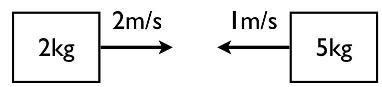
Sample Exam 2 Questions

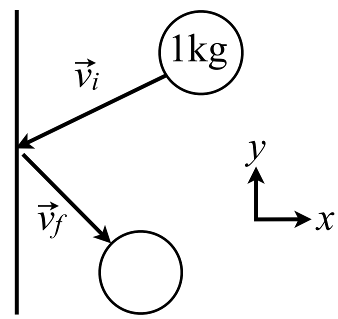
Physics 101, Fall 2016

$\boxed{3}$ **1.** <u>**A**</u> A 2 kg block is moving to the right at 2 m/s, and a 5 kg block is moving to the left at 1 m/s. What is the total momentum $\vec{p}$ of both blocks together?

A) $1\,\mathrm{kg\,m/s} \leftarrow$ **B)** $1\,\mathrm{kg\,m/s} \rightarrow$
C) $9\,\mathrm{kg\,m/s} \leftarrow$ **D)** $9\,\mathrm{kg\,m/s} \rightarrow$



2. A 1 kg ball is moving with velocity $\vec{v}_i = (-3\hat{x} - 3\hat{y})\,\mathrm{m/s}$ before it hits a vertical wall. Right after the collision, the ball's velocity is $\vec{v}_f = (1\hat{x} - 3\hat{y})\,\mathrm{m/s}$.



$\boxed{3}$ (a) <u>**A**</u> What is the change in the ball's momentum $\Delta\vec{p}$?

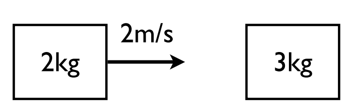
A) $4\hat{x}\,\mathrm{kg\,m/s}$ **B)** $-4\hat{x}\,\mathrm{kg\,m/s}$
C) $4\hat{x} - 3\hat{y}\,\mathrm{kg\,m/s}$ **D)** $-4\hat{x} + 6\hat{y}\,\mathrm{kg\,m/s}$
E) Other (explain)

$\boxed{2}$ (b) What is the impulse $\vec{J}$ of the wall on the ball?

$$\vec{J} = \Delta\vec{p} = 4\hat{x}\,\mathrm{kg\,m/s}$$

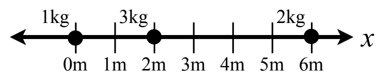
$\boxed{3}$ **3.** <u>**B**</u> A 2 kg block is moving at 2 m/s when it collides with a 3 kg block at rest. The collision is *maximally inelastic*. How fast is the 3 kg block moving after the collision?

A) 0 m/s **B)** 0.8 m/s **C)** 1.3 m/s **D)** 1.6 m/s **E)** 2 m/s **F)** 3 m/s



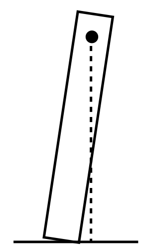
3 **4.** C Three masses sit on a number line as shown. Their center of mass is at the point marked

A) 1 m **B)** 2 m **C)** 3 m **D)** 4 m **E)** 5 m



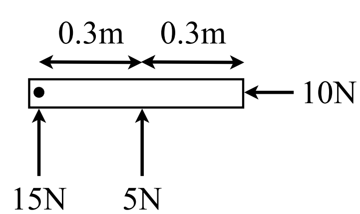
3 **5.** B This block has a center of mass at the location marked with the dot. Which is true?

A) The block feels a counterclockwise torque and will end up on its short end
B) The block feels a clockwise torque and will end up on its long end
C) The block feels no torque and remains balanced in that position

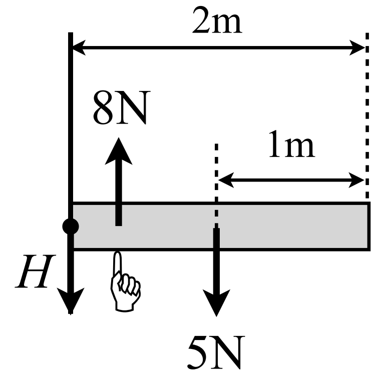


3 **6.** A The figure shows three forces applied to a door. Which force exerts the largest torque around the dot (the pivot)?

A) 5 N **B)** 10 N **C)** 15 N
D) Two or more exert the same torque. (Explain.)



