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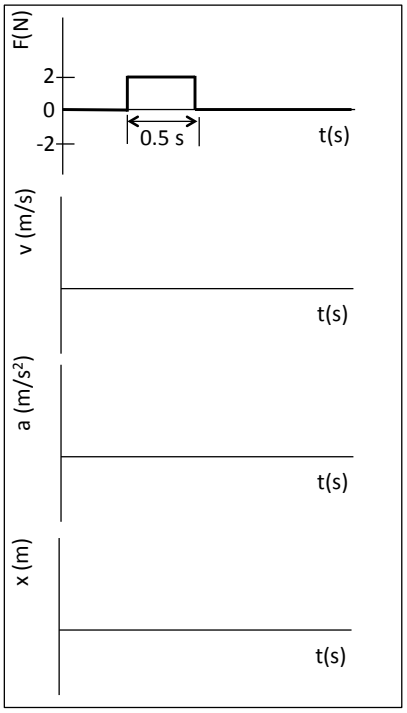
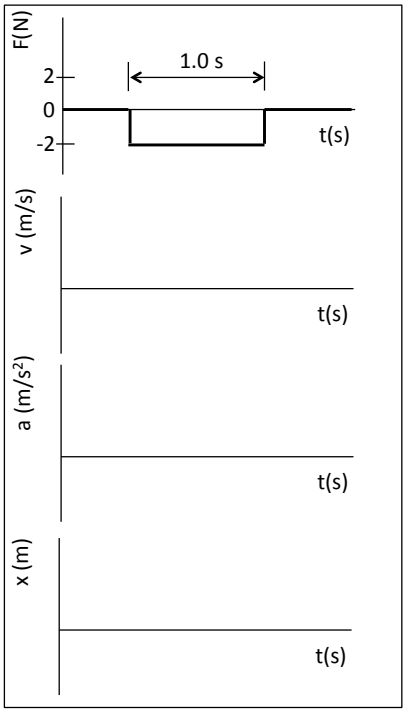
Worksheet 5: Momentum and Rot. Motion

1 Impulse

At t=0 a 2 kg object starts moves away from the origin to the right with a constant speed of 1 m/s when at t=0.5 s it experiences an impulse due the the force shown in the graph. Do your best to plot the object's velocity, acceleration, and position. Use the equations, $I = \Delta p = F\Delta t$.





2 Races

A) Blocks A and B, both initially at rest, are pushed to the right continuously by identical constant forces. Block B is more massive than Block A. Which block crosses the finish line with more momentum?

B) Same situation as in A) except now A and B have equal mass, but A already has velocity when it crosses the starting line. Which block undergoes a larger *change* in momentum?

C) Same situation as in A) except now there isn't a finish line but the force is only applied for 1.0 s. Which block has more momentum after 1.0 s?

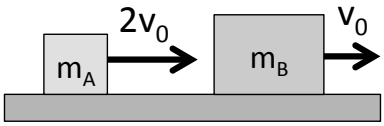
3 Elastic collisions

The formulas for perfectly elastic collisions are the following:

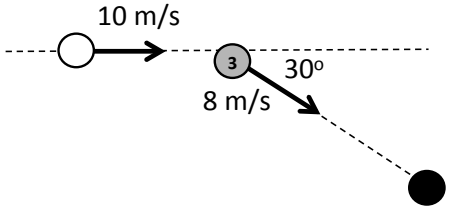
$$v_{1f} = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) v_{1i} + \left(\frac{2m_2}{m_1 + m_2}\right) v_{2i}$$
$$v_{2f} = \left(\frac{2m_1}{m_1 + m_2}\right) v_{1i} + \left(\frac{m_2 - m_1}{m_1 + m_2}\right) v_{2i}$$

A) A 12.0 g bouncy ball is used to knock over a 100 g wood post in a carnival game. The ball hits the post with 20 m/s and the collision is perfectly elastic. What is the final velocity of the wood post?

B) Mass A has has velocity 2 v_0 moving to the right and mass B, which is three times as massive, has velocity v_0 also to the right. Mass A starts out to the left of mass B, but catches up and collides with mass B elastically. What are the final velocities of mass A and mass B?



C) Billiard balls are all 160 g. If you shoot the white ball at the number 3 ball (which is initially at rest) with an initial velocity of 10 m/s so that the number 3 ball has a velocity of 8 m/s and goes into the corner pocket, what is the final speed and direction of the white ball? Assume the collision is perfectly elastic.



4 Inelastic collisions

A) A 12.0 g ball of clay is used to knock over a 100 g wood post in a carnival game. The ball hits the post with 20 m/s and the collision is perfectly inelastic. What is the final velocity of the wood post and clay?

