1. Here is the situation. It is late in the Super Bowl and your favorite team has a 4th down and 5.00 m to go. On this play the fullback (m = 110 kg) is given the ball and starts running up field at 8.00 m/s. He leaps to avoid another player on the ground and at the highest point in the leap, when he is 0.800 m above the ground, he collides head-on, completely inelastically, with a defensive back (m = 82.0 kg) who is traveling toward him at 4.00 m/s. Assume the collision occurs at the instant the momentum vectors for each player are horizontal.

A. Taking the system to be the two football players, which component of the total momentum of the system is conserved? Which component is not conserved?

B. What is the magnitude of the total momentum of the system just before the collision and just after the collision. You may consider that the brief moment just before, during and just after the collision all the momenta are essentially horizontal?

C. What is the velocity of the fullback-defensive back combination just after the collision?

D. Assuming the collision occurs 1.50 m from the 1st down marker, will the fullback hit the ground before, at, or beyond the 1st down marker? You MUST show your work?

2. A. When an actor in a movie, usually a stunt person, leaps out a second floor window to avoid a raging fire in the building, the actor normally lands on an off-camera soft mat that protects the actor from injury. Explain how the mat protects the actor from injury using physics principles. Be specific.

B. For items a and b below identify which of the events (numbered 1, 2, 3, 4 and/or 5 below) fit.

_______ a. The events for which the momentum of the stated system is conserved.

_______ b. The events for which the KE of the stated system is conserved.

1. A basketball bouncing off the floor. The basketball is the system of interest. The ball does not rise to the same height it fell from.

2. A lump of clay hitting a stationary wooden block inelastically on a frictionless surface. The lump of clay is the system of interest.

3. Same as #2 but the lump of clay and the block make up the system of interest

4. Two blocks of equal mass, one moving and one stationary, colliding elastically on a frictionless surface. The system of interest is the block that is initially moving.

5. Same as #4 but the system of interest is the pair of blocks.

3. A. Two objects, A and B, are hurled vertically upward from the same starting location with the same KE. The mass of A is twice the mass of B. In the spaces provided enter A, B, same, or neither that best satisfies the statement. Take the starting location to be the reference position for gravitational PE for both objects.

1. ________ The object with the greater initial speed

2. ________ The object with the larger GPE at the highest position reached for that object

3. ________ The object that travels the larger vertical distance

4. ________ The object with the larger mechanical energy at the starting location
5. The object with the larger initial momentum (double star)
6. The object conserving momentum during the entire trip

B. Front air bags in automobiles are used to reduce the severity or eliminate entirely injuries to passengers in front end collisions. Explain carefully, using the physics principles you learned about during the past weeks, how air bags work.

C. A disk (as shown) starting from rest rotates about a fixed axis with a constant angular acceleration. Three points, A, B and C are on the disk and rotate with the disk. In the spaces below enter A, B, C, or same to best fit the statement. Note: \( r_A < r_B < r_C \).

1. The point(s) with the smallest angular speed
2. The point(s) with the largest tangential speed
3. The point(s) with the smallest angular acceleration
4. The point(s) with the smallest tangential acceleration
5. The point(s) with the smallest centripetal acceleration

4. B. You are watching a merry-go-round from above. The merry-go-round starts from rest and undergoes a uniform, counterclockwise, angular acceleration. Points A, B and C are identified along a single radius line. Enter A, B, C, or same to best fit the following statements.

1. The point showing the largest angular velocity after \( t \) seconds.
2. The point showing the smallest tangential velocity after \( t \) seconds.
3. The point showing the largest tangential acceleration after \( t \) seconds.
4. The point showing the largest angular displacement after \( t \) seconds.
5. The point traveling the greatest translational distance after \( t \) seconds.

C. Your physics instructor steps off the lecture table and lands on the floor. Explain why, using physics ideas presented over the past few week, he is less likely to injure himself if he lands bent-kneed than if he lands stiff-legged.

5. B. A yo-yo is released from rest and falls with constant acceleration so that after dropping 1.00 m the downward velocity of the center of mass (CM) of the yo-yo is 0.750 m/s. The inner and outer radii are \( r = 2.00 \text{ cm} \) and \( R = 4.00 \text{ cm} \).

