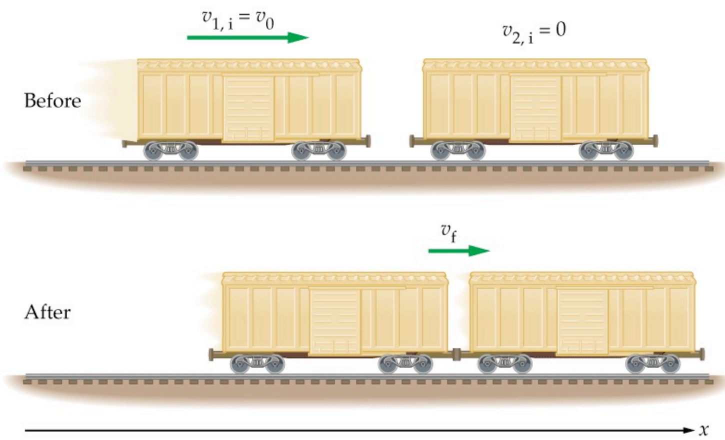
PHYS 1410: College Physics I **Spring 2009**

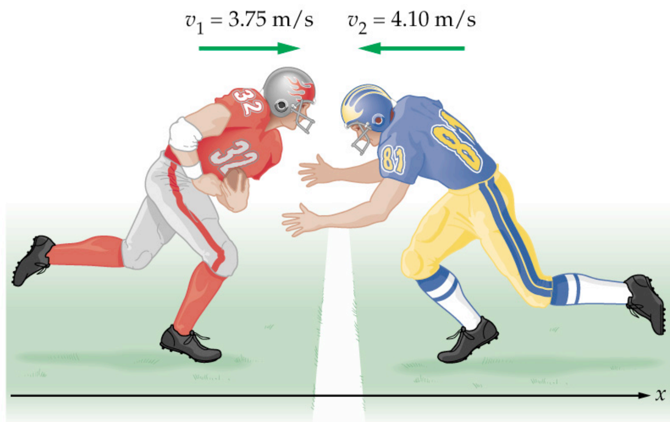
Exam III: Solution

1. Two railroad cars collide as shown. Car 2 is initially at rest when car 1 collides and couples with it. You observe that $\mathbf{v_o} = \mathbf{10m/s}$. If you assume the cars have **equal mass**, what do you *predict* the final velocity of the system will be?
   A) $v_f = 0$
   B) $v_f = 0.5 m/s$
   C) $v_f = 2$ m/s
   D) $v_f = 5$ m/s
   E) $v_f = 10$ m/s
   F) $v_f = 20$ m/s



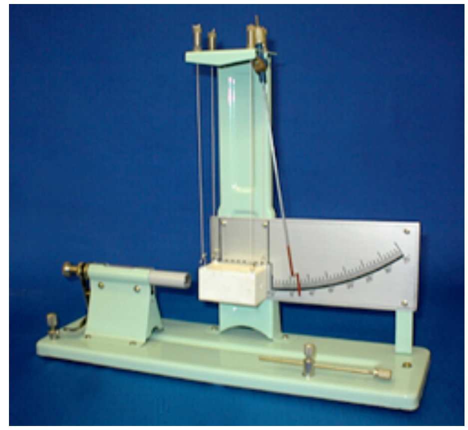
2. Because the cars are closed, you cannot see what they are actually loaded with. After the collision, you measure the velocity $\mathbf{v_f}$ of the combined cars. You notice that $\mathbf{v_f} = \mathbf{¾v_o}$.
   A) This is not possible. If the cars are stuck together, then $v_f = v_o$. This is *always* true for perfectly inelastic collisions.
   B) Since you can't see what's inside, you can't assume that the cars have the same mass. Your velocities indicate that car 1 is more massive than car 2 (by a factor of 3).
   C) Your reasoning is correct, but your conclusion is not: the cars must not have equal mass. Car 2, though, must be the more massive car. It is three times as massive as car 1 ($m_2 = 3m_1$).
   D) Car 2 must be the less massive car. It has to have ¾ the mass of car 1 ($m_2 = ¾m_1$).
   E) The cars have the same mass, or if they don't the difference is negligible. The 25% of the energy that was used up in coupling the cars resulted in a momentum loss. This is why you do not have $v_f = v_o$.

3. Turk and Tank are best friends, even though they play for rival teams. Tank (83, on the right) is getting ready to tackle Turk (32, on the left, carrying the ball). The collision will be *perfectly inelastic*, because they stick together (as Tank tries to force a fumble). Just after the collision, the pair is moving to the **right**.
   A) Turk (32) is more massive than Tank (83).
   B) Turk is less massive than Tank.
   C) Both players have exactly the same mass.
   D) There is no way to say anything conclusive about the mass of either player.
   E) It is not possible for the pair to be moving to the right, since Tank's initial velocity v_2 to the left is larger than Turk's initial velocity v_1.



4. Two carts collide *perfectly elastically* on an air track. Each cart has *exactly* the same mass. Cart 1 has an intial velocity $+\mathbf{v_i}$, and cart 2 has initial velocity $-\mathbf{v_i}$. What is the final velocity of each cart?
   A) $v_1 = 0$, $v_2 = +2v_i$
   B) $v_1 = -v_i$, $v_2 = +v_i$
   C) $v_1 = +2v_i$, $v_2 = -2v_i$
   D) $v_1 = -2v_i$, $v_2 = 0$
   E) None of these choices is correct.

5. Explain why, for the previous perfectly elastic collision, $v_1 = 0$ and $v_2 = 0$ is not a possible outcome.
   A) It *is* a possible outcome, because it clearly conserves the system momentum.
   B) This cannot happen because it would violate momentum conservation for the system.
   C) The outcome is not possible because, even though momentum is conserved, energy is not.
   D) These velocities violate both momentum and energy conservation, so this is not a possible outcome.
   E) These velocities do not *technically* violate momentum conservation, but you know that if objects in the system are moving before the collision, then there *has* to be something moving within the system after the collision as well.



6. The ballistic pendulum shown on the **right** is identical to the apparatus we used in lab. How is the momentum of the ball related to the momentum of the block?
   A) They are the same. Momentum of the ball before the collision precisely matches the block after the collision.
   B) The momentum of the ball before the collision is less than the momentum of the block afterwards, because the block was literally 10 times more massive.
   C) The momentum of the ball is slightly larger than that of the block, because after the collision the ball still has some momentum–not all of the ball's the momentum is transferred to the block.

7. Compare the **potential energy** of the system (block + ball) to the **kinetic energy** of the just ball at the instant before the collision.
   A) The final potential energy after the collision is exactly equal to the initial kinetic energy before the collision.
   B) The final potential energy after the collision is greater than the initial kinetic energy before the collision.
   C) The final potential energy of the system is less than the initial kinetic energy of the ball before the collision.
   D) The potential energy might be bigger or smaller; there is no way to know without reading the angle of the pointer.
   E) There is no comparison between these quantities, because they are unrelated.

