SECOND MIDTERM -- REVIEW PROBLEMS

A solution set is available on the course web page in pdf format. A data sheet is provided. Not all problems have solutions.

1. (a) Convert 756 J to foot-pounds. ________________
(b) A 675 kg object is raised vertically. If 19,000 J of work are expended, how high was it raised? _____
(c) A spring is stretched 3.50 inches by a force of 14.6 pounds. Find the spring constant. ________________
(d) Convert 13,600 watts to horsepower. ________________
(e) A 10.5 kg mass moves at constant velocity across a horizontal surface when acted upon by a 18.0 N horizontal force. Find the coefficient of sliding friction. ________________

2. (a) Convert 324 J to English units. ________________
(b) Convert 472 kilowatts to horsepower. ________________
(c) The moon orbits the Earth in 27 1/3 days at a distance of 240,000 mi. Assume the mass of the moon is small compared to the mass of the Earth. Calculate the inward acceleration of the moon in m/s^2. ________________
(d) A car skids to a stop from a speed of 60.0 mi/hr in a distance of 220 feet. Calculate the average value of the coefficient of kinetic friction. ________________
(e) A block slides with constant velocity down the plane shown. The mass is 4.25 kg. Calculate the work done by friction while it slides 1.50 m.

3. An external force F is applied on the block as shown. The coefficient of sliding friction is \( \mu_s \) and of static friction is \( \mu_k \). The block has a mass M. Assume the block is small compared to the dimensions of the plane.

(a) What is the minimum force F necessary to move the block from A to B at constant velocity?
(b) How much work is done to move the block slowly from point A to point B, by the force F calculated in (a). (If you can't do (a), do this part with F as a symbol.)

4. A non-Hooke's law spring follows the force law \( F = -kx - Bx^3 \) where k and B are positive constants, and \( x = 0 \) is the equilibrium position. An external force of 10.0 N compresses the spring 3.21 cm, and an external force of 20.0 N compresses it 4.92 cm. (Be very careful about the sign you use for the 10 N and 20 N forces in using the equation above.)

(a) Find the constants k and B, with proper units.
(b) Calculate the potential energy stored in the spring when it is compressed 9.00 cm. (Do this symbolically if you can't do part (a).)
5. (a) Convert 265 ft-lbs to joules.
(b) A 1200 kg object is raised vertically a distance of 27.5 ft. How much work is done on the object?
(c) A car of weight 3250 pounds is traveling at 65 mi/hr. The brakes are put on and it skids to a stop with constant deceleration in a distance of 225 ft. Find the power being dissipated as heat after the car has traveled 125 ft.
(d) A block slides with constant velocity on a plane inclined at 29.0° from the horizontal. Calculate the coefficient of kinetic friction.
(e) A peculiar spring follows the force law \( F = -kx^5 \). (The sign convention is as used in Hooke's Law.) If \( k = 37.5 \text{ N/m}^5 \), find the energy stored in the spring when it is compressed 0.27 m.

6. A very light rigid rod whose length is \( L \) has a ball of mass \( m \) attached to one end as shown. The other end is pivoted without friction in such a way that the ball moves in a vertical circle. The system is launched from the horizontal position A with downward initial velocity \( v_o \). The ball just reaches point D and then stops.

(a) Derive an expression for \( v_o \) in terms of \( L \), \( m \) and \( g \).
(b) What is the tension in the rod when the ball is at B?
(c) A little grit is placed on the pivot, after which the ball just reaches C when launched from A with the same speed as before. How much work is done by friction during this motion?

7. The system shown is released from rest with the spring in its unstretched condition. \( m_1 \) is attached to the spring. The pulley is massless. Use energy methods.

(a) How far will \( m_1 \) move until the system is instantaneously at rest if the plane is frictionless?
(b) If the coefficients of friction between the block and plane are \( \mu_k = 0.33 \) and \( \mu_s = 0.44 \), how far will \( m_1 \) move before instantaneously coming to rest for the first time?

8. A massless Hooke's Law spring has unstretched length of 1.750 m. When a 37.5 kg mass is placed on it, and slowly lowered until the mass is at rest, the spring is squeezed to a length of 1.712 m. A mass of 95.2 kg is dropped on the spring from a height of 3.75 m. Use energy methods.

(a) What is the length of the spring at maximum compression as a result of the mass dropping on it? (Numerical answer.)
(b) What is the energy stored in the spring when the velocity of the block is 2.50 m/s? (Numerical answer.)
9. (a) Calculate $\mathbf{A} \cdot \mathbf{B}$, if

$$\mathbf{A} = 5.0 \mathbf{i} + 6.0 \mathbf{j} - 9.5 \mathbf{k}$$

$$\mathbf{B} = -3.0 \mathbf{i} - 7.0 \mathbf{j} - 4.5 \mathbf{k}$$

(b) A force of 75.0 N acts through a distance of 45.0 m. Calculate the work done in ft-lbs.

(c) Assume a spring with a force law given by $F = -kx^3$. If $k = 250 \text{ N/m}^3$, calculate the work done to compress the spring from $x = 0$ to $x = 1.25 \text{ cm}$ in joules.

(d) Calculate the maximum safe speed for a car traveling around an unbanked curve of radius 400 ft if the friction coefficients are $\mu_s = 0.75$ and $\mu_k = 0.55$. (The answer should be in ft/s.)

(e) A car goes around an unbanked curve at 40.0 mi/hr. The curve has a radius of 500 ft. At what angle to the vertical does a weight suspended on a string hang in the car?

