Physics 101 Exam 2 Solutions

November 14, 2016

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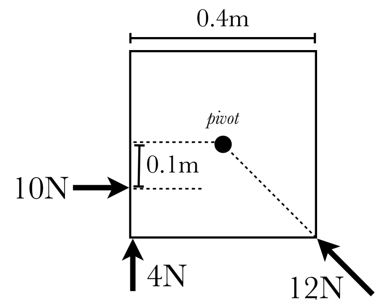
1. Three forces are applied to a square with side 0.4 m, as shown. Consider their associated torques around the pivot, which is at the center of the box.



$\boxed{3}$ (a) **B** What is the torque due to the 10 N force?

A) 0 Nm **B)** 1 Nm **C)** 2 Nm **D)** 4 Nm **E)** 10 Nm

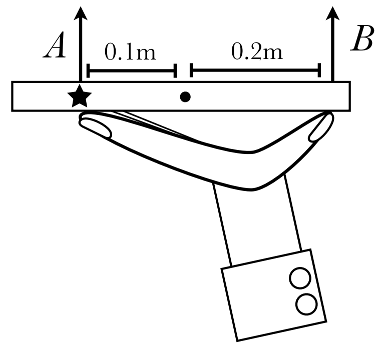
$\boxed{3}$ (b) **B** Which force exerts the largest torque?

A) 4 N **B)** 10 N **C)** 12 N

$\boxed{3}$ (c) **A** What direction does the 4 N torque point?

A) clockwise ↻ **B)** counterclockwise ↺

$\boxed{4}$ 2. A waiter carries a plate with weight $mg = 6\,\mathrm{N}$ in one hand, as shown. The plate is in equilibrium, and its center of mass is at the dot The fingers exert a force A upward on the plate, and the thumb a force B.



(a) If upward is positive, write an expression for the net force F_{net} on the plate, in terms of A and B.

$$A + B - 6$$

(b) If counterclockwise is positive, write an expression for the net torque τ_{net} on the plate. The pivot is marked by the star.

$$0.3B - 0.1mg \quad \text{or} \quad 0.3B - 0.6$$

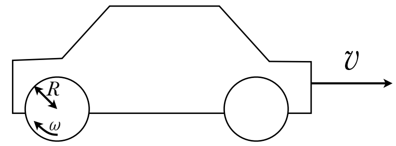
(c) Find the magnitude of the force A.

Net force and torque are both zero.

$$0.3B - 0.6 = 0 \implies B = 2$$

$$A + B - 6 = 0 \implies A = 6 - B = \boxed{4\,\mathrm{N}}$$

3. A car has wheels of radius $R = 0.21\,\mathrm{m}$. As the car drives along the road, each wheel spins with an angular velocity of $\omega = 240\,\mathrm{rad/s}$.



$\boxed{3}$ (a) **B** What is the period of the wheel? That is, how long does it take for the wheel to go around once?

A) 0.0041 s **B)** 0.026 s **C)** 0.038 s **D)** 38 s

$$T = \frac{1}{f} = \frac{2\pi}{\omega} = \frac{2\pi}{240} = 0.026$$

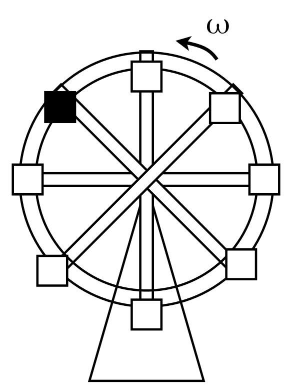
$\boxed{3}$ (b) **A** How fast is the car moving? (i.e. What's v?)

A) 50 m/s **B)** 100 m/s **C)** 240 m/s **D)** 1140 m/s

$$v = R\omega = (0.21)(240) = 50\,\mathrm{m/s}$$

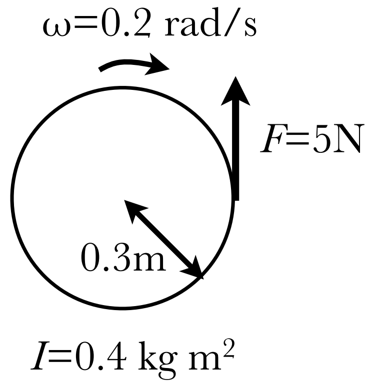
$\boxed{3}$ 4. **E** A Ferris wheel is rotating counterclockwise. If its spin is slowing down, the passengers in the black car will feel an acceleration in which direction?

