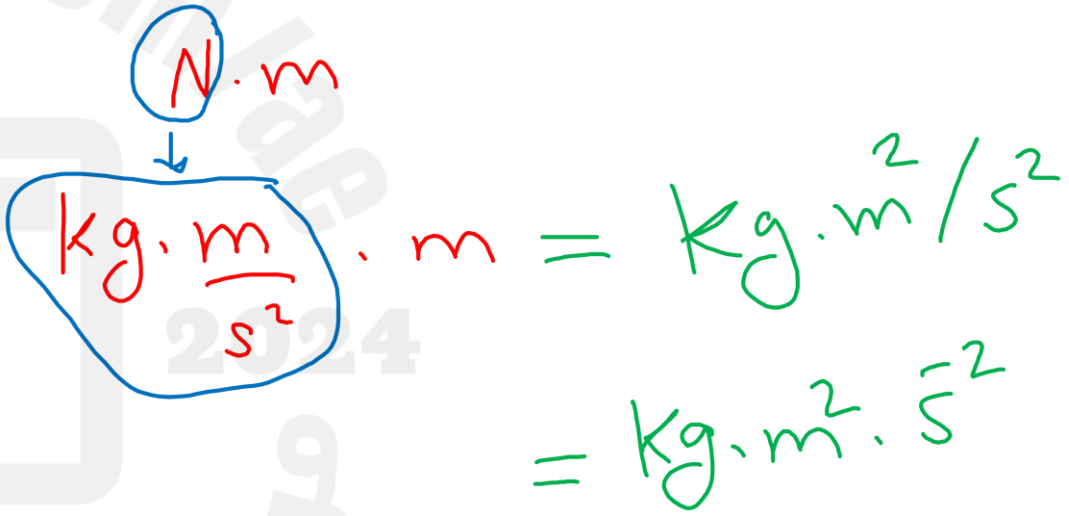
أي مما يلي وحدة قياس صحيحة لعزم الدوران؟

$kg.m^2.S^{-2}$

$kg.m^2.S^{-1}$

$kg.m.S^{-2}$

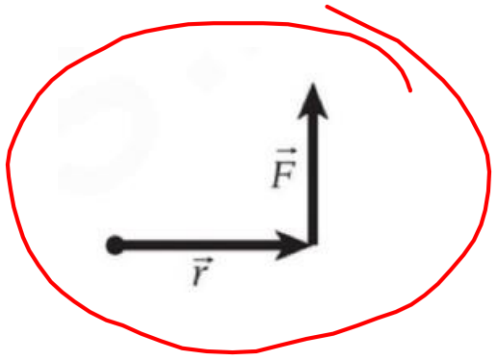
$kg.m^2.S^2$

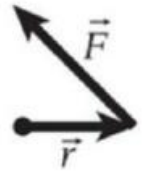


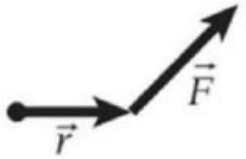
# WS # 26 : (Exercise 3)

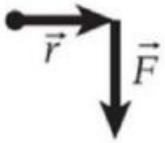
Which combination of position vector r, and force vector F, that produces the torque of highest magnitude around the point indicated by the black dot?

أي ثنائي من متجه الموقع r ، ومتجه القوة F ينتج أكبر عزم دوران حول النقطة التي تشير إليها النقطة السوداء؟



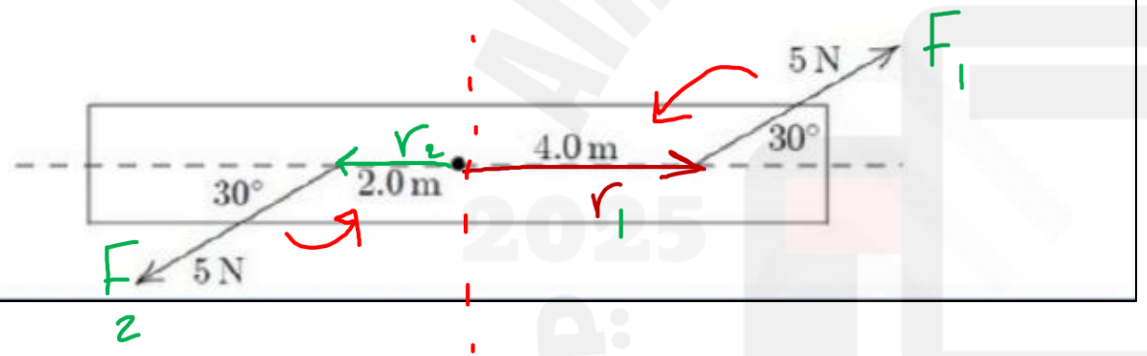



# WS # 26 : (Exercise 4)

A rod is pivoted about its center. A 5 N force is applied 4m from the pivot and another 5 N force is applied 2m from the pivot, as shown. What is the total torque about the pivot?