10. A block of mass $m = 0.175 \text{ kg}$, is launched with an initial velocity $v_o = 1.37 \text{ m/s}$ down the incline. The coefficients of friction are $\mu_s = 0.65$ and $\mu_k = 0.55$. Use the work-energy theorem to calculate how far down the incline the block slides before stopping. The plane is as long as needed.

11. (a) Calculate $\mathbf{A} \cdot \mathbf{B}$ if

$$\mathbf{A} = -3.00 \mathbf{i} + 4.00 \mathbf{j} + 7.25 \mathbf{k}$$

and

$$\mathbf{B} = +5.25 \mathbf{i} - 4.00 \mathbf{j} - 2.00 \mathbf{k}$$

(b) A car goes around a curve that is not banked at 65.0 mi/hr. The curve has a radius of curvature of 720 ft. At what angle to the vertical does a weight suspended on a string hang in the car?

(c) Convert 7,200 ft to ft pounds.

(d) If a spring has the force law $F = -kx - bx^3$, calculate the work to stretch it from $+x_1$ to $+x_2$, where neither $x_1$ nor $x_2$ are the unstretched length. (The unstretched position is $x = 0$.)

(e) A mass of $m = 4.70 \text{ kg}$ is accelerated by a horizontal force of 27.0 N on a horizontal, frictionless surface. How much work is done by the force in 2.00 seconds if the mass starts from rest?

12. A block of mass $m$ ($m = 1.80 \text{ kg}$) is pulled at constant speed down the plane as shown. The coefficients of friction are: $\mu_s = 0.75$ and $\mu_k = 0.55$.

(a) Calculate the numerical value of $P$.

(b) Find the work done by $P$ to move the block 2.50 m along the plane.

(c) Determine the work done by gravity when the block moves 2.50 m along the plane.

(d) Calculate the work done by friction when the block moves 2.50 m along the plane.
13. (a) Calculate $\mathbf{A} \cdot \mathbf{B}$ if

$$\mathbf{A} = 9.20\mathbf{i} + 8.70\mathbf{j}$$
$$\mathbf{B} = -3.20\mathbf{i} + 3.70\mathbf{j}$$

(b) Convert 62.7 Joules into foot-pounds using the data given.

(c) A non-Hooke's Law spring has the force law $F = -kx^3$ (the sign convention is as in Hookes Law). If $k = 125$ N/m$^3$, calculate the work done to stretch the spring from $x = 0$ to $x = 0.360$ m.

(d) A car comes to a stop with constant acceleration. If the initial speed is 60.0 ft/s, and the stopping distance 250 feet, calculate the angle from the vertical for a mass suspended on a string in the car (while it is slowing down). Assume no oscillations, just the steady state.

(e) An object weighing 275 pounds is raised vertically 4.20 m. Calculate the work (in Joules) necessary to do this.

14. The block of mass $m$ (m = 2.75 kg) is pushed up the inclined plane at constant speed by the force $F$, directed as shown. $\mu_s = 0.600, \mu_k = 0.400$

(a) Calculate the magnitude of the force $F$.
(b) Calculate the work done on the block by gravity when it moves 1.27 m up the plane.
(c) Calculate the work done by friction on the block when it moves 1.27 m up the plane.

15. In this system the block, whose mass is given, is launched with an initial velocity $V_o$, as shown. The coefficients of friction are given. The spring has a force constant $k$. The distance shown is from the initial position (where the block has $V = V_o$) to the end of the spring when the spring is neither squeezed nor stretched. USE ENERGY METHODS FOR BOTH PARTS.

$$V_o = 4.70 \text{ m/s} \quad m = 1.25 \text{ kg}$$
$$\mu_k = 0.40 \quad \mu_s = 0.60 \quad k = 350 \text{ N/m}$$

(a) Calculate the magnitude of the velocity of the mass just before it first touches the spring.
(b) Calculate the TOTAL distance the mass travels before its velocity first becomes zero.

16. (a) A car weighing 3000 pounds is traveling at 25.0 mi/hr. Calculate its kinetic energy in Joules.
(b) A 1500 kg car loses speed (40.0 m/s to 30.0 m/s) over a distance of 100 m when sliding with the wheels locked. Calculate the coefficient of kinetic friction between the tires and road.
(c) A block of mass 23.0 kg is moved at a steady speed of $v = 15.0 \text{ m/s}$ with an external force of 35.0 N. Calculate the power delivered by this force.

(d) If 1.25 hp are delivered by a force acting on a mass moving at 25.0 ft/s, what is the force.
(e) Calculate the work (in Joules) needed to slowly raise a 756 pound object 13.0 feet vertically.
17 A block is launched up an inclined plane with an initial velocity of $v_0 = 6.50$ m/s. See figure. The coefficients of friction and other values are given in the table. The spring is massless and is in its unstretched state. Show clearly how you define $PE = 0$. **USE ENERGY METHODS.**

(a) Calculate the magnitude of the amount the spring is squeezed when the block comes to zero velocity.

(b) Determine the position of the block when it comes to rest on the way down. Measure this as the distance from its *initial* position. Up is positive, down is negative from there.

\[ \mu_k = 0.65 \quad \mu_s = 0.75 \]
\[ d = 1.25 \text{ m} \quad m = 0.70 \text{ kg} \]
\[ k = 2100 \text{ N/m} \]

18 A small block is launched into a frictionless tube as shown. The curved part is a circle of radius $R$. The plane of the drawing is the vertical plane, with up shown. The spring constant is $k$.