A) $\nwarrow$ **B)** $\uparrow$ **C)** $\nearrow$
D) $\leftarrow$ **E)** $\rightarrow$
F) $\swarrow$ **G)** $\downarrow$ **H)** $\searrow$



Circular acceleration $\searrow$, tangential acceleration $\nearrow$

5. A disk with radius 0.3 m and rotational inertia $I = 0.4\,\mathrm{kg}\cdot\mathrm{m}^2$ is spinning clockwise with angular velocity $\omega = 0.2\,\mathrm{rad/s}$. A 5 N force is applied upward on the right-hand side of the disk.



3 (a) **A** What is the torque τ on the disk, due to the 5 N force?

A) 1.5 Nm **B)** 5 Nm **C)** 17 Nm

$$\tau = rF = (0.3\,\mathrm{m})(5\,\mathrm{N}) = 1.5\,\mathrm{Nm}$$

3 (b) What is the angular acceleration α of the disk due to the application of the torque?

$$\alpha = \frac{\tau}{I} = \frac{1.5\,\mathrm{Nm}}{0.4\,\mathrm{kg}\cdot\mathrm{m}^2} = \boxed{3.75\,\mathrm{rad/s^2}}$$

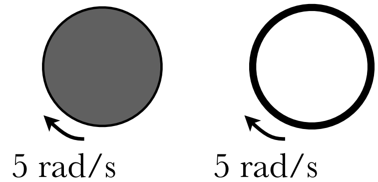
6. A wheel starts off spinning clockwise with an angular velocity of $\omega_i = 5\,\mathrm{rad/s}$. It makes 20 full turns, slowing at a constant rate until it is spinning at $\omega_f = 1\,\mathrm{rad/s}$ clockwise instead. How long Δt does the slowing process take? (Fill out this table for partial credit.)

$\Delta\theta$	**20 rev =40π rad**
ω_i	**5 rad/s**
ω_f	**1 rad/s**
α	DKDC
Δt	NEED

$$\Delta\theta = \frac{1}{2}(\omega_i + \omega_f)\Delta t$$

$$\implies \Delta t = \frac{2\Delta\theta}{\omega_i + \omega_f} = \frac{2(40\pi)}{5+1} = \boxed{42\,\mathrm{s}}$$

7. Consider a solid disk (think "cookie") and a ring (think "hula hoop"), both with the same mass and radius, and both spinning at 5 rad/s.



$\boxed{3}$ (a) B Which has the larger rotational inertia I?

A) disk **B)** ring **C)** both the same

$\boxed{3}$ (b) B Which has the larger angular momentum L?

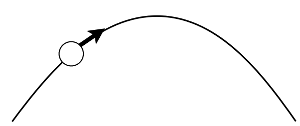
A) disk **B)** ring **C)** both the same

$\boxed{3}$ 8. B Which of the following is a measure of angular velocity?

A) angular displacement $\Delta\theta$ **B)** frequency f **C)** torque τ

$\boxed{3}$ 9. F True or False: If I throw a ball across the room, momentum is conserved during its flight (ignoring air resistance).

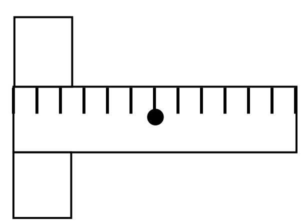
The ball feels an external force,
so momentum is not conserved.



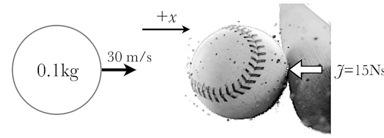
$\boxed{3}$ 10. B A T-square is hung on a wall by a nail placed at the point shown. What is the direction of the torque on the square due to gravity?

A) clockwise ↻ **B)** counterclockwise ↺

C) There is no torque.



11. A 0.1 kg baseball travels at 30 m/s to the right when it collides with a baseball bat, which imparts an impulse of $J = 15\,\mathrm{Ns}$ to the left on the baseball.



$\boxed{3}$ (a) **A** What is the momentum p_{ix} of the ball before it collides with the bat?

A) 3 Ns **B)** 15 Ns **C)** 30 Ns **D)** 45 Ns

$$p_{ix} = mv_i = (0.1\,\mathrm{kg})(30\,\mathrm{m/s}) = 3\,\mathrm{Ns}$$

$\boxed{3}$ (b) **C** What is the momentum p_{fx} of the ball right after it collides with the bat? Positive is to the right.