1. What are the tangential speed of the edge of the inner radius hub and the angular speed of the yo-yo about the axis through the yo-yo's center of mass after the yo-yo falls 1.00 m? [Hint: To get \( v \), think about how much string unwraps in 1.0 s relative to the vertical distance the center of mass falls in 1.0 s.]
2. What are the tangential acceleration of the inner radius hub and the angular acceleration of the entire yo-yo about the axis through the yo-yo's center of mass?
3. Through how many rotations has the yo-yo rotated during the 1.00 m fall?

6. B. Two objects, A and B, have masses 2 m and m, respectively, and are initially at rest on separate horizontal, frictionless surfaces. A pair of identical forces \( \vec{F} \) are applied to both A and B. These forces are applied for 5.0 s to both objects. See figure. If the physical quantity in the statement is the same for A and B, write same.

1. The object that experiences the greater net force.
2. The object experiencing the larger impulse.
3. The object with the larger momentum after 5.0 s.
4. The object with the greater speed after 5.0 s.
5. The object that has traveled the smaller distance in 5.0 s.
6. The object on which \( \vec{F} \) does the greater amount of work in 5.0 s.
7. The object with the greater kinetic energy after 5.0 s.
8. The object on which \( \vec{F} \) produces the larger amount of power during the 5.0 s.
7. A. Using the physics you studied in chapter 7, Impulse and Momentum, explain how the use of sand- or water-filled barrels found at many places on interstate highways, helps reduce the severity or prevent entirely serious injuries when collisions occur.

B. Imagine just when the bucket of water reaches the top of the well, the person (not shown) hauling the bucket up suddenly lets go of the crank. The bucket then accelerates uniformly back toward the water and covers 24.0 m in 6.00 s.

1. What is the linear acceleration of the bucket during its fall?
2. What is the constant angular acceleration of the hand crank while the bucket falls.
3. What are the (i) the angular speed and (ii) the tangential speed of the crank handle after the bucket has fallen 24.0 m?

8. A. Two objects, A of mass m and B of mass 2m, are subject to the same impulse. Assume both A and B are initially at rest. In the following statements fill in the blanks with either A for object A, B for object B, the same if objects A and B have the same value, or cannot tell.

At the end of the time interval,

1. ________ is the object with the greater speed.
2. ________ is the object with the greater momentum.
3. ________ is the object with the greater acceleration during the impulse time.
4. ________ is the object with the greater KE.
5. ________ is the object that traveled the greater distance.

9. A 3.25 gram bullet traveling at $v_{01}$ m/s, strikes a 0.850 kg wooden block in a ballistic pendulum situation (see drawing). The block with the embedded bullet rises a vertical distance $h = 15.5$ cm.

A. What is the speed $V$ of the block with the embedded bullet just after impact?
B. What is the speed $v_{01}$ of the bullet just before hitting the wooden block?
C. If the bullet passed all the way through the block and kept going but at a reduced speed, would the block rise not as high, higher, or the same 15.5 cm?

10. A. Two objects, A of mass m and B of mass 2m, are both hanging from strings the same distance $h$ above the ground. The strings holding A and B are cut at the same instant. In the blank spaces provided, enter A, B or the same to best answer the questions.

1. ________ For the flight to the ground, which balls feels the greater impulse?
2. ________ Which ball undergoes the greater momentum change in the flight to the ground?
3. ________ Which ball has the greater speed just prior to hitting the ground?
4. ________ Which ball undergoes the greater KE increase on the way to the ground?
5. ________ Which ball is experiencing the greater acceleration?

C. Explain how an airbag protects the passengers of a car from serious injury in an accident from the perspective of the physics you learned in chapter 7 of the text.
11. A 850 kg car is stopped at a traffic light. A 1.20 × 10^3 kg van traveling at speed \( v \), towards the stopped car makes a perfectly inelastic collision with the car, i.e., the van and the car lock bumpers. At the instant of the collision, the wheels of the car and the van lock and the two vehicles execute a skid that covers 12.5 m. Assume the road is horizontal. The coefficient of kinetic friction between the tires and the surface of the road is \( \mu_k = 0.725 \).

A. With what speed did the locked van and car start the skid just after the collision?
B. The police cited the van for speeding based on the skid evidence. The speed limit through the intersection is 25.0 m/s. Determine \( v \) to see if the police got it right.

12. A couple of movers are allowing a very heavy crate to slide slowly down a truck ramp at a constant speed by hanging tightly onto a rope tied to the crate (see drawing). There is kinetic friction between the crate and the ramp. In the space provided below, enter the name of the force (or forces) requested or a symbol representing the force. None is a possible entry.