(a) Calculate the minimum compression of the spring, $d$, that will cause the block to arrive at the top with zero velocity

(b) If the spring is compressed a distance $d$ before launching the block, what is the normal force on the block at point B, exactly at the same vertical position as the center of the loop? $d$ is large enough that the velocity at A is greater than zero. [Not the same as (a).]

(c) For the case in (a), find the normal force on the block at C, the exact bottom. (Here the velocity at A is infinitesimally greater than zero.)

19 (a) Calculate $\mathbf{\vec{A} \cdot \vec{B}}$ if

\[ \vec{A} = 4.70 \mathbf{i} + 3.30 \mathbf{j} \]
\[ \vec{B} = 2.75 \mathbf{i} - 4.29 \mathbf{j} \]

(b) Convert 427 Joules into ft/lbs using the data given.

(c) An object whose weight is 350 pounds is lifted a distance of 75.0 ft. Calculate the work, in Joules, necessary to do this.

(d) The coefficient of static friction between the block and plane shown is 0.75. Calculate the frictional force on the block.

(e) Assume a peculiar spring with the force law $F = -kx^5$. If $k = 175 \text{ N/m}^5$, calculate the work that must be done on the spring to stretch it from $x = 0$ to $x = 2.0 \text{ cm}$.

20 Block $m$ starts at rest as shown in the drawing. The spring is initially unstretched and not squeezed. This spring is a normal Hooke's Law spring.

(a) Calculate the work done by $F$ on the block to move the block 0.500 m up the plane.

(b) Find the work done by friction on the block when the block is moved 0.500 m up the plane.

(c) Determine the work done by gravity on the block when the block is moved 0.500 m up the plane.

(d) What is the work done by the spring on the block when it moves 0.500 m up the plane?
21 (a) How much work is done by a person moving a 5.00 kg box up a frictionless hill with $s = 10.0 \text{ m}$ and $h = 3.00 \text{ m}$?
(b) Convert 105 horsepower into watts.
(c) How much work is done by gravity when a 10.0 kg object is lifted 5.00 m?
(d) A Hooke's Law spring with $k = 37.5 \text{ N/m}$ is compressed 20.0 cm. Find the work that must be done on the spring to achieve this.
(e) A car rounds a curve at 65.0 mph. The curve has a radius of 700 ft. A weight is suspended on a string inside the car. What is the angle of the string with respect to the vertical?

22 A spring has a force law of

$$F = -kx$$

The sign convention is as discussed in class.

(a) Calculate the work done to compress the spring by 1.50 cm from the equilibrium position.
(b) Determine the work done to stretch the spring by 0.75 cm from the equilibrium position.

$$k_1 = 200 \text{ N/m} \quad k_2 = 75 \text{ N/m}^3$$

23 (a) Calculate the kinetic energy, in Joules, of a $2.45 \times 10^6 \text{ kg}$ asteroid at 15,000 m/s as it enters the Earth's atmosphere.
(b) Determine the work done to stretch the spring by 0.75 cm from the equilibrium position.
(c) A block slides with constant velocity down an inclined plane at an angle of $33^\circ$ from the horizontal. Calculate the coefficient of kinetic friction.
(d) In this drawing the coefficient of static friction is 0.60. The block (mass = 4.75 kg) is not moving. Find the frictional force acting on it.

24 The block shown has a mass of 1.58 kg. The block is pulled up the incline an external force $F$, as shown. The coefficients of friction are $\mu_s = 0.70$ and $\mu_k = 0.55$. The force $F$ is 7.50 N. The block stays in contact with the plane at all times. If the block is moved 2.25 m up the incline, calculate (including signs):

(a) the work done by gravity on the block;
(b) the work done on the block by the normal force;
(c) the work done by $F$ on the block;
(d) the work done by friction on the block.
25. (a) Calculate \( \mathbf{A} \cdot \mathbf{B} \) where \( \mathbf{A} = -4.00\hat{i} + 5.00\hat{j} - 8.00\hat{k} \) and \( \mathbf{B} = 3.00\hat{i} - 6.00\hat{j} + 7.00\hat{k} \). 

(b) A car goes around a horizontal (not banked) curve whose radius of curvature is 240 m. If the car is traveling at a constant speed of 100 km/hr, at what angle from the vertical does a mass suspended on a string hang inside the car? You must draw a diagram.

(c) A rubber band obeys the force law \( F = -kx - cx^4 \). Assume that \( x = 0 \) for one end of the unstretched rubber band. If this end is stretched from \( x_1 \) to \( x_2 \) (\( x_1 \) and \( x_2 \) are both greater than zero) calculate the work done on the rubber band.

(d) The potential energy as a function of position for an object of mass \( m \) is given by \( U(x) = ax^2 - bx^3 \). Calculate the force on the object as a function of \( x \).

(e) A 2000 kg car initially traveling on ice at 120 km/hr puts its brakes on slides (with the wheels locked) to a stop in 100 m. Find the instantaneous power being dissipated as heat after the car has skidded 50 m.

26. Consider the potential energy curve shown in the figure. A 10 kg mass is accelerated to an initial velocity \( v_0 \) by compressing a spring of force constant \( k = 100 \text{ N/m} \). The heights at points A, B, C and D are 20 m, 35 m, 10 m, and 30 m, respectively.

(a) Assume there is no friction. Calculate the minimum initial velocity, \( v_{in} \), required to clear the second hill (point D).

(b) Calculate the compression of the spring that is required to achieve the initial velocity found in part (a).

(c) Calculate the velocity of the 10 kg mass at point D given the initial velocity found in part (a).