8. Convert 4.35 radians to degrees. Answer with three sig figs.

$$4.35\text{rad}\left(\frac{360°}{2\pi\text{rad}}\right) = 249°$$

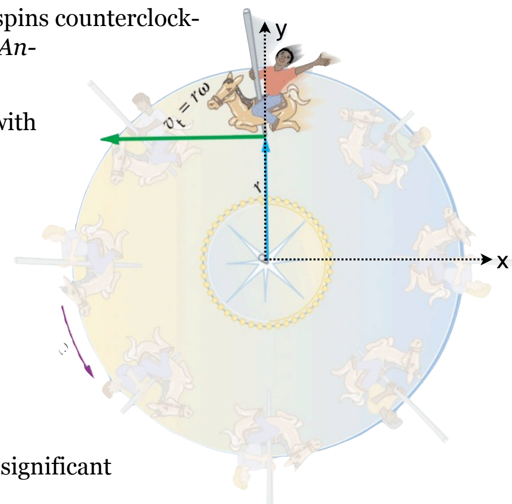
9. How many complete revolutions is 10.5 radians? Answer with three sig figs.

$$10.5\text{rad}\left(\frac{1\text{rev}}{2\pi\text{rad}}\right) = 1.67\text{rev}$$

10. Convert 225° to radians. Answer with three sig figs.

$$225°\left(\frac{2\pi}{360°}\right) = 3.93\text{rad}$$

Terence is on the carousel, constrained to move on a circular path with radius **r = 2m**. Starting from an initial angular velocity $\boldsymbol{\omega_0} = \mathbf{0}$ **rad/s**, the carousel spins counterclockwise, **speeding up** and eventually reaching $\boldsymbol{\omega} = \mathbf{3}$ **rad/s** after **10 seconds**. *Answer questions 11–17 using this information.*



11. What is the **magnitude** of his tangential velocity at t = 10 sec? Answer with two significant digits.

$$v = \omega r = \left(3\,\tfrac{\text{rad}}{\text{s}}\right)(2\text{m}) = 6\,\tfrac{\text{m}}{\text{s}}$$

12. What is the vector direction of the angular velocity?
   A) +x
   B) −x
   C) +y
   D) −y
   E) +z
   F) −z

13. What is the **magnitude** of the angular acceleration α? Answer with two significant digits.

$$\alpha = \frac{\Delta\omega}{\Delta t} = \frac{3\,\frac{\text{rad}}{\text{s}}}{10\text{s}} = 0.3\,\tfrac{\text{rad}}{\text{s}^2}$$

14. At the instant shown, what is the vector direction of centripetal acceleration a_c?
   A) +x B) −x C) +y **D) −y** E) +z F) −z

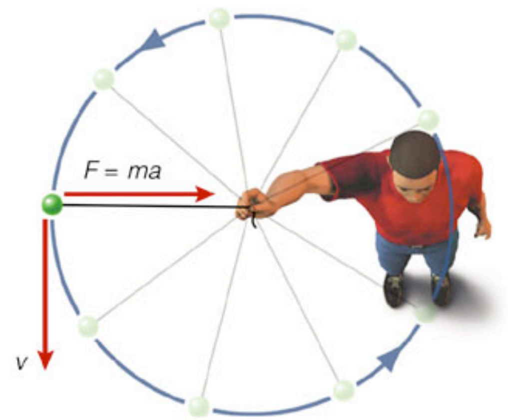
15. At the instant shown, what is the vector direction of tangential acceleration a_t?
   A) +x **B) −x** C) +y D) −y E) +z F) −z

16. True or **false**: Because Terence experienced a constant angular acceleration α, both his centripetal and tangential accelerations were also constant.

17. **True** or false: If the carousel slows down from ω to ½ω, Terence's centripetal acceleration decreases from a_c to ¼a_c.

18. You are standing next to Terence on the carousel, and you are not holding on to anything. What force causes *your* centripetal acceleration?
   A) Centripetal force
   B) Centrifugal force.
   C) Gravity.
   D) Normal force.
   E) Static friction.
   F) Tension.

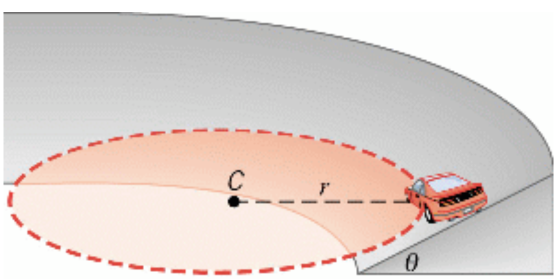
19. Let's swing a yo-yo. Swing it in a **vertical** circle, keeping the **speed constant**. What happens to the tension in the cord?
   A) Nothing. Since T = mg, the tension remains constant no matter where the yo-yo is on its circular path.
   B) The tension cannot vary. Constant speed means constant centripetal acceleration, so the force must be constant as well. But it is *not* by definition T = mg: the tension must be $T = ma_c$, whatever the values for m and a_c are.
   C) The tension must change as the yo-yo swings. It will be maximum when the yo-yo is at the bottom of its swing, and minimum when the yo-yo is at the very top of its swing.
   D) Since the tension has nothing to do with the centripetal acceleration of the yo-yo, the question is meaningless. Gravity causes a_c, and gravity is constant. Who knows what happens to the tension?!



Ok,now swing the yo-yo in a **horizontal** circle, as shown on the left. The view shown is top-down, so the circle described is parallel to the floor.

20. True or **false**: The cord is horizontal as the yo-yo swings in a circle.

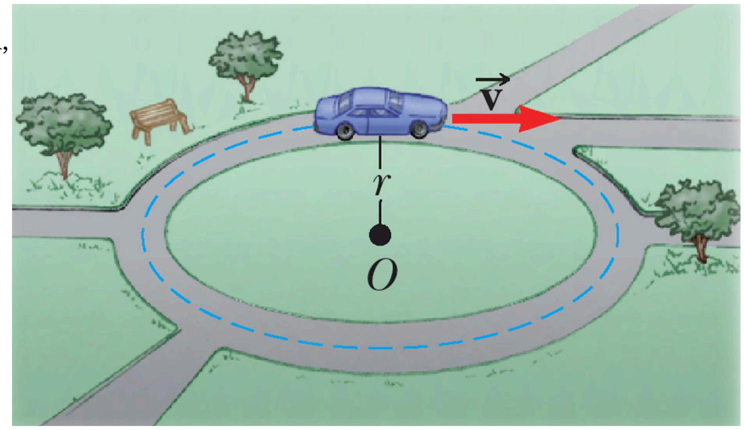
21. As you swing it faster and faster, the cord
   A) gets increasingly vertical. When the cord is perfectly vertical, the centripetal acceleration is maximum.
   B) gets increasingly horizontal. The x–component of the tension increases to provide centripetal acceleration.
   C) starts horizontal and stays horizontal. The tension has nothing to do with the centripetal acceleration.
   D) starts vertical and stays vertical. The y–component of the tension provides the centripetal acceleration.
   E) remains at whatever angle you started at, for however long you swing. The string angle cannot change, no matter how fast or how slow you you swing the yo–yo.



The car shown (professional driver on a closed course) on the left drives on a circular track banked at an angle θ.