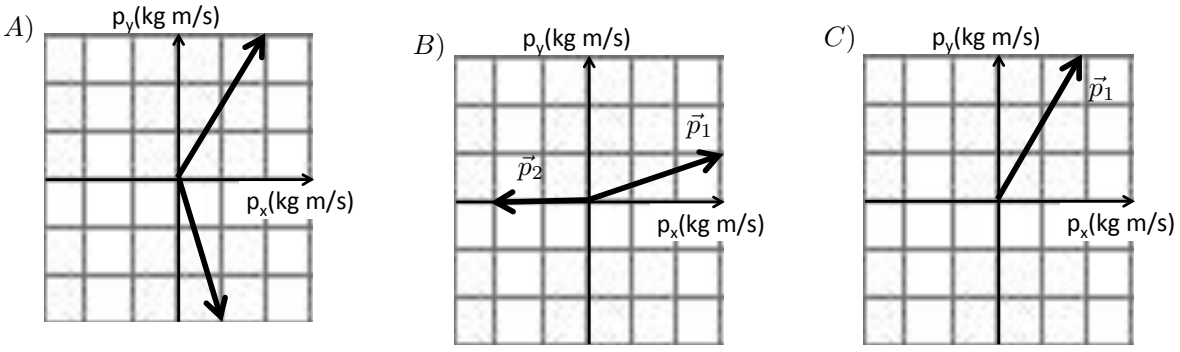
B) Mass A has has velocity 2 v_0 moving to the right and mass B, which is three times as massive, has velocity v_0 also to the right. Mass A starts out to the left of mass B, but catches up and collides with mass B inelastically. What is the final velocity of mass A and mass B?

C) A 1500 kg car is rolling at 2.0 m/s. You would like to stop the car by firing a 10 kg blob of sticky clay at it. How fast should you fire the clay?

D) A 50 kg archer, standing on frictionless ice, shoots a 100 g arrow at a speed of 100 m/s. What is the recoil speed of the archer?

E) Dan is gliding on his skateboard at 4 m/s. He suddenly jumps backward off the skateboard, kicking the skateboard forward at 8 m/s. How fast is Dan going as his feet hit the ground? Dan's mass is 50 kg and the skateboard's mass is 5 kg.

Draw the missing momentum vector for the description of the collision.



A) An object initially at rest explodes into three fragments. Draw $\vec{p}_3$.

An 2 kg object moving in the positive direction y direction with a velocity 2 m/s explodes into 3 fragments. Draw $\vec{p}_3$.

C) The initial momentum of object 1 is shown. Draw the initial momentum of object 2 if the two collide inelastically end up with a final x momentum -1 kg m/s.

5 Rotational Kinematics

Determine the signs (+ or –) for ω and α.

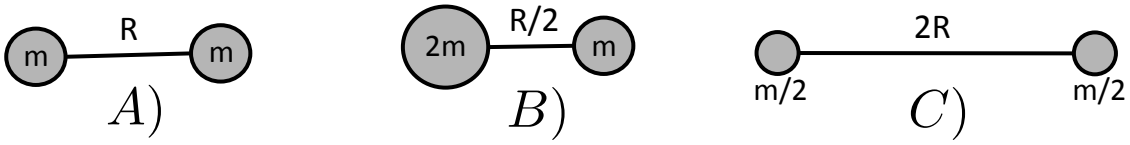
A)
Counterclockwise, speeding up.
ω _____
α _____

B)
Clockwise, speeding up.
ω _____
α _____

C)
Counterclockwise, slowing down.
ω _____
α _____

D)
Clockwise, slowing down.
ω _____
α _____

6 Moment of Inertia

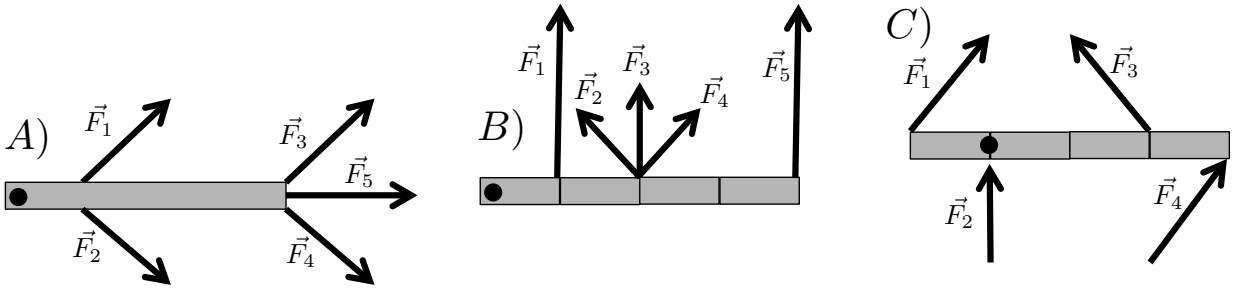


Rank the moments of inertia I_A, I_B, I_C about the midpoint of each connecting rod:

What is the moment of inertia I_B about its center of mass?