(d) If the energy lost to friction is 300 J when the 10 kg mass reaches point B and 900 J when the mass reaches point D, calculate the minimum initial velocity, \( v_{in} \), necessary to pass point D?

(e) Find the answer to part (d) if the mass is 100 kg but the energy lost to friction is the same (smaller \( \mu_s \) in this case).

27. (a) Calculate the conversion identity between joules and ft-pounds.

(b) We find that the potential energy of an object in the Earth's gravity is given by \( U = -(A/R) \) where \( A \) is a constant and \( R \) the distance to the center of the Earth. Calculate the force in the \( R \) direction associated with this potential energy.

(c) Calculate the energy (in joules) represented by a power of 1735 kilowatts acting for 325 seconds.

(d) A car skids with wheels locked for 165 ft before stopping. The mass of the car is 2500 kg. The coefficients of friction are \( \mu_s = 0.750 \) and \( \mu_k = 0.650 \). Calculate the kinetic energy of the car (in joules) when it just starts to skid.

(e) A car of mass 2500 kg is traveling at 75.0 mi/hr. The brakes are put on and it skids with the wheels locked to a stop in 325 ft. Find the power being dissipated as heat (in watts) after it has skidded 162.5 ft.
28. (a) Given a potential energy function \( U = Ax + Bx^2 + Cx^3 \) where A, B and C are constants. Calculate the force described by this function as a function of \( x \).

(b) A spring follows the force law \( F = -kx \). If \( k = 12.5 \text{ N/m} \), find the energy stored in the spring when it is compressed by 0.12 m.

(c) A block slides with constant velocity on an inclined plane at an angle of 27°. Find the coefficient of kinetic friction.

(d) Convert 1532 J to ft-lbs.

(e) A 12.5 kg rock is dropped from 15.7 m above the surface of a lake. While in the lake the rock falls at a constant velocity of 5.00 m/s. Find the energy lost to heat when the rock reaches 10.0 m below the surface of the lake.

29. On the loop-the-loop shown a block of mass \( m \) slides without friction. The block starts with a speed \( v_o \) at a height of 6R from the bottom of the loop. (R is the radius of the loop.) \( v_o \) is given by \( v_o = \sqrt{3gR} \).

(a) Find the velocity of the block at point A.

(b) Find the normal force on the block at point B.

30. A block of mass \( m \) is launched in the frictionless circular loop-the-loop shown. Given that the spring constant is \( k \), the radius \( R \) and the mass \( m \), find the distance the spring must be compressed before launch if the normal force on the block at top of the loop is 2 mg.

31. A small object of mass \( M \) is launched with a velocity \( v_o \) at the top of the frictionless track shown. Calculate the normal force on the object at point A. The curved portion of the track has a radius of curvature \( R \). A is the exact bottom of the curve.

32. A spring of spring constant \( k \) is used to launch a block of mass \( m \) up the curved track shown. The track is in a vertical plane. The maximum height observed for the block is given by \( h \). If \( k = 2.75 \times 10^4 \text{ N/m} \), \( m = 3.25 \text{ kg} \), \( h = 7.50 \text{ cm} \) and the initial compression of the spring is 2.25 cm, find the energy lost to friction.
33. In the roller coaster loop-the-loop shown, the frictionless car starts with zero velocity at a height \( h \). The normal force at the top of the loop (point A) is found to be three times the weight of the cart. Take the radius of the loop as \( R \).

(a) Calculate \( h \) in terms of \( R \) and \( g \).
(b) Calculate the normal force on the car at point B where \( \theta = 30^\circ \) from the horizontal. Express this as a number or fraction times the weight of the car.

(c) Find the normal force on the block at A as a function of \( x \).

34. A small block is launched on the frictionless loop-the-loop shown. The spring launcher has a spring constant \( k \).

(a) Find the velocity at the top of the loop as a function of the displacement \( x \) of the spring launcher from its equilibrium length.
(b) Find the minimum value of \( x \) such that the block goes over the top in contact with the track.

35. A small block of mass \( m \) slides along the frictionless loop-the-loop shown.

(a) If it starts from rest at P, what is the normal force acting on it at Q?
(b) At what height above the bottom of the loop should the block be released so that the force it exerts against the track at the top of the loop is equal to its weight?

36. A mass of \( m = 4.75 \) kg is attached to a massless rod of length \( L = 1.32 \) m. The rod is pivoted at P so that it can rotate in the vertical plane. When the mass is directly above P it is given an initial horizontal velocity of 2.75 m/s.

(a) Calculate the tension in the rod (in newtons) when the mass is exactly below the pivot point P.
(b) Calculate the kinetic energy of the mass when the rod is at an angle of 45° from the vertical as shown.

37. A frictionless plane is at an angle \( \theta \) with the horizontal. A pivot in the middle is attached to a string of length \( R \). Attached to the string is a mass \( m \), so that the mass can move in a circular path about the pivot. When the mass is at its lowest point it is given an initial tangential velocity \( v_\theta \). When the mass is at its topmost point the tension in the string is measured to be 2 times the weight of the mass. Calculate the initial velocity \( v_\theta \), in terms of \( m \), \( g \), \( R \) and \( \theta \).
38. On the incline shown, a block of mass 2 kg is launched upward with an initial velocity at point A of \( v_0 \). The block strikes a massless spring at B and compresses it. The relaxed length of the spring, \( \ell_0 \), is 0.5 m. The distance AB is 2.5 m. The coefficient of sliding friction is 0.3 and the spring constant \( k \) is 2500 N/m. If the spring is compressed to a length 0.3 m by the impact of the block (before the block stops), find the value of \( v_0 \). (Use energy methods.)