22. What force causes the centripetal acceleration of the car?
   A) Gravity. Without the force of gravity, the car would skid right up the track and into the stands (which would *not* be good for NASCAR's image as family-friendly entertainment).
   B) Friction. Kinetic friction between the tires and the track keep the car on its circular path.
   C) Normal. The normal force has a horizontal component that points to the center of the circle, while the vertical component balances the force due to gravity.
   D)Centripetal force. The centripetal force, by definition, is the force that causes centripetal acceleration. It exists only while the car moves in a circular path, then disappears when the car starts going in a straight line.
   E) Centrifugal force. The car is like a red blood cell in a test tube in a centrifuge. Just like spinning the tube causes centrifugal force that makes the plasma separate.

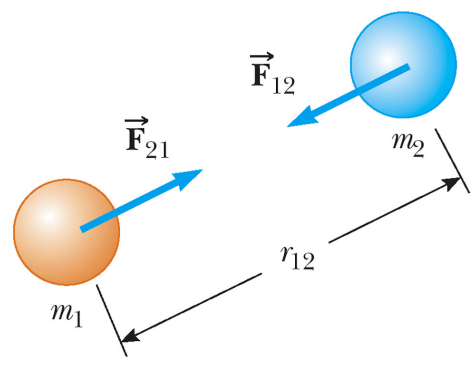
23. If the driver above starts to speed up, what happens?
   A) Increased speed means increased centripetal acceleration. It has to come from somewhere...friction?
   B) Speeding up increases the centripetal acceleration, but that implies a *reduced* force. The normal force decreases.
   C) An *increase* in speed means a *decrease* in centripetal acceleration. The car will start to slide down the embankment, decreasing the radius of the curve. This will compensate for a slower speed, and restore the original acceleration.
   D) Changing the speed has no effect on the centripetal acceleration, because a_c is caused by the force of gravity, which will not change The car is going to weigh the same no matter how fast it goes!
   E) He will pass the other cars on the track, win the race, and drink a big bottle of milk. No wait, forget the milk. That's only if you win at Indy on Memorial Day.



24. The car shown drives the circular roundabout at a **constant speed**. It must be somewhere in England, since he is circling clockwise (which means he is sitting on the right and driving on the left side of the road!). The road is **flat** and **dry**. The centripetal acceleration is due to
    A) the weight of the car $\mathbf{W} = m\mathbf{g}$.
    B) the normal force $\mathbf{N}$.
    C) kinetic friction $\mathbf{f_k} = \mu_k\mathbf{N}$.
    D) static friction $\mathbf{f_s} = \mu_s\mathbf{N}$.
    E) tension in the brake cable $\mathbf{T}$.

25. A second car enters the roundabout (driving in the same direction), and **accelerates** recklessly. The mobile phone and iPod tossed carelessly on the dashboard
    A) remain stationary. There is no horizontal force to move either object in any direction!
    B) slide toward the right side (toward the driver) of the car, pulled in by the centripetal force.
    C) slide toward the right side of the car, but not because of *centripetal* force. Gravity pulls the objects toward the driver.
    D) slide towards the left side. This is actually a straight line motion, as the static friction between the objects and the dash is insufficient to keep them on a circular path.
    E) slide towards the left side, but it has nothing to do with friction. It's *centrifugal* force. The mobile and the iPod are like a red blood cells in a test tube in a centrifuge...

26. According to Newton's law of universal gravitation, the force between any two masses
    A) is always neutral, neither attracting nor repelling masses toward or away from each other.
    B) can be either attractive or repulsive: like masses attract, and opposite masses repel.
    C) can be either attractive or repulsive: *like* masses *repel*, and *opposite* masses *attract*.
    D) is always repulsive, pushing the masses away from each other.
    E) is always attractive, pulling the masses towards each other.



27. The force on mass m_1 shown on the right is $\mathbf{F_{21} = 45N}$. What will the force be if m_2 is moved from $r_{12} = 10\text{m}$ to a new location $\mathbf{r = 30m}$? Two sig figs.

$$F = G\frac{m_1 m_2}{r^2} = 45\text{N}$$

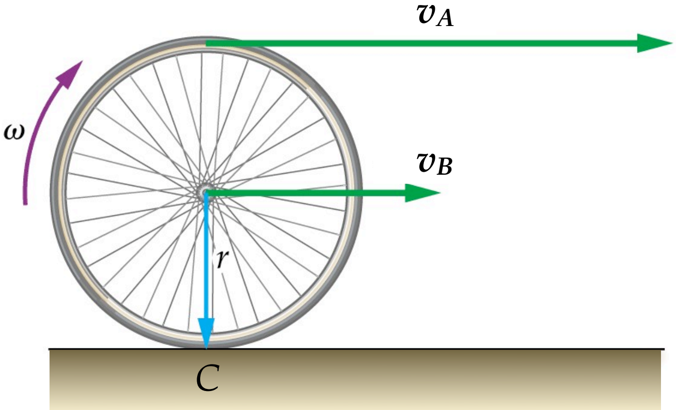
$$F = G\frac{m_1 m_2}{(3r)^2} = \tfrac{1}{9}G\frac{m_1 m_2}{r^2} = 5\text{N}$$

28. The masses shown are separated by a distance r_{12}. If m_1 is replaced by a new mass $m = \frac{1}{4}m_1$, where should we place m_2 so that the net force is unchanged?
    A) Leave m_2 where it is. Changing the separation of the masses has no effect on the gravitational force between them.
    B) Place m_2 at a distance $r = 4r_{12}$.
    C) Place m_2 at a distance $r = 2r_{12}$.
    D) Place m_2 at a distance $r = \frac{1}{4}r_{12}$.
    E) Place m_2 at a distance $r = \frac{1}{2}r_{12}$.

29. The planet Venus has a mass almost identical to the Earth's (just a smidge less). However, it is located 108 million km from the sun (compared to 150 million km average distance from the Earth to the sun).
    A) Same mass, closer distance? This means greater gravitational force. More force means more acceleration. Venus must be moving faster than the Earth, taking less time to complete one full trip around the sun.
    B) Venus experiences a reduced gravitational pull compared to the Earth. It would have less centripetal acceleration, move more slowly, and thus take longer to complete a revolution.
    C) The sun's pull on Venus must be essentially identical to the sun's pull on the Earth. Thus, it takes Venus just about the same amount of time (365 days) to make one full revolution about the sun.
    D) Everybody knows that Venus is farther from the sun than the Earth is. This, however, has nothing to do with the fact that it takes Venus longer to make a revolution. Venus rotates really slowly, and this is why is takes so long.
    E) The whole notion of Venus orbiting the sun is bogus. It was conclusively demonstrated by Galileo in 1609 that Venus orbits the planet Jupiter, along with several other moons. Technically, it takes Venus the same amount of time to orbit the sun as it takes Jupiter to orbit the sun, which about 12 years.

30. To put a satellite in geosynchronous orbit around the Earth, it must be located at r_1 = 42,000km above the center of the Earth. Mars has a smaller mass than the Earth, but approximately the same period of rotation (one Mars day is about the same as one Earth day). A satellite placed in Mars-synchronous orbit must be located at r_2 (above the center of Mars)
   A) at the same distance: $r_2 = r_1$.
   B) closer to Mars: $r_2 < r_1$.
   C) farther from Mars: $r_2 > r_1$.
   D) anywhere at all: r_2 = any value.