7. The figure shows a 2 m long rod which is attached to the wall by a hinge. The rod has a weight of 5 N which pulls downward at the center of the rod. The hinge exerts a downward force H, and a finger exerts an 8 N force upward between the other two forces, as shown. The rod is in equilibrium.



$\boxed{3}$ (a) What is the magnitude of the force H?

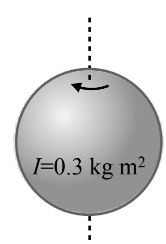
The total vertical force on the rod must be zero. Since 8 N is the force upward, and 5 N + H is the force downward, $\boxed{H = 3\,\mathrm{N}}$

$\boxed{3}$ (b) How far away is the finger from the hinge? (Note: the figure is not drawn to scale.)

Calculate the torque with the hinge as the pivot. H exerts no torque, and gravity exerts a torque of $\tau = (5\,\mathrm{N})(1\,\mathrm{m}) = 5\,\mathrm{Nm}$ clockwise. The finger must exert the same torque in the opposite direction, so

$$(8\,\mathrm{N})x = 5\,\mathrm{Nm} \implies x = \boxed{\frac{5}{8}\,\mathrm{m}}$$

8. A sphere with moment of inertia $I = 0.3\,\mathrm{kg}\cdot\mathrm{m}^2$ spins around its axis, so that it goes around once every 3.0 s. Other than the spinning, the sphere is stationary. *(No, you don't need the radius of the sphere.)*

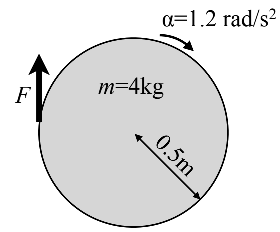


$\boxed{3}$ (a) **B** What is the sphere's angular velocity ω?
A) 0.33 rad/s **B)** 2.1 rad/s **C)** 3.0 rad/s **D)** 19 rad/s

It goes around once every 3 s so $f = \frac{1}{3\,\mathrm{s}}$, and

$$\omega = 2\pi f = \frac{2\pi}{3\,\mathrm{s}} = 2.1\,\mathrm{rad/s}$$

9. A 4 kg disk with radius 0.5 m starts at rest, and then a constant torque is applied for 3 s, causing it to accelerate at $\alpha = 1.2\,\text{rad/s}^2$. The moment of inertia of the disk is $I = 0.5\,\text{kg}\,\text{m}^2$.



$\boxed{3}$ (a) How many times does the disk go around during those 3 s? Give your answer in either radians or revolutions (but indicate which!)

This is a constant acceleration problem. We know $\Delta t = 3\,\text{s}$, $\omega_i = 0\,\text{rad/s}$, and $\alpha = 1.2\,\text{rad/s}^2$, and we want $\Delta\theta$, so we choose the equation

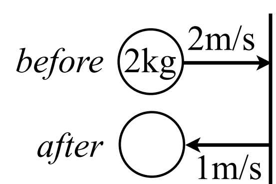
$$\Delta\theta = \omega_i \Delta t + \frac{1}{2}\alpha(\Delta t)^2 = 0 + \frac{1}{2}(1.2\,\text{rad/s}^2)(3\,\text{s})^2 = \boxed{5.4\,\text{rad}} = 0.86\,\text{rev}$$

It doesn't even go around once!

$\boxed{3}$ (b) What is the torque on the disk?

$$\tau = I\alpha = (0.5\,\text{kg}\,\text{m}^2)(1.2\,\text{rad/s}^2) = \boxed{0.6\,\text{N}\,\text{m}}$$

10. A 2 kg ball bounces off a wall. Before the collision it is moving at 2 m/s to the right; after, 1 m/s to the left.



$\boxed{3}$ (a) **A** The impulse $\vec{J}$ of the wall on the ball (which is equal to the change in the ball's momentum) is
A) $6\,\text{N}\cdot\text{s}$ to the left **B)** $2\,\text{N}\cdot\text{s}$ to the left
C) $2\,\text{N}\cdot\text{s}$ to the right **D)** $6\,\text{N}\cdot\text{s}$ to the right

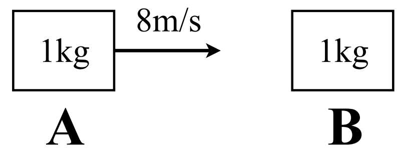
Let $+\hat{x}$ point to the right.

$$\vec{J} = \Delta\vec{p} = \vec{p}_f - \vec{p}_i$$

$$= (2\,\text{kg})(-1\,\text{m/s}\hat{x}) - (2\,\text{kg})(2\,\text{m/s}\hat{x})$$

$$= -(6\,\text{m/s})\hat{x}$$

11. A 1 kg block A moves at 8 m/s to the right towards a stationary 1 kg block B.



3 (a) What is the total momentum of both blocks?