40. A block of mass 3.00 kg is launched down the inclined plane with a velocity of 2.25 m/s. When it reaches the bottom it has a velocity of 4.15 m/s.

(a) Using energy methods, calculate the coefficient of kinetic friction between the block and the plane.

(b) If it is launched up the plane from the bottom with a velocity of 2.25 m/s, find how far up the plane it goes.

41. A block is moved up an inclined plane by a constant horizontal force, \( P \). The block starts with an initial velocity, \( V_0 = 1.50 \) m/s, and stops exactly at the top.

(a) Draw a clear free body diagram for the block.

(b) Find the value of \( P \). (Use energy methods.)

\[
\begin{align*}
\mu_k &= 0.70 \\
\mu_s &= 0.55 \\
\theta &= 30.0^\circ \\
m &= 3.25 \text{ kg} \\
\end{align*}
\]

42. A block, of mass 1.75 kg, slides down the plane shown. The coefficients of friction are \( \mu_s = 0.470 \), \( \mu_k = 0.415 \). The block starts at rest and slides 1.25 m before striking a spring of spring constant \( k = 130 \) N/m. Calculate the amount by which the spring is compressed when the block is brought to a stop.
43. A constant force, \( F = 40.0 \text{ N} \), is applied to the massless string. A block starts at rest.

(a) Calculate the kinetic energy of the block after it has traveled 1.75 m up the plane.

(b) Determine the work done by friction while the block is traveling 1.75 m up the plane.

(c) Find the work done by gravity on the block while traveling 1.75 m up the plane.

\[ \mu_s = 0.65; \mu_k = 0.60; m = 3.25 \text{ kg}; \theta = 25.0^\circ \]

44. A massless Hooke's Law spring has a unstretched length of 2.25 m. When a 10.0 kg mass is placed on it, and slowly lowered until the mass is at rest, the spring is squeezed to 2.00 m length. The same 10.0 kg mass is dropped from a height of 6.25 m above the spring.

(a) What is the maximum value of the compression of the spring? (Numerical answer.)

(b) What is the velocity of the block after the spring has been compressed 0.25 m. (Numerical answer.)

45. A sphere of mass 0.750 kg is attached to a massless rod whose length is 1.45 m. The rod is pivoted at \( P \) so that it moves in a vertical plane. When the mass is directly above \( P \) it is given an initial velocity of \( v_o = 2.55 \text{ m/s} \).

(a) Calculate the velocity of \( m \) when it is directly below \( P \).

(b) Determine the tension in the rod when it is at 30° from the vertical as shown by the dotted lines.

46. A block of mass \( m \) is moved down the plane with a constant force \( P \) (constant in magnitude and direction). Initially the block is at rest, and at the bottom it has a velocity of \( v = 1.75 \text{ m/s} \). A clear free body diagram and separate force diagram for the block are essential for full credit. Calculate using these numerical values: \( \mu_s = 0.75, \mu_k = 0.55 \) and \( m = 1.35 \text{ kg} \)

(a) Find the work done by friction on the block.

(b) Calculate the work done by \( P \) on the block.

47. A block moves on the frictionless loop-the-loop shown. The initial position is at a height \( h \) and has an initial velocity \( v_o \). The block is to be considered very small.

(a) If \( h = 2R \), calculate the minimum value of \( v_o \) so that the block remains in contact with the loop all the way around.

(b) If \( v_o = (2gR)^{1/2} \) and \( h = 2R \), calculate the normal force on the block at point \( B \), exactly opposite the center of the loop.

(c) If \( v_o = (2gR)^{1/2} \) and \( h = 2R \), calculate the normal force on the block at \( C \), exactly at the bottom. (At \( C \), the track is curved in the circular shape of the loop with radius \( R \).)
48. In the diagram shown the force, \( F \), is at 15.0° above the horizontal.

(a) Calculate the work done by gravity when the block is moved 1.35 m down the plane.
(b) What is the work done by the force (\( F \)) when the block is moved 2.35 m down the plane.
(c) Find the work done by friction when the block is moved 2.35 m down the plane.

\[ m = 3.20 \text{ kg}; \mu_s = 0.75; \mu_k = 0.55; F = 35.0 \text{ N} \]

49. Find the work done by the force \( \overrightarrow{F} = y\overrightarrow{i} - z\overrightarrow{j} \) on the path:

(a) CA
(b) BC
(c) AB
(d) Is \( \overrightarrow{F} \) a conservative force?

50. The block, as shown in the drawing, is launched up the incline with an initial velocity of \( v_0 = 4.00 \text{ m/s} \). A very weak spring with \( k = 20.0 \text{ N/m} \) is placed on the top of the incline a distance 1.00 m from the block. The block hits the spring, compresses it and stops. (No energy is lost when the block hits the spring.)

(a) What is the maximum compression of the spring?
(b) The spring launches the block back. What will be the velocity of the block when it is again 1.00 m from the spring (at its initial position)?

\[ \mu_k = 0.24; \mu_s = 0.30; \ell = 1.00 \text{ m}; m = 2.00 \text{ kg}; k = 20 \text{ N/m} \]

51. A small sphere of mass \( m = 2.30 \text{ kg} \) is attached to a massless, rigid rod. The length of the rod is 0.870 cm, and it is pivoted at point P. The spring has a spring constant of 205 N/m. It is initially squeezed 0.25 m from its equilibrium length, and is in contact with the sphere. The left end of the spring is rigidly fixed.