1. What is/are the conservative forces acting on the crate as it moves along the ramp?
2. What is/are the nonconservative forces acting on the crate as it moves down the ramp?
3. The conservative forces doing positive work.
4. The conservative forces doing negative work.
5. The nonconservative forces doing positive work.
6. The nonconservative forces doing negative work.

B. The following equations were presented in lecture and used in a homework item for calculating the final velocities of two masses, \( m_1 \) and \( m_2 \), after a 1-dimensional collision for which \( m_1 \) was moving to the right (positive velocity) with an initial velocity \( v_{i1} \) and \( m_2 \) was initially stationary.

\[
\begin{align*}
V_1 &= \left( \frac{m_1 - m_2}{m_1 + m_2} \right) v_{i1} \\
V_2 &= \frac{2m_1}{m_1 + m_2} v_{i1}
\end{align*}
\]

Below are a set of possible conditions.

a. \( m_1 = m_2 \)  
   b. \( m_1 > m_2 \)  
   c. \( m_1 < m_2 \)
   
   d. \( m_1 \) is much, much larger than \( m_2 \)  
   e. \( m_1 \) is much, much smaller than \( m_2 \)

In the spaces below, enter the letter of a single condition (from above) that best accounts for the statement.

1. The masses exchange velocities, i.e., \( v_1 = 0 \) and \( v_2 = v_{i1} \).
2. \( v_i \) is pretty much the same as \( v_{i1} \) and \( v_2 \) is twice \( v_{i1} \).
3. After the collision \( v_i \) is negative.
4. After the collision both masses are moving with positive velocities whose values depend on \( m_1, m_2 \), and \( v_{i1} \).
5. \( v_1 \) is the opposite of \( v_{i1} \), and \( v_2 \) is \( = 0 \), i.e., \( m_1 \) barely moves, if at all.
13. A. A $2.00 \times 10^2$ N force is applied to a full Costco shopping cart and pushes the cart (m = 55.0 kg) down one of the aisles of the store. The force is directed toward the floor at an angle of 28.0° below the horizontal. The coefficient of kinetic friction is $\mu_k = 0.120$ and the cart travels down the aisle a distance of 24.0 m. Note: This pushing force is large enough to cause the cart to accelerate.

1. Find the work done on the cart by the pushing force.
2. Find the work done on the cart by the force of kinetic friction.

B. A small block of mass $m = 1.65$ kg is projected from point A down a curved runway at an initial speed of $v_i = 4.00$ m/s (see drawing). At the initial instant, the center of mass of the block is 3.80 m (h) above the bottom of the runway. The block leaves the runway at point B traveling vertically upward. While the block is on the runway, nonconservative forces do 35.0 J of negative work while the block is on the runway. Determine the maximum height, $h$, above the bottom of the runway the block attains after leaving the runway.

1. What is the velocity of the block/embedded object immediately after the perfectly inelastic collision?
2. What is the velocity of the object, $v$, just before the collision?

15. A. Two objects, A and B, have identical masses, $m_A = m_B = m$, and are initially at rest on separate, frictionless, horizontal surfaces. Simultaneous horizontal forces are applied to each object ($F_A$ to object A and $F_B$ to object B) for a time of 5.0 s each. $F_A = 2F_B$. In the spaces below enter A, B, or same (if the quantity described is the same for A and B) to best answer the statements.

1. The object that experiences the greater net force.
2. The object that experiences the larger impulse over the 5.0 s.
3. The object with the smaller momentum after 5.0 s.
4. The object that has traveled the greater distance in 5.0 s.
5. The object upon which the greater amount of work was done by the applied force over the 5.0 s.
6. The object with the greater KE after the 5.0 s.
7. The object on which the average power produced by the applied force during the 5.0 s was greater.
8. The object with the smaller speed at the end of 5.0 s.
B. Starting from rest a wheel undergoes a uniform counterclockwise circular acceleration. Points A, B and C are located along a radius line. See figure. In the spaces below enter A, B, C or same (the quantity described is the same at A, B and C) that best answers the questions.

1. ________ The point showing the largest instantaneous angular speed.
2. ________ The point showing the largest tangential speed.
3. ________ The point showing the largest angular acceleration.
4. ________ The point showing the largest tangential acceleration.
5. ________ The point shown the largest centripetal acceleration at a given instant.
6. ________ The point that rotates through the largest number of radians in 3.0 s.
7. ________ The point that travels the smallest distance in 3.0 s.