$\vec{p}_{tot} = \vec{p}_1 + \vec{p}_2 = (1\,\text{kg})(8\,\text{m/s} \rightarrow) + 0 = 8\,\text{kg}\cdot\text{m/s}$ to the right

3 (b) **B** Before the collision, the system's center of mass is

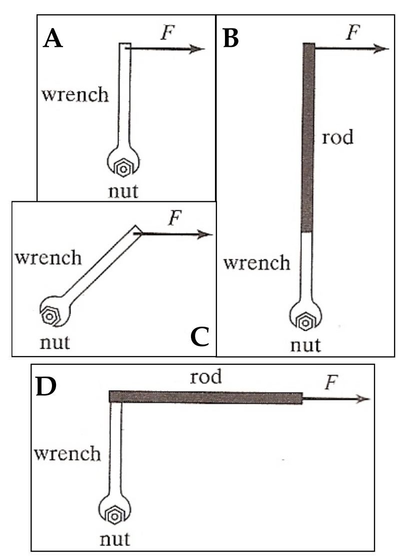
A) stationary
B) moving to the right at 4 m/s
C) moving to the right at 8 m/s

$$\vec{p}_{tot} = m_{tot}\vec{v}_{com} \implies \vec{v}_{com} = \frac{1}{m_{tot}}\vec{p}_{tot} = \frac{1}{2\,\text{kg}}(8\,\text{kg}\cdot\text{m/s}) = 4\,\text{kg}\cdot\text{m/s}$$

3 (c) **E** If the two blocks collide and the collision is maximally inelastic, what are the final speeds of the two blocks?

	Velocity of A	Velocity of B
A)	8 m/s ←	0 m/s
B)	8 m/s ←	8 m/s →
C)	4 m/s ←	4 m/s →
D)	0 m/s	8 m/s →
E)	4 m/s →	4 m/s →
F)	8 m/s →	8 m/s →

12. You are using a wrench and trying to loosen a rusty nut, using the same applied force F in four different configurations (as shown).



2 (a) **A** The torque in B is . . . the torque in A.
A) greater than **B)** equal to **C)** less than

Longer lever arm

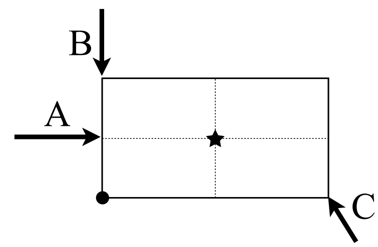
2 (b) **C** The torque in C is . . . the torque in A.
A) greater than **B)** equal to **C)** less than

The force isn't perpendicular to the lever arm (the wrench) so it doesn't exert as much torque.

2 (c) **B** The torque in D is . . . the torque in A.
A) greater than **B)** equal to **C)** less than

$\tau = r_\perp F$, and $r_\perp$ is the same for both.

13. Three forces act on a block as shown.



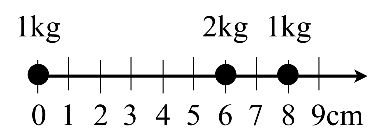
2 (a) B If the pivot is at the star at the center of the block, the force B contributes
A) a clockwise torque
B) a counterclockwise torque
C) no torque

2 (b) C If the pivot is at the dot in the bottom-left corner, the force B contributes
A) a clockwise torque
B) a counterclockwise torque
C) no torque

+3 (c) **Extra credit:** Explain why this block cannot be in equilibrium, if the three forces point in the directions shown, no matter what the magnitudes of the forces are.

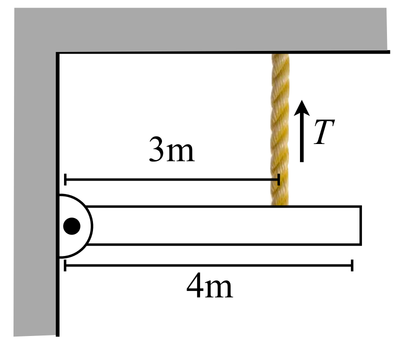
If we consider the star as the pivot, then A contributes no torque, and B and C both contribute a counterclockwise torque. Thus the net torque around the star cannot be zero, and so the block cannot be in equilibrium.