(a) Calculate the speed of the sphere at A (directly above P).
(b) Determine the force on the sphere due to the rod, including direction (in or out), at A.
(c) What is the minimum compression of the spring such that the sphere reaches point A, directly above P.
52. The block shown starts at rest and slides 1.25 m before striking the spring. The coefficients of friction are \( \mu_s = 0.70 \) and \( \mu_k = 0.60 \). The mass of the block is 0.375 kg. The spring constant is 210 N/m.

(a) Calculate the amount of compression from equilibrium of the spring at the point when the block first comes to \( v = 0 \).
(b) What is the maximum distance back up the plane the block will slide. Measure this from \( A \), the equilibrium point of the spring.

53. A massless Hooke's Law spring has an unsqueezed, unstretched length of 1.90 m. When a 12.0 kg mass is placed on it, and slowly lowered until the mass is at rest, the spring is squeezed to 1.75 m in length. Now, with the 12.0 kg mass removed, drop a 10.0 kg mass from a height of 4.25 m above the spring.

(a) What is the maximum value of the compression of the spring from its unsqueezed, unstretched length? (Numerical answer.)
(b) What is the velocity of the block after the spring has been compressed 0.350 m from its unsqueezed length. (Numerical answer.)

54. The block shown has a mass of 1.75 kg and is launched down the inclined plane at an initial velocity \( V_0 \) of 2.35 m/s. The spring is 0.75 m long when unstretched and unsqueezed, and its spring constant is 1400 N/m.

(a) In the absence of friction, calculate the length of the spring when the block is brought to rest.
(b) In the presence of friction, calculate the length of the spring when the block is brought to rest.

(b) \( V_0 = 2.35 \text{ m/s} \)
\( m = 1.75 \text{ kg} \)
\( k = 1400 \text{ N/m} \)
\( \mu_s = 0.70 \)
\( \mu_k = 0.55 \)

55. (a) A spring can be described by the following force, \( F = -kx + cx^3 \), where \( x \) is measured with respect to the equilibrium length. Calculate the potential energy of this spring (as a function of \( x \)).
(b) Calculate the work done in stretching the spring of part (a) from \( x_1 \) to \( x_2 \) (\( x_1 \) and \( x_2 \) are both greater than zero).
(c) A car of mass 2000 kg slides (skids) on level ground with its wheels locked for 150 m before it stops. The coefficients of static and kinetic friction are \( \mu_s = 0.600 \) and \( \mu_k = 0.300 \), respectively. Calculate the kinetic energy of the car just before it starts to skid.
(d) Find the power being dissipated as heat (in watts) in part (c) after the car has slid for 100 m.
(e) \( \vec{A} = -4.00\hat{i} + 5.00\hat{j} - 6.00\hat{k} \); \( \vec{B} = 7.00\hat{i} - 6.00\hat{j} - 8.00\hat{k} \)
Calculate \( (\vec{A} + \vec{B}) \cdot \vec{B} \).
56. A particle of mass $m$ moves in two dimensions from the origin to the point where $x = 2.00 \text{ m}$ along the curve $y = ax^3 + bx^2$ ($a = 2 \text{ m}^2$ and $b = 3 \text{ m}^{-1}$). The particle is subject to a force $\mathbf{F} = y\hat{i} + x\hat{j} \text{ N}$. $\mathbf{dF}$ can be written $\mathbf{dF} = dx\hat{x} + dy\hat{y}$.

(a) Find the work done by the force on the particle $F_x = y\hat{i} \text{ N}$.  
(b) Find the work done by the force on the particle $F_y = x\hat{j} \text{ N}$.  
(c) Find the total work.

57. A block of mass 1.00 kg is accelerated to a velocity $v_o$ using a spring of spring constant, $k = 50.0 \text{ N/m}$. The radius of the circular loop is 6.00 m.

(a) If the track is frictionless, calculate the minimum velocity, $v_{min}$, required to make it to the end of the track.  
(b) Calculate the compression of the spring that is necessary to achieve the velocity, $v_{min}$, found in part (a).  
(c) If the block is launched from rest ($v_y = 0$) at point A ($y = 30 \text{ m}$) will it make it around the circular loop? You must show your work. The low point of the loop is at a height of 10.0 m.

58. A 160 lb student is standing on the floor and then jumps up. Her center of mass raises by 1 ft. What is the work done by the normal force at her feet? Explain your reasoning.

B. You want to lift a 2.0 kg bowling ball 51 cm in 5.0 s. What minimum power do you need to provide?

C. Your 1000 kg sports car just ran out of gas at the bottom of a 20 m high hill. You decide to push it up the hill. If 84 kJ are lost due to friction and air resistance, how much work do you have to do to push your car all the way up to the top of the hill?

59. A 15 kg object and a 10-kg object are suspended, joined by a cord that passes over a pulley with a radius of 10.0 cm and a mass of 3.00 kg (see figure). The cord has a negligible mass and does not slip on the pulley. The pulley rotates on its axis without friction. The objects start from rest 3.00 m apart. Treat the pulley as a uniform disk, and determine the speeds of the two objects as they pass each other.