31. The wheel shown rolls without slipping across the floor. Why is the vector velocity arrow $\boldsymbol{v_A}$ drawn longer than vector $\boldsymbol{v_B}$?



   A) The velocity vector v_A must be longer than v_B. The velocity vector has two components: the forward translation and the tangential velocity due to rotation. At point B there is only translation; there is no rotation with respect to the axle, so v_B has no tangential component.
   B) Velocity vector $\boldsymbol{v_A}$ must be longer than $\boldsymbol{v_B}$. This is because the wheel rolls forward. If the wheel was rolling backwards, then the relationship would be reversed: $\boldsymbol{v_A} < \boldsymbol{v_B}$.
   C) Because the picture is inaccurate. Both velocity vectors $\boldsymbol{v_A}$ and $\boldsymbol{v_B}$ should be exactly the same length.
   D) The picture is inaccurate, but $\boldsymbol{v_B}$ should be longer than $\boldsymbol{v_A}$. $\boldsymbol{v_A}$ is pure translation, and $\boldsymbol{v_B}$ is pure rotation.
   E) The picture is not just wrong, it's *really*, *really* wrong! The vector $\boldsymbol{v_A}$ should be shorter : it should be the length that vector $\boldsymbol{v_B}$ is drawn. Then vector $\boldsymbol{v_B}$ should be erased entirely, because $\boldsymbol{v_B}$ is exactly zero.

32. In the picture above, where is the instantaneous center of rotation?
   A) At point A, the very top of the wheel. This is because the velocity is maximum at this point.
   B) Point B, the center of the wheel. This is because the axle just moves forward, it does not rotate.
   C) Point C, the point of contact between the wheel and the ground. This is because the wheel does not slip: the instantaneous velocity at point C is exactly $v_c = 0$.
   D) Nowhere; the instantaneous center of rotation is not a meaningful idea for a rolling wheel.
   E) Anywhere. You can pick any point you want as the instantaneous center of rotation, it's just that some points are easier to use for calculating the numbers.

33. Treat the wheel as a hoop with radius **r = 0.27m** (ignore spokes). The mass of the wheel is **m = 0.850kg**. What is the moment of inertia of the wheel with respect to its center of mass?

$$I = mr^2 = (0.85\text{kg})(0.27\text{m})^2 = 0.062\text{kg}\cdot\text{m}^2$$

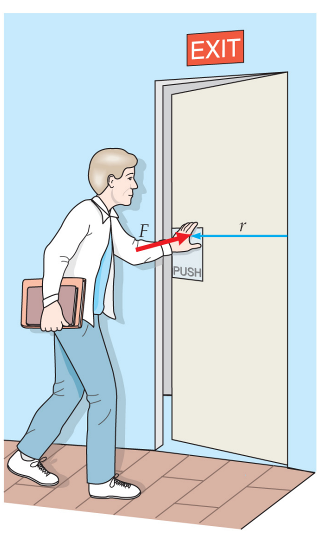
   A) 0.025 kg·m² B) 0.031 kg·m² **C) 0.062 kg·m²** D) 0.124 kg·m²

34. The wheel (**m = 0.850kg** and **r = 0.27m**) rolls forward with a speed of **3m/s**. What is the kinetic energy?

$$K = \tfrac{1}{2}mv^2 + \tfrac{1}{2}I\omega^2 = \tfrac{1}{2}mv^2 + \tfrac{1}{2}\left(mr^2\right)\omega^2 = mv^2$$

$$K = (0.85\text{kg})\left(3\tfrac{\text{m}}{\text{s}}\right)^2 = 7.65\text{J}$$

   A) 1.91 J
   B) 3.06 J
   C) 3.83 J
   D) 5.36 J
   E) 7.65 J



Nigel is leaving the lecture hall. The door is clearly labeled PUSH, so he pushes with a force F perpendicular to the surface of the door, as shown. Alex is a rebel (well, a bit of delinquent, really), and is *not* going to do what *anybody* says, especially not a stupid door. Alex pushes the door at a distance (⅔r) from the hinges.

35. To apply the same amount of torque to the door as Nigel, Alex must push perpendicular to the surface and apply how much force?
   A) The same amount of force F as Nigel did.
   B) Exactly twice as much force (2F) as Nigel did.
   C) Exactly half as much force (½F) as Nigel did.
   D) Two thirds as much force (⅔F) as Nigel did.
   E) Three halves as much force (3/2)F as Nigel applied.

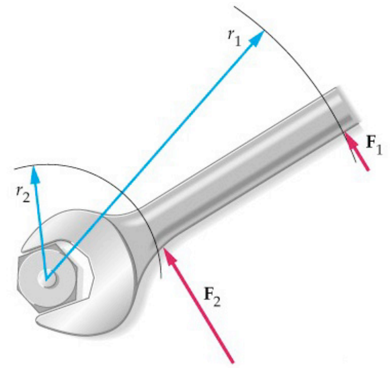
36. Alex has a pal, Dim. Dim wants to do whatever Alex does. But because he is, well, *dim*, he doesn't always achieve the same results. What happens if Dim does not push perpendicular to the surface of the door?
   A) Nothing. Unless the applied force is exactly perpendicular to the door, no torque is applied to the door.
   B) If he applies the same amount of force as Alex, the applied torque will also be the same.
   C) As long as he does not push parallel to **r** (even Dim is not *that* dim), there will be a

torque. However, only the force component parallel to r creates the torque.

D) The torque depends on the angle between the force and r. If that angle is 0°, no torque. The amount of applied torque increases as the angle increases to 90°.

E) Answer D is almost correct, but backwards. Maximum torque when the angle is 0°, decreasing to a minimum torque when the angle between **r** and **F** goes to 90°.

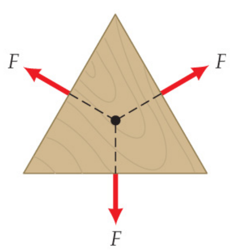
Forces $\mathbf{F_1}$ **= 5N** and $\mathbf{F_2}$ **= 15N** are applied to the wrench on the right. The wrench handle is **30 cm** long, and F_2 is applied at $\mathbf{r_2}$ **= 8 cm** as shown.



37. **True** or false: The direction of the torque vector due to $\mathbf{F_1}$ is +z.

38. For what range of values will the torque $\boldsymbol{\tau}_1$ created by F_1 exceed the torque $\boldsymbol{\tau}_2$ created by F_2?
    A) Any value, as long as $r_1 > r_2$.
    B) For $\boldsymbol{\tau}_1 > \boldsymbol{\tau}_2$, any value of $r_1 < r_2$.
    C) If $r_1 \geq$ 15cm, then $\boldsymbol{\tau}_1 > \boldsymbol{\tau}_2$.
    D) Only values of $r_1 \geq$24 cm will create $\tau_1 > \tau_2$.
    E) As shown, r_1 = 30 cm. This is the only possible value.