3 **14.** B Three masses sit on a number line as shown. At what point on the number line does their center of mass lie?
A) 4 cm **B)** 5 cm **C)** 6 cm **D)** 7 cm

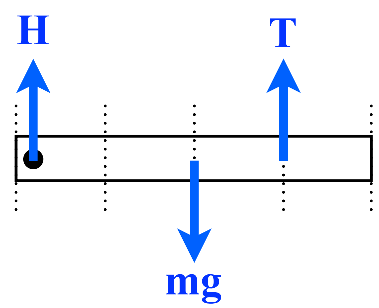


$$x_{com} = \frac{m_1x_1 + m_2x_2 + m_3x_3}{m_1 + m_2 + m_3} = \frac{(1\,\mathrm{kg})(0\,\mathrm{cm}) + (2\,\mathrm{kg})(6\,\mathrm{cm}) + (1\,\mathrm{kg})(8\,\mathrm{cm})}{4\,\mathrm{kg}} = \boxed{5\,\mathrm{cm}}$$

15. A $4\,\mathrm{m}$ long rod of uniform density and mass m is attached to a wall by a hinge, and to the ceiling by a rope with tension T which is attached $1\,\mathrm{m}$ from the right end of the rod. The rod is in equilibrium.



$\boxed{3}$ (a) Draw the three forces acting on the rod, at the points where the forces are acting. Call the hinge's force H. All forces are vertical. (The dotted lines are a meter apart.)



Gravity acts at the center of mass. The hinge must exert an upward force if the bar is in equilibrium: if the pivot is at the center of mass, then H must counteract the counterclockwise torque of the tension.

$\boxed{3}$ (b) __B__ The tension T in the rope is

A) $\frac{1}{2}mg$ **B)** $\frac{2}{3}mg$ **C)** $\frac{3}{4}mg$ **D)** mg **E)** $\frac{4}{3}mg$

Let the hinge be the pivot. The torque caused by gravity is $mg(2\,\mathrm{m})$ clockwise, and the torque caused by the rope is $T(3\,\mathrm{m})$ counterclockwise. For the bar to be in equilibrium these torques must be equal in magnitude:

$$(2\,\mathrm{m})mg = (3\,\mathrm{m})T \implies T = \frac{2}{3}mg$$

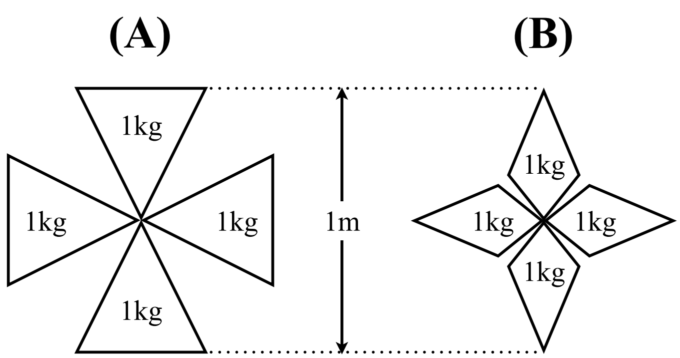
(which incidentally makes $H = \frac{1}{3}mg$*.)*

$\boxed{3}$ **16.** The Earth spins around its axis once a day (86,400 s). The Earth's radius is $R = 6.4 \times 10^6$ m. What is the Earth's angular velocity ω?

The Earth's rotational period is $T = 86400\,\text{s}$; in that time it rotates 2π radians, so its angular velocity is

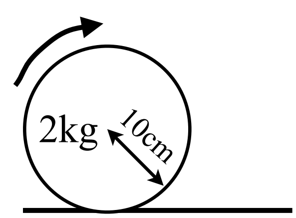
$$\omega = \frac{2\pi}{T} = \frac{2\pi}{86400\,\text{s}} = \boxed{7.27 \times 10^{-5}}\,\text{rad/s}$$

$\boxed{3}$ **17.** __A__ The figure shows two fans; both fans have the same mass and radius. Which one has the greater moment of inertia I?



A has its mass distributed farther from the center.

18. A wheel ($I = \frac{1}{2}MR^2$) with radius $R = 0.1$ m and a mass of 2 kg is rolling along a street at 5 m/s.



$\boxed{3}$ (a) What is the angular velocity ω of the wheel?

For a rolling object,

$$\omega = \frac{v}{r} = \frac{5\,\text{m/s}}{0.1\,\text{m}} = 50\,\text{rad/s}$$