60. A marble of mass $M = 60 \text{ g}$ and radius $R = 5 \text{ mm}$ rolls without slipping down the track AB starting from rest at a height $h_A = 50 \text{ cm}$ as shown in the figure. The marble then slides up the frictionless track BCD up to a maximum height $h_C$. Find $h_C$ in cm. Assume the marble is a uniform solid sphere, and neglect rolling friction and air resistance. Hint: The marble keeps spinning as it slides up the track BCD.
61. A block of mass $m = 1.2$ kg can slide between two walls on a horizontal surface having coefficient of kinetic friction $\mu_k = 0.20$. The block is connected to the walls by two identical springs, one on each side of the block. Each spring has spring constant $k = 40$ N/m and is 5 cm long when unstretched. In equilibrium, the block is at the center and the springs have length $L = 20$ cm, as shown in figure 4. If the block is displaced a distance $d = 7.0$ cm from the center and then released from rest (figure 1), find:

(a). the speed $v$ of the block when it passes the center for the first time (figure 2);
(b) the maximum distance $d_{\text{max}}$ the block travels on the other side of the center (figure 3);
(c) the total work $W_f$ done by friction from the moment the block was released until it eventually stops at the center (figure 4).

62. A field of force is given by the expression $\mathbf{F} = -2x^2 \hat{i} - 2y^2 \hat{j}$, with $x$ and $y$ in meters and $F$ in Newtons. Compute the work done by $\mathbf{F}$ along the straight path from the origin to $x = 2$ m, $y = 0$.

B. Suppose the net force on an object is zero. Can the total work done on the object be different from zero? If yes, give an example. Explain your reasoning.

C. Finally following the advise of your doctor, you decide to do a long series of push-ups. At the beginning you feel energetic and can raise your center of mass by as much as 14 in. At the end you are so tired that your center of mass rises by only 2 in. Considering the whole series of push-ups, what is the total work done by the normal forces at your hands and feet? Explain your reasoning.

63. To reduce the power requirement of elevator motors, elevators are counterbalanced with weights connected to the elevator by a cable that runs over a pulley at the top of the elevator shaft. Suppose a 1200-kg elevator can safely carry a maximum load of 800 kg and is counterbalanced with a mass of 1500 kg over a massless pulley.

A. What is the power provided by the motor when the elevator ascends fully loaded at a speed $v = 2.3$ m/s? Hint: in a time $\Delta t$, the elevator rises a height $\Delta h = v \Delta t$.

B. What is the power provided by the motor when the elevator descends empty at a speed $v = 2.3$ m/s?
64. The Royal Gorge Bridge over the Arkansas River is 310 m above the river. A bungee jumper of mass 60 kg has an elastic cord of unstretched length 50 m attached to her feet. The jumper leaps, barely touches the water, and after numerous ups and downs comes to rest at a height $h$ above the water. Assume the cord acts like a spring of force constant $k$. Notice that the cord exerts no tension in the first 50 m of descent because it is slack.

A. Find the jumper’s kinetic energy after the first 50 m of descent, assuming she started from rest.
B. Find the spring constant $k$.
C. Find the height $h$.

65. A uniform ball of mass 0.30 kg and radius 2.0 cm starts from rest at the top of the track shown in the figure. The upper part of the inclined segment is 0.90 m high and is rough (coefficient of static friction 0.80 and coefficient of kinetic friction 0.55). The lower part of the inclined segment is also 0.90 m high but is frictionless. After reaching the bottom of the incline, the ball continues on the frictionless horizontal part until it compresses a spring of force constant 85.0 N/m and bounces back.

A. Find the velocity of the center of mass of the ball when it leaves the rough part (point A).
B. Find the velocity of the center of mass of the ball when it is sliding along the horizontal portion (point B). Hint: Consider if the angular velocity of the ball changes after point A.
C. Find the maximum compression $d$ of the spring when the ball bounces (neglect friction between ball and spring plate).

66. (a) A car, weighing 2000 pounds, is traveling at 30 miles per hour. Calculate its momentum, in British units.
(b) Calculate the kinetic energy, in joules, of the car in (a).
(c) A 10.0 kg man moves with velocity 12.5 m/s. Find its momentum.
(d) Convert $7.0 \times 10^4$ kg·m/s of momentum to British units.

67. (a) A big truck weighing 20,000 pounds is traveling at 60 miles per hour. Calculate its momentum (in British units).
(b) Calculate the kinetic energy, in joules, of the same truck.
(c) A 3.0 kg mass moves with velocity 7.5 m/s. Find its momentum.
(d) Convert $2.0 \times 10^4$ kg·m/s of momentum to British units.

68. (a) Find the momentum of a 10 kg object moving at a speed of 35 m/s.
(b) Find the momentum of a 256 pound object moving at a speed of 35 ft/s.
(c) Find the x coordinate of the center of mass of a system consisting of a 10 kg object at $x = 0$ and a 0.55 kg object at $x = +8$ m.

69. (b) Calculate the momentum (in British units) of a truck that weighs 7525 lbs moving at 55.0 mi/hr.
(c) Calculate the kinetic energy, in joules of the truck in (b).

70. (c) Convert 375 ft·pounds into the proper SI unit.
(d) A football player of mass 100 kg is moving with a speed of 8.75 m/s. Calculate the magnitude of his momentum.
(e) Find the x-coordinate of the center of mass of a system consisting of 1.25 kg at $x = -1.00$ m, 2.75 kg at $x = +1.50$ m and 3.25 kg at $x = +2.25$ m.
71. Two particles, one having twice the mass of the other, are held together with a compressed spring between them. The energy stored in the spring is 60 J.

(a) How much kinetic energy does each particle have after they are released? Assume that all the stored energy is transferred to the particles and that neither particle is attached to the spring after they are released.

(b) Find the ratio of the velocities of the two particles.

72. (a) Find the y coordinate of the center of mass of the object shown. The object is a sheet metal of density \( \rho \) and thickness \( t \).

(b) Find the mass of this object.

73. Calculate the x coordinate of the center of mass of object shown. The object is the lined region. It is a sheet of thickness \( t \) and density \( \rho \).