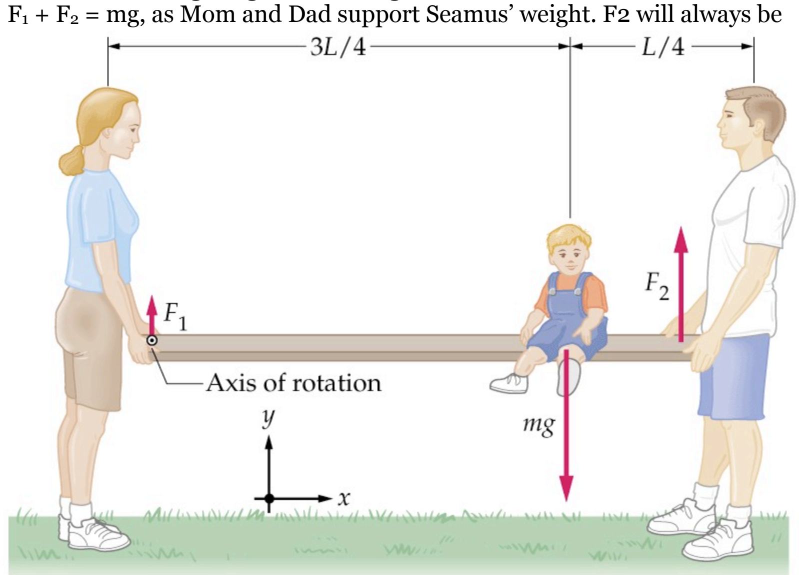
39. We know that for the static equilibrium of an object, $\Sigma\mathbf{F} = 0$. But why must the condition $\Sigma\boldsymbol{\tau} = 0$ also be met?
    A) $\Sigma F = 0$ is the condition for no sliding. You also need a condition for no spinning: $\Sigma\tau = 0$. An object in static equilibrium cannot be sliding or spinning.
    B) The condition $\Sigma\boldsymbol{\tau} = 0$ is necessary to make sure that all of the forces have the same point of application. For the wrench on the right, F_1 and F_2 are applied at different places, so the wrench could not be in equilibrium, even if the magnitudes of the forces were the same. Forces with different application points cannot sum to zero.
    C) The torque condition is not separate from or independent of the force condition. If $\Sigma\mathbf{F} = 0$, then the torques will automatically always add up to zero as well. Like this: $\Sigma\boldsymbol{\tau} = (F1 + F2 + F3 + \cdots)r = (\Sigma\mathbf{F})r = (0)r = 0$.
    D) The conditions are *not* both necessary. It is adequate to meet one or the other. If $\Sigma\mathbf{F} = 0$, then $\Sigma\boldsymbol{\tau} = 0$ is not required. If $\Sigma\boldsymbol{\tau} = 0$, then $\Sigma\mathbf{F} = 0$ is not necessary.
    E) The premise is incorrect. The condition $\Sigma\boldsymbol{\tau} = 0$ is not required for equilibrium. In fact, it is important that when $\Sigma\mathbf{F} = 0$ is true that $\Sigma\boldsymbol{\tau} \neq 0$ also be true. This insures that you are seeing an equilibrium situation in which the object is fully at rest, as opposed to a situation where it only *seems* at rest (like if you are holding a cup while riding in the car: the cup looks to *you* like it is in equilibrium, but if I watch from the sidewalk, I can clearly see it moving).



The block shown on the left is an equilateral triangle, subject to three forces as shown. The applied forces have equal magnitude.

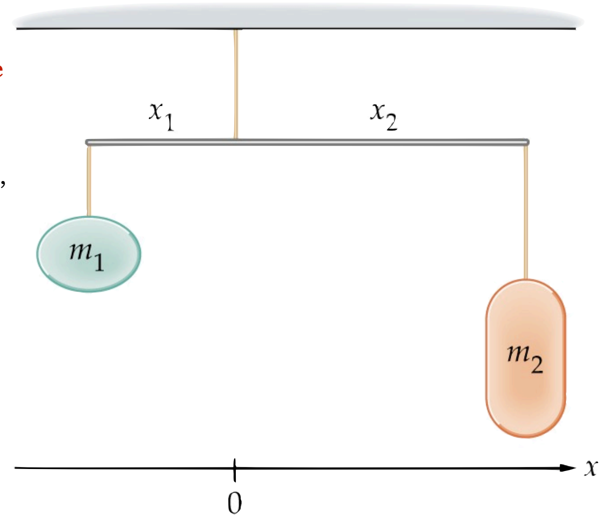
40. **True** or false: The block is in static equilibrium.

41. Mom and Dad are moving some deck boards, and taking Seamus (Molly's little brother) for a ride as well. At this instant, they have just lifted the board, and are at rest. Notice that the force exerted by Mom is smaller than the force exerted by Dad. If Seamus was closer to his Mom than his Dad ($x < L/2$), how would the forces F_1 and F_2 change? Ignore the weight of the board itself.
    A) They would be unaffected. $F_1 + F_2 = mg$, as Mom and Dad support Seamus' weight. F2 will always be bigger because Dad is stronger, so he supports more weight.
    B) F_1 and F_2 both get bigger, but F_1 remains smaller than F_2.
    C) F_1 and F_2 both get smaller, and F_1 remains smaller than F_2.
    D) The closer Seamus moves to Mom, the larger F_1 becomes. F_2 gets correspondingly smaller, because $F_1 + F_2 = mg$.
    E) As Seamus moves closer to Mom, F_2 gets bigger while F_1 gets smaller. It is still true that $F_1 + F_2 = mg$.



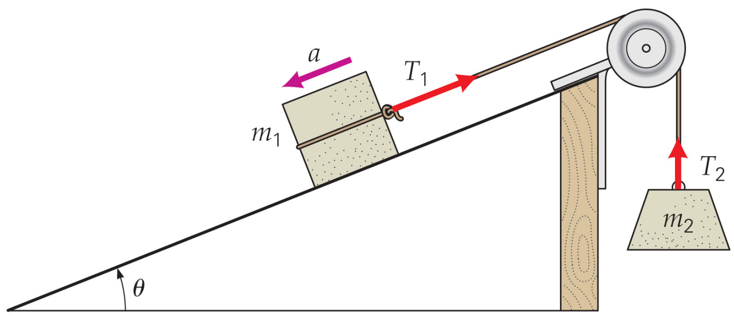
42. The mobile shown is hanging in equilibrium. Notice that the support bar is perfectly horizontal.
   A) The center of mass of the system is located where the vertical cord attaches to the bar. This is labeled 0 on the x–axis.
   B) The center of mass is not at 0. The mass center is at the center of the horizontal bar, which is somewhere to the right of 0, so $x_{cm} > 0$.
   C) The center of mass is located to the left of 0, $x_{cm} < 0$.

43. According to the picture, mass m_1 is closer to the vertical cord from which the mobile hangs ($x_1 < x_2$). Assuming that picture is drawn accurately, what can you tell about the masses m_1 and m_2?
   A) The mass m_1 must be smaller than m_2.
   B) The mass m_2 must be smaller than m_1.
   C) The masses are identical: $m_1 = m_2$.
   D) Nothing. You need the numbers to make any comparison.