تدور عصا حول مركزها. يتم تطبيق قوة 5N على بعد 4m من المحور ويتم تطبيق قوة أخرى بمقدار 5N على بعد 2m من المحور ، كما هو موضح. ما محصلة عزم الدوران الكلي حول المحور؟




15 N/m clockwise
15 N/m مع اتجاه عقارب الساعة

15N.m
15 N/m counterclockwise
15 N/m عكس اتجاه عقارب الساعة

0 N/m

10 N/m clockwise
10 N/m مع اتجاه عقارب الساعة

$\tau_1 = rF\sin\theta$

$= (4)(5)\sin 30^\circ$

$= 10\ N.m$

counterclockwise

$\tau_2 = (2)(5)\sin 30^\circ$

$= 5\ N.m$

counter clockwise

$\Sigma\tau = 10 + 5 = 15\ N.m$

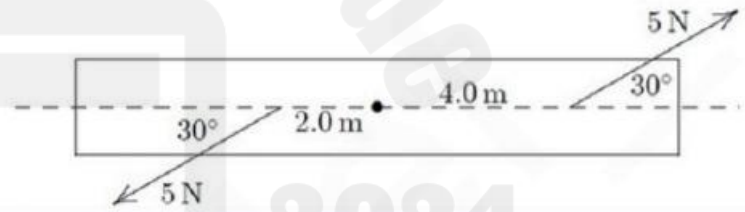
counter clockwise

# WS # 26 : (Exercise 5)

A rod is pivoted about its center. A 5 N force is applied 4m from the pivot and another 5 N force is applied 2m from the pivot, as shown. What is the direction of the rotation of the rod?

تدور عصا حول مركزها. يتم تطبيق قوة 5N على بعد 4m من المحور ويتم تطبيق قوة أخرى بمقدار 5N على بعد 2m من المحور ، كما هو موضح. ما اتجاه دوران العصا؟

**2022-2023**




a. clockwise
مع اتجاه عقارب الساعة

b. counterclockwise
عكس اتجاه عقارب الساعة

c. the rod is not rotating
العصا لا تدور

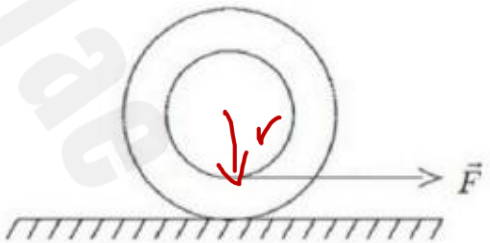
d. cannot be determined without knowing the mass of the rod
يمكن تحديده بدون معرفة كتلة العصا

# WS # 27 : (Exercise 1)

A yo-yo rests on a frictionless surface as shown. When a force F is applied to the string, what will happen to the yo-yo?

توضع لعبة يويو على سطح عديم الاحتكاك كما هو موضح بالشكل. عندما يتم تطبيق القوة F على الخيط، ماذا سيحدث لليويو؟

2022-2023




Counterclockwise

a. moves to the right and rotates counterclockwise
تتحرك لليمين وتدور عكس عقارب الساعة

b. moves to the le and rotates counterclockwise
تتحرك لليسار وتدور عكس عقارب الساعة

c. moves to the le and rotates clockwise
تتحرك لليسار وتدور مع عقارب الساعة

d. moves to the right and rotates clockwise
تتحرك لليمين وتدور مع عقارب الساعة

moves to the right and rotates counterclockwise
تتحرك لليمين وتدور عكس عقارب الساعة

# WS # 27 : (Exercise 2)

$r = \frac{30}{2} = 15\,cm = \frac{15}{100} = 0.15\,m$

●●**10.49** A disk with a mass of 14.0 kg, a diameter of 30.0 cm, and a thickness of 8.00 cm is mounted on a rough horizontal axle as shown on the left in the figure. (There is a friction force between the axle and the disk.) The disk is initially at rest. A constant force, $F = 70.0$ N, is applied to the edge of the disk at an angle of 37.0°, as shown on the right in the figure. After 2.00 s, the force is reduced to $F = 24.0$ N, and the disk spins with a constant angular velocity.


a) What is the magnitude of the torque due to friction between the disk and the axle?

$\tau_{net} = 0$

$\tau_f = ?$

$\tau = r f \sin\theta$

$= (0.15)(24)\sin 37°$

$= 2.17\,N\cdot m$

$\tau_{net} = \tau - \tau_f$

$0 = 2.17 - \tau_f$

$\tau_f = 2.17\,N\cdot m$