16. A. A trunk of 34.0 kg is sitting on a horizontal surface. A tension of $\mathbf{T} = 250. \text{ N}$ is applied to a trunk at an angle of 60.0° down from vertical. The coefficient of kinetic friction between the trunk and the surface is $\mu_k = 0.600$. See drawing. If the trunk moves a distance of 12.0 m to the right across the surface, find the work done by each actual force the trunk feels. Make sure you include the name of the force with each work you are calculating.

B. A top is a toy that is made to spin on its pointed end by pulling on a string that is wrapped around the body of the top. The string has a length of 75.0 cm and is wrapped around the top at a place where the radius is 2.00 cm. The thickness of the string is negligible. Someone pulls on the free end of the string in such a way the top undergoes a uniform angular acceleration during the 2.25 s it takes for the string to fully unwind from the top.

1. During the time the string unwinds, how many rotations has the top made?
2. What is the constant angular acceleration of the top during the time the string is unwinding?
3. At the instant the string is fully unwound, what is the angular speed of the top?

17. A 2.50 gram bullet traveling with a velocity of $v_{ob} = 385 \text{ m/s}$. It embeds itself in block wood whose mass is 275 grams. The block and embedded bullet proceed up a 37.0° incline. See figure. The amount of work done by the kinetic frictional force on the block and embedded bullet in traveling up the incline is $-0.400 \text{ J}$.

A. Find the initial speed $V$ with which the block and embedded bullet move up the incline.
B. What is the distance $s$ the block travels along the incline before stopping?

18. A. Identical forces $\mathbf{F}$ act on two blocks, A with mass $m$ and B with mass $2m$. Each block is initially at rest, sits on a horizontal frictionless surface, and is moved a distance $\Delta x$ as a result of the force $\mathbf{F}$ that is applied. In the spaces provided enter A, B, or same to best fit the statement that follows.

1. ________ The block on which the greater amount of work is done.
2. ________ The block experiencing the larger acceleration.
3. ________ The block with the larger KE after moving the distance $\Delta x$.
4. ________ The block with the greater speed after moving the distance $\Delta x$.
5. ________ The block that takes the longer time to travel the distance $\Delta x$.
6. ________ The block with the larger momentum after traveling the distance $\Delta x$. 
B. At the initial instant $t_0 = 0$ the crank handle is released and the water bucket accelerates into the well while the rope unravels from the shaft. For the statements below, circle the parenthetical item that correctly completes the sentence.

1. At any instant later than $t_0$ the angular speed of the crank handle is \((\text{equal to, greater than, less than})\) the angular speed of the shaft.
2. The constant angular acceleration of the shaft is \((\text{equal to, greater than, less than})\) the angular acceleration of the crank handle.
3. At any instant later than $t_0$ the tangential speed of the crank handle is \((\text{equal to, greater than, less than})\) the tangential speed of a point on the shaft.
4. The tangential acceleration of the crank handle is \((\text{equal to, greater than, less than})\) the tangential acceleration of a point on the shaft.
5. The downward acceleration of the water bucket is \((\text{equal to, greater than, less than})\) the tangential acceleration of the crank handle.
6. The downward acceleration of the water bucket is \((\text{equal to, greater than, less than})\) the tangential acceleration of a point on the shaft.
7. At any instant later than $t_0$ the downward speed of the water bucket is \((\text{equal to, greater than, less than})\) the tangential speed of the crank handle.

19. Examine the two-block system shown where $m_1 = 6.00 \text{ kg}$ and $m_2 = 4.00 \text{ kg}$. At $t_0 = 0$ the system is released and $m_1$ and $m_2$ accelerate together. The magnitude of the kinetic frictional force between the table top and $m_1$ is $26.5 \text{ N}$.

A. What is the work done by the frictional force between the surface of the table and $m_1$ if $m_2$ falls 0.750 m?
B. What is the speed of $m_2$ after falling 0.750 m? Use energy methods.
C. What is the net work done by the tension?

20. An 1800 kg car stalled in intersection is struck perfectly inelastically in a broadside collision with another car whose mass is 2200 kg and traveling at a speed of 22.0 m/s as shown in the drawing. The pair of cars, locked together, skid to a stop a distance of 35.0 m beyond the collision point.

A. What is the speed of the pair of cars just after the collision?
B. What impulse \(\mathbf{I}\) acts on the 2200 kg car during the collision?
C. What is the magnitude of the frictional force that brings the two-car wreck to a stop after the collision?