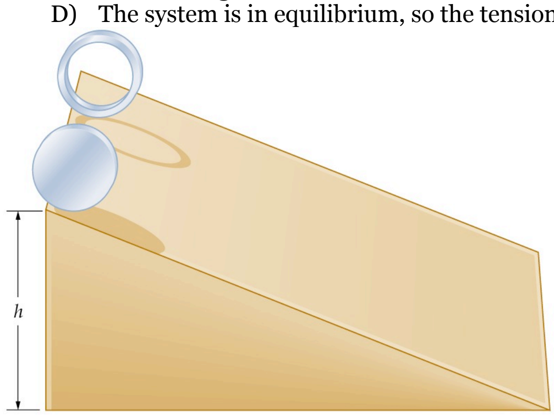
44. The rods shown left are identical, except they are to be rotated with respect to different axes. Which rod has the greater moment if inertia?
   A) If the rods are identical, then so are the moments of inertia. Same mass, same length, same moment: $I = (1/12)mL^2$.
   B) The rod rotated about the mass center has greater moment of inertia. This is because there is mass on either side of the midpoint.
   C) The rod rotated about its end has greater moment of inertia. More of the mass is farther away from the rotation axis, so it will be more difficult to spin. The center of mass axis is always the easiest axis to spin around.

Two masses are attached by a cord running over a pulley. Mass m_1 = 10kg, and m_2 = 4 kg. Assume the pulley (mass m = 1 kg) is frictionless and the incline angle is 30°.



45. True or **false**: Gravity creates the torque that causes the pulley to spin.

46. What can you say with certainty about tension in the cable shown?
   A) Since it is a single cable attached to both blocks, the tension is constant everywhere.
   B) The tension T_1 (attached to m_1) must be greater than T_2 (attached to m_2).
   C) T_2 must be greater than T_1.
   D) The system is in equilibrium, so the tension is zero everywhere.



The hoop and the disk shown below have the same mass, and are each released from rest from the top of the incline.

47. Which has the greater kinetic energy when they reach the bottom of the ramp?
   A) The hoop has greater kinetic energy because it has a greater moment of inertia.
   B) The disk has greater kinetic energy because it has a smaller moment of inertia.
   C) Trick question. They have the same total kinetic energy, because they started with equal potential energy. Thus, they must have the same velocity as well.
   D) The kinetic energy is the same for each, but the hoop will have a greater forward velocity than the disk.
   E) The kinetic energy is the same for each, but the disk will have a greater velocity than the hoop.

48. A hoop and a sphere (same mass, same radius) roll without slipping on a flat horizontal surface. They have the same kinetic energy. Which has the greater velocity?
   A) Trick question. They have the same velocity if they have the same kinetic energy. They have to.
   B) The sphere.
   C) The hoop.

49. Molly stands at the edge of a horizontal circular platform. Both the girl and the platform are initially at rest, but the platform is free to rotate frictionlessly about a vertical axis through its center. She begins to walk **counterclockwise** around the perimeter.
    A) The platform begins to spin clockwise.
    B) The platform begins to spin counterclockwise underneath her feet.
    C) The platform remains stationary underneath her feet.

50. The platform with Molly on it has a moment of inertia **I_1 = 112.5 kg·m²**. It spins initially with angular speed **ω_1 = 3rad/s**. When Dad sets little Seamus down on the platform, the speed decreases to **ω_2 = 2.2rad/s**. What is the new moment of inertia **I_2** of the system? Answer with three sig figs.

$$\left(112.5\text{kg}\cdot\text{m}^2\right)\left(3\tfrac{\text{rad}}{\text{s}}\right) = I_2\left(2.2\tfrac{\text{rad}}{\text{s}}\right)$$
$$I_2 = 153\text{kg}\cdot\text{m}^2$$

Part 2: Problem Solving

Problem 01

Molly is on the merry-go-round at the park again. The platform has a radius of **1.5 m**. After Dad pushes a few times, the platform has an initial angular velocity of **ω_o = 4.5 rad/s**. The platform comes to **rest** after rotating through **10 revolutions**.

$$r = 1.5\text{m} \qquad \omega_o = 4.5\tfrac{\text{rad}}{\text{s}}$$
$$\theta = 10\text{rev} = 20\pi\text{rad} \qquad \omega = 0$$

A) Find the **angular acceleration** of the merry-go-round.

$$\omega^2 = \omega_o^2 + 2\alpha\theta$$
$$0 = \left(4.5\tfrac{\text{rad}}{\text{s}}\right)^2 + 2\alpha\left(20\pi\text{rad}\right)$$
$$\alpha = -0.161\tfrac{\text{rad}}{\text{s}^2}$$

B) How much **time** does it take for the platform to come to rest?

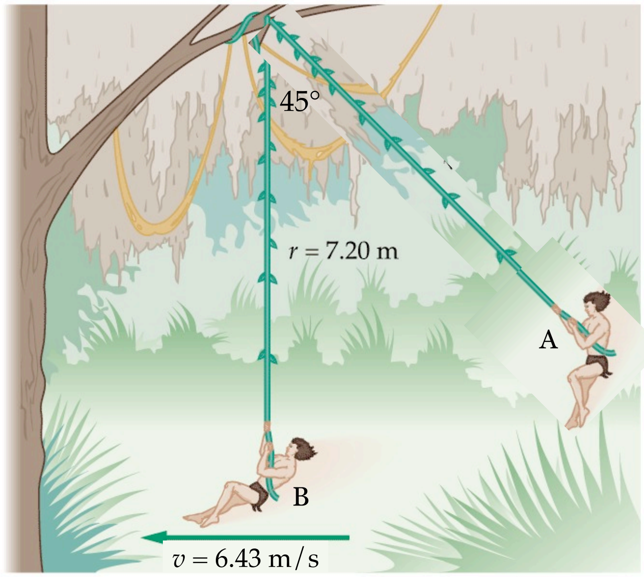
$$\omega = \omega_o + \alpha t$$
$$0 = \left(4.5\tfrac{\text{rad}}{\text{s}}\right) + \left(-0.161\tfrac{\text{rad}}{\text{s}^2}\right)t$$
$$t = 27.9\text{s}$$

C) If Molly sits **1.2 m** from the center of the platform, what is her initial **centripetal acceleration a_c**?

$$r = 1.2\text{m}$$
$$a_c = \omega_o^2 r = \left(4.5\tfrac{\text{rad}}{\text{s}}\right)^2\left(1.2\text{m}\right) = 24.3\tfrac{\text{m}}{\text{s}^2}$$

D) What is her **tangential acceleration a_t**?

$$r = 1.2\text{m}$$
$$a_t = \alpha r = \left(-0.161\tfrac{\text{rad}}{\text{s}^2}\right)\left(1.2\text{m}\right) = -0.193\tfrac{\text{m}}{\text{s}^2}$$



Problem 02

Meanwhile, back in Africa, Tarzan (**m=100 kg**) truly is the King of the Jungle. Just look at him swing! Tarzan was initially at rest (**v_A = 0, ω_A = 0**) when the vine was at an angle of **45°** to the vertical as shown (point A).