A) -30 Ns **B)** -18 Ns **C)** -12 Ns **D)** -3 Ns **E)** 15 Ns **F)** 18 Ns

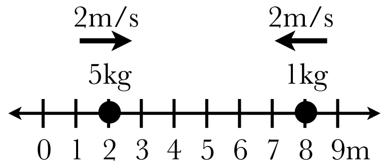
$$p_f = p_i + J = 3\,\mathrm{Ns} - 15\,\mathrm{Ns} = -12\,\mathrm{Ns}$$

$\boxed{3}$ (c) **D** If the ball is in contact with the bat for 0.001 s, what is the average force on the ball?

A) 0.015 N **B)** 7.5 N **C)** 15 N **D)** 15,000 N

$$F_{avg} = J/\Delta t = 15\,\mathrm{Ns}/0.001\,\mathrm{s} = 15{,}000\,\mathrm{N}$$

12. A 5 kg mass is at $x = 2\,\text{m}$, and a 1 kg mass is at $x = 8\,\text{m}$, as shown.



$\boxed{3}$ (a) **A** What is the position x of the particle's center of mass, at the moment pictured?

A) 3 m **B)** 4 m **C)** 5 m **D)** 6 m **E)** 7 m

$$\frac{(5\,\text{kg})(2\,\text{m}) + (1\,\text{kg})(8\,\text{m})}{5\,\text{kg} + 1\,\text{kg}} = \frac{18}{6} = 3\,\text{m}$$

$\boxed{3}$ (b) **C** If both blocks are moving at $2\,\text{m/s}$ towards each other, what is their total momentum?

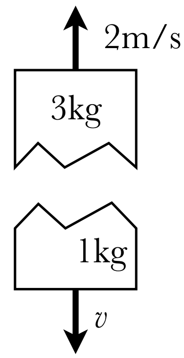
A) 0 Ns **B)** 4 Ns **C)** 8 Ns **D)** 12 Ns **E)** 16 Ns

$$(5\,\text{kg})(2\,\text{m/s}) + (1\,\text{kg})(-2\,\text{m/s}) = 8\,\text{Ns}$$

$\boxed{3}$ (c) As the balls approach one another, the position of their center of mass changes. With what speed is the center of mass moving?

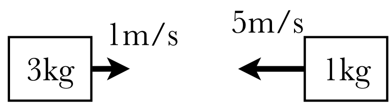
$$p_{tot} = m_{tot} v_{com} \implies v_{com} = \frac{p_{tot}}{m_{tot}} = \frac{8\,\text{Ns}}{6\,\text{kg}} = \boxed{\frac{4}{3}\,\text{m/s}}$$

$\boxed{3}$ 13. A 4 kg rectangle at rest suddenly explodes into two parts. A 3 kg piece is moving at 2 m/s upward right after the explosion. What is the speed v of the other piece right after the explosion?



The total momentum must be zero. The momentum of the top piece is $6\,\mathrm{Ns}$ upward, so the momentum of the bottom piece must be $(1\,\mathrm{kg})v = 6\,\mathrm{Ns}$ downward, so $\boxed{v = 6\,\mathrm{m/s}}$.

$\boxed{3}$ 14. **A** A 3 kg block and a 1 kg block, as shown, collide and stick together. How fast will the blocks be moving after the collision? Positive is to the right.



A) $0.5\,\mathrm{m/s} \leftarrow$ **B)** $3\,\mathrm{m/s} \leftarrow$ **C)** $4\,\mathrm{m/s} \leftarrow$ **D)** $0\,\mathrm{m/s}$
E) $0.5\,\mathrm{m/s} \rightarrow$ **F)** $3\,\mathrm{m/s} \rightarrow$ **G)** $4\,\mathrm{m/s} \rightarrow$

The initial momentum is

$$p_i = (3\,\mathrm{kg})(1\,\mathrm{m/s}) + (1\,\mathrm{kg})(-5\,\mathrm{m/s}) = -2\,\mathrm{Ns}$$

If both move at velocity v afterwards, the final momentum is

$$p_f = (3\,\mathrm{kg} + 1\,\mathrm{kg})v$$

Thus

$$(4\,\mathrm{kg})v = -2\,\mathrm{Ns} \implies v = -\frac{1}{2}\,\mathrm{m/s}$$