74. The cross-hatched figure shown has a thickness \( t \), a uniform density mass \( \rho \) and it is bounded by the horizontal x axis, the line \( x = x_o \) and the curve \( y^2 = x \).

(a) Calculate the x coordinate of the center of mass of the figure shown. (Express your answer as a number times \( x_o \)).

(b) Calculate the y coordinate of the center of mass of the same object. (Express your answer in terms of \( x_o \)).

75. (a) Convert 2.30 horsepower into watts.

(b) Convert 625 foot-pounds into joules. (You will have to work out the conversion factor from the definitions and the ones given.)

(c) A car is moving at 50.0 mi/hr. If it has a mass of 1750 kg, calculate its linear momentum in SI units (metric).

(e) A car of mass 2100 kg is traveling at 60.0 mi/hr. The brakes are put on and it skids to a stop in 418 ft. Find the power being dissipated as heat (in watts) after it has skidded 400 ft, assuming constant deceleration.
76. A car on a frictionless roller-coaster is released from rest at a height \( h \) as shown. At the top of the hump the radius of the curvature of the track is \( R \). The height of the top of the hump is shown in the diagram.

(a) If the apparent weight of a person in the car 1/3 of his normal weight at the top of the hump (point B), calculate \( h \) in terms of \( R \), \( g \) and numbers. The person and car are assumed small compared to \( R \).

(b) For the same starting conditions, calculate the apparent weight of a 100 kg person at point C, if the radius of the curvature at C is 2\( R \).

77. The object shown has a uniform density \( \rho \), and a constant thickness \( t \) in the \( z \) direction. Calculate the \( x \)-coordinate of the center of mass in terms of \( A \), \( B \) and numbers, as needed.

78. (a) A car weighing 2000 pounds is moving at 30.0 mi/hr. Calculate its linear momentum in SI units.

(c) A golf ball at rest is struck and leaves with a velocity of 110 m/s. If the mass of the ball is 0.075 kg, calculate the impulse applied to the ball.

(e) Calculate the kinetic energy, in joules, of the car in (a).

79. Calculate the \( y \)-coordinate of the center of mass of the object shown. The object is a uniform sheet of thickness \( t \) and density \( \rho \).

80. (a) Calculate the linear momentum of a 17.0 kg object moving at 15.2 m/s.

(c) Calculate the kinetic energy, in Joules, of a car of mass 1500 kg moving at 60 mi/hr.

(d) Convert 875 ft-lb into the proper SI unit.

81. (a) A car has a kinetic energy of 70,000 J. If its mass is 1500 kg, calculate its linear momentum.

(d) A baseball of mass = 0.250 kg is moving at 60.0 m/s. It is struck by a bat and now moves at 75.0 m/s in exactly the opposite direction. If the time of collision with the bat is 0.020 s, calculate the average force applied to the ball.

(e) Calculate the linear momentum of a car whose weight is 2500 pounds if it is traveling at 100 ft/s.
82. The object shown is a sheet of material of density $\rho$ bounded by the line $y = 0$, $x = x_o$, and the curve $y = ax^3$. The thickness perpendicular to the paper varies according to the relationship $t = Cx$. $C$, $a$, and $x_o$ are constants. Calculate the $x$ coordinate of the center of mass of this object. Express your answer in terms of numbers, $x_o$, $c$ and $a$ as needed.

83. The object shown is bounded by the horizontal $x$-axis, the line $x = x_o$, and the curve $y = ax^3$. It has a thickness $t$, and a density $\rho$. Calculate the $x$-coordinate of the center of mass of this object.

84. (c) A car with a mass of 1250 kg has a kinetic energy of $1.40 \times 10^6$ J. Determine its linear momentum.

(e) Convert 4750 J to ft-pounds of energy.

85. (a) A car weighing 6235 lbs is moving at 65.0 mi/hr. Find the momentum of the car in SI units. 

(b) For the car in (a), calculate the energy in Joules.

86. (b) Find the linear momentum of Karl Malone ($m = 120$ kg) moving at a speed of 6.50 m/s.

(c) Find the kinetic energy of Karl Malone as described in (b).

(d) A car that weighs 2200 pounds and is moving at 65.0 mi/hr slams on the brakes and comes to rest after 100 feet. Calculate the energy lost to friction (in ft-pounds).

(e) A 2.00 kg mass is pushed up the incline at a constant speed for a distance of 4.00 m. Find the work done on the block by friction if the coefficients of friction are $\mu_s = 0.78$ and $\mu_k = 0.70$. 

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**Diagram:**

- **Problem 83:**
  - Graph showing a curve $y = ax^3$.
  - boundaries $y=0$, $x=0$, $x=x_o$.

- **Problem 84 (c):**
  - Car with mass $M = 1250$ kg.
  - Kinetic energy $KE = 1.40 \times 10^6$ J.

- **Problem 85 (a):**
  - Car weight $W = 6235$ lbs.
  - Velocity $v = 65.0$ mi/hr.

- **Problem 86 (b):**
  - Karl Malone mass $m = 120$ kg.
  - Speed $v = 6.50$ m/s.

- **Problem 86 (e):**
  - 2.00 kg mass.
  - Incline angle $\theta = 22.0^\circ$.
  - Distance $4.00$ m.
  - Coefficients of friction $\mu_s = 0.78$, $\mu_k = 0.70$. 

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87. (a) Calculate the x-coordinate of the center of mass of the object shown. It is a thin sheet of metal of uniform density in the shape given.
(b) If the density depends on x as \( \rho = \rho_0 x \), now recalculate the x-coordinate of the center