7 Torque

For each case, rank the torques from most negative to most positive.

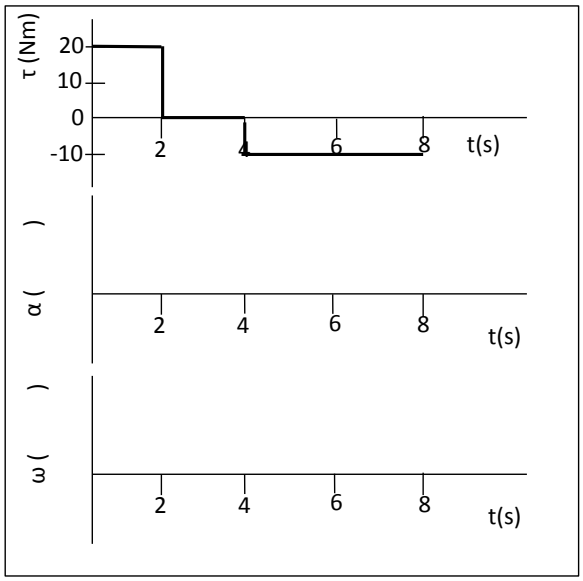


A) Five forces with equal magnitude are applied to a door and we are looking at it with a birds-eye-view.

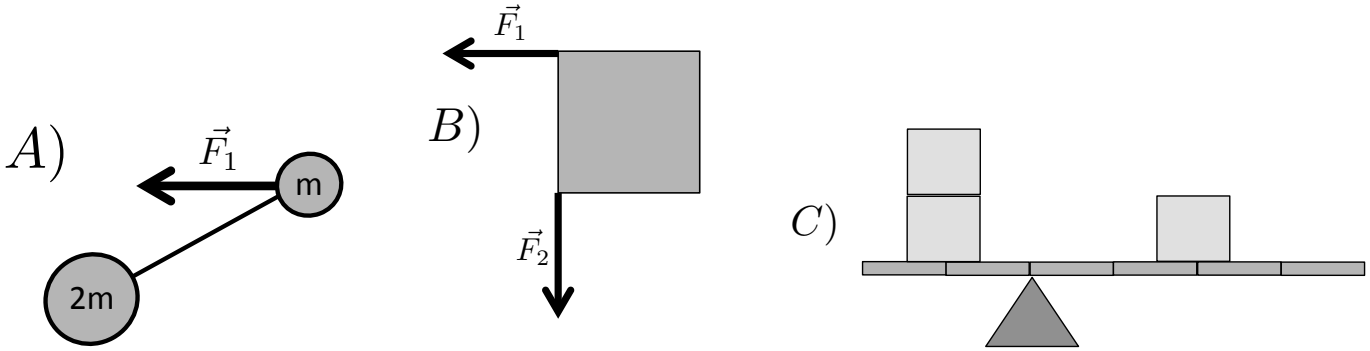
B) The door has been divided into four equal segments. $\vec{F}_1$ and $\vec{F}_2$ are twice as strong as the other three.

C) Here the pivot point has moved. The forces are all equal in magnitude.

The top graph shows the torque on a rotating wheel as a function of time. The wheel's moment of inertia is 10 kg m^2. Draw graphs of α vs t and ω vs t assuming $\omega_0 = 0$.



8 Rotational equilibrium



A) Draw a force on the heavier mass such that the dumbbell will have translational motion but not rotational motion.

Forces $\vec{F}_1$ and $\vec{F}_2$ have the same magnitude. They are applied to the corners of the square plate shown. Draw and label a single force vector F_3 to create total static equilibrium.

C) The see-saw shown has the same mass as each of the boxes put on top of it. Add a single box to the see-saw so that it will be in equilibrium.

9 Angular momentum

A) A hoop of mass M and radius R is rotating with angular speed 60 rpm about its axis. What would be its angular speed if its mass suddenly doubled? What if its radius doubled without changing its mass?

B) A disk of mass M and radius R is rotating with angular speed 60 rpm about its axis. A wad of clay of mass m is dropped on dropped on the outer radius. What is the new angular speed? How much energy has been lost?

10 Conservation of Energy with Rotation

A solid cylinder and a solid sphere of equal mass and equal radius roll without slipping down a ramp. Which will have a larger final velocity at the bottom of the ramp?

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