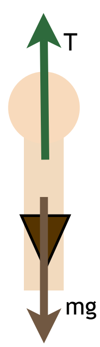
A) Tarzan's tangential velocity at point B is **v = 6.43m/s**. What is his **angular velocity ω_B** at this instant?

$$r = 7.20\text{m}$$
$$v = 6.43\,\tfrac{\text{m}}{\text{s}}$$
$$\omega_B = \frac{v}{r} = \frac{6.43\,\frac{\text{m}}{\text{s}}}{7.20\text{m}}$$
$$\omega_B = 0.893\,\tfrac{\text{rad}}{\text{s}}$$

B) Calculate Tarzan's **angular acceleration α** as he swung from A to B (assume **α** is constant, and convert his angular displacement of 45° from degrees to radians).

$$\omega_A = 0$$
$$\theta = 45°\left(\frac{2\pi}{360°}\right) = 0.785\text{rad}$$
$$\omega_B^2 = \omega_A^2 + 2\alpha\theta$$
$$\left(0.893\,\tfrac{\text{rad}}{\text{s}}\right)^2 = 0 + 2\alpha(0.785\text{rad})$$
$$\alpha = 0.508\,\tfrac{\text{rad}}{\text{s}^2}$$

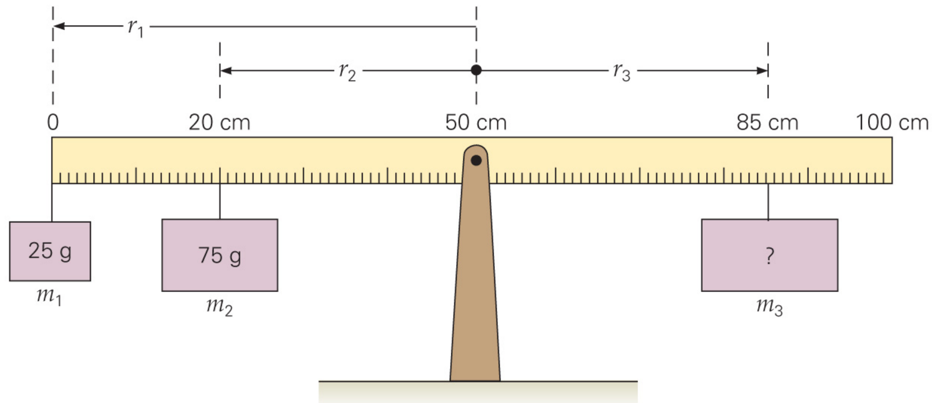
C) Draw the **force diagram** for Tarzan as he reaches point B. Clearly label all the forces acting on Tarzan.



D) At point B, what is the **tension** in Tarzan's vine?

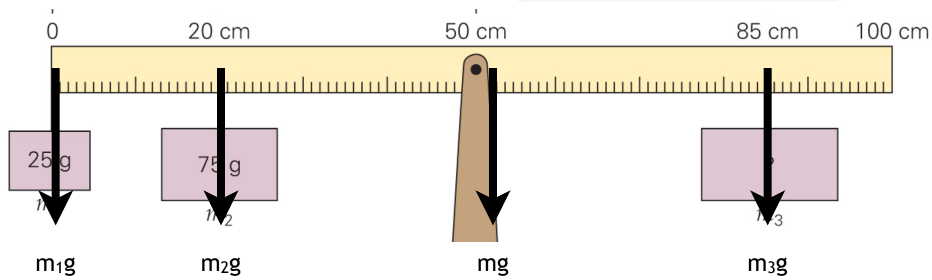
$$\sum F = T - mg = ma_c = m\frac{v^2}{r}$$
$$T = mg + \frac{mv^2}{r}$$
$$T = (100\text{kg})\left(9.8\,\tfrac{\text{m}}{\text{s}^2}\right) + \frac{(100\text{kg})\left(6.43\,\frac{\text{m}}{\text{s}}\right)^2}{(7.20\text{m})}$$
$$T = 1554\text{N}$$

Problem 03



Meanwhile, back in the lab, we are balancing the meterstick. In this case, the stick has a mass of **90g**, and its mass center is located at the **50.6 cm** mark. The stick is in equilibrium.

A) Draw the force diagram for the meterstick as shown. Label each force clearly.



B) Determine how much mass must be suspended at m_3 for the system to maintain equilibrium.

$m_1 = 25\text{g}$ $\quad m_2 = 75\text{g}$ $\quad m = 90\text{g}$ $\quad m_3 =$

$r_1 = (50 - 0)\text{cm} = 50\text{cm}$ $\quad r_2 = (50 - 20)\text{cm} = 30\text{cm}$ $\quad r = (50.6 - 50)\text{cm} = 0.6\text{cm}$ $\quad r_3 = (85 - 50)\text{cm} = 35\text{cm}$

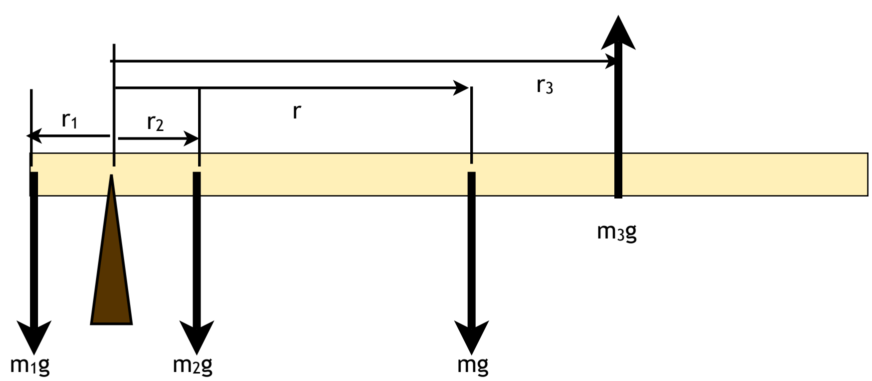
$$\sum \tau = (m_1 g)r_1 + (m_2 g)r_2 - (mg)r - (m_3 g)r_3 = 0$$

$$m_3 r_3 = m_1 r_1 + m_2 r_2 - mr$$

$$m_3(35\text{cm}) = (25\text{g})(50\text{cm}) + (75\text{g})(30\text{cm}) - (90\text{g})(0.6\text{cm})$$

$$m_3 = 98.5\text{g}$$

C) The meterstick is re-positioned so that the **pivot** is located at the **10 cm** mark. Masses m_1 and m_2 are not changed or moved. In which direction should the force $T_3 = m_3g$ be applied to maintain equilibrium (assume that you can attach the string to the top or bottom of the stick, like we did in lab: should the tension pull up or down?), if m_3 is constrained to be attached to the right of m_2? Demonstrate your answer by drawing a force diagram for this situation.



D) Leaving the **pivot** at the **10 cm** mark, and m_1 and m_2 unchanged and unmoved, find the equilibrium location (to the right of m_2) of $\mathbf{m_3 = 75g}$. Express your answer in terms of the mark on the meterstick.

$m_1 = 25\text{g}$ $\quad m_2 = 75\text{g}$ $\quad m = 90\text{g}$ $\quad m_3 = 75\text{g}$

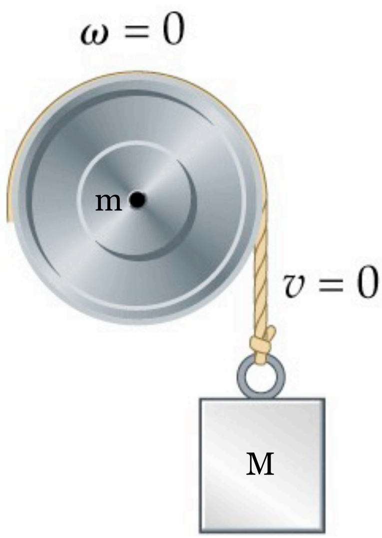
$r_1 = (10 - 0)\text{cm} = 10\text{cm}$ $\quad r_2 = (20 - 10)\text{cm} = 10\text{cm}$ $\quad r = (50.6 - 10)\text{cm} = 40.6\text{cm}$ $\quad r_3 = (x_3 - 10)\text{cm}$

$$\sum \tau = (m_1 g)r_1 - (m_2 g)r_2 - (mg)r + (m_3 g)r_3 = 0$$

$$m_3 r_3 = m_2 r_2 + mr - m_1 r_1$$

$$(75\text{g})(x_3 - 10)\text{cm} = (75\text{g})(10\text{cm}) + (90\text{g})(40.6\text{cm}) - (25\text{g})(10\text{cm})$$

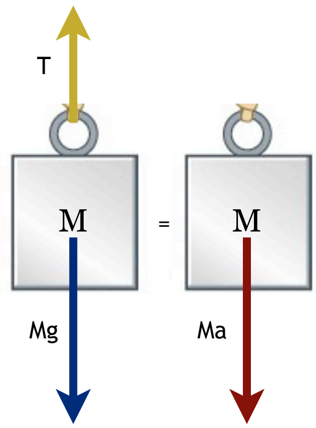
$$x_3 = 65.4\text{cm}$$



Problem 04

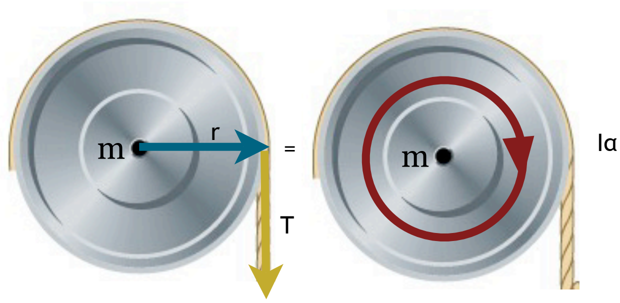
Mass **M = 3kg** is attached to a rope wound around the pulley (a disk with **m = 1.5 kg** and **r = 0.15m**). The system is released from rest.

A) Draw the force diagram for falling block. Label all forces clearly, and write Newton #2 for the block.



$$\sum F = Mg - T = Ma$$

B) Draw a torque diagram for the pulley. Label all torques clearly, and write Newton #2 for the spinning pulley



$$\sum \tau = Tr = I\alpha$$

C) Determine the acceleration of the block, and the tension in the rope.

$$\sum F = Mg - T = Ma \qquad \sum \tau = Tr = I\alpha \qquad a = \alpha r$$

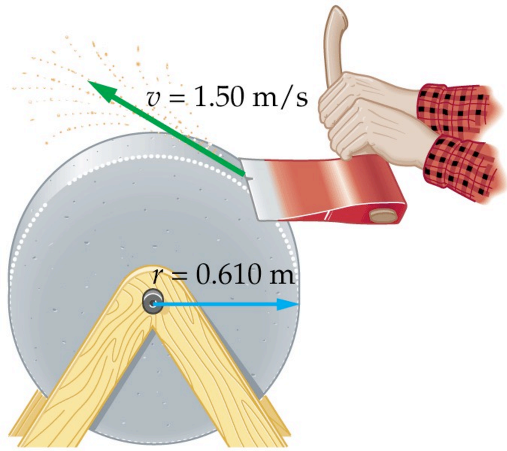
$$Tr = \left(\tfrac{1}{2} mr^2\right)\alpha \qquad T = \tfrac{1}{2} m(\alpha r) = \tfrac{1}{2} ma \qquad Ma + T = Mg$$

$$Ma + \tfrac{1}{2} ma = Mg \qquad a = \frac{Mg}{(M + 0.5m)}$$

$$a = \frac{(3\text{kg})\left(9.8\,\tfrac{\text{m}}{\text{s}^2}\right)}{\left(3\text{kg} + 0.5(1.5\text{kg})\right)} = 7.84\,\tfrac{\text{m}}{\text{s}^2}$$

$$T = 0.5(1.5\text{kg})\left(7.84\,\tfrac{\text{m}}{\text{s}^2}\right) = 5.88\text{N}$$

Problem 05



Meanwhile, Paul Bunyan is sharpening up his ax. The whetstone has a tangential velocity **v = 1.50m/s** ($\omega_o = v/r$)at the instant shown. The large lumberjack holds the ax steady in place until the stone comes **rest**, after turning through **20 full revolutions**. The stone has a mass **m = 25 kg**.

$$v = 1.50\,\tfrac{\text{m}}{\text{s}} \qquad \omega_o = \frac{v}{r} = \frac{1.50\,\frac{\text{m}}{\text{s}}}{0.610\text{m}} = 2.46\,\tfrac{\text{rad}}{\text{s}} \qquad m = 25\text{kg}$$

$$r = 0.610\text{m} \qquad \omega_f = 0 \qquad \theta = 20\text{rev} = 40\pi\text{rad}$$

A) Treating it as a disk, calculate the initial **kinetic energy K_o** of the stone.

$$K_o = \tfrac{1}{2} I\omega_o^2$$

$$K_o = \tfrac{1}{2}\left(\tfrac{1}{2}mr^2\right)\omega_o^2 = \tfrac{1}{4}mv^2$$

$$K_o = \tfrac{1}{4}(25\text{kg})\left(1.50\,\tfrac{\text{m}}{\text{s}}\right)^2 = 14.1\text{J}$$

B) How much **work** does the ax do on the stone as it comes to rest?

$$W = K_f - K_o = -K_o = -14.1\text{J}$$

C) Use angular work-energy ($K_o + \tau\theta = K_f$) to find the **torque** exerted by the ax on the stone.

$$K_o + \tau\theta = K_f$$

$$14.1\text{J} + \tau(40\pi\text{rad}) = 0$$

$$\tau = -0.112\text{N}\cdot\text{m}$$

D) Use angular impulse-momentum ($I\omega_o + \tau t = I\omega_f$) to determine how much **time** it takes to stop the stone turning.

$$I\omega_o + \tau t = I\omega_f$$

$$\left(\tfrac{1}{2}mr^2\right)\omega_o + \tau t = 0$$

$$\tfrac{1}{2}(25\text{kg})(0.610\text{m})^2\left(2.46\,\tfrac{\text{rad}}{\text{s}}\right) + (-0.112\text{N}\cdot\text{m})t = 0$$

$$t = 102\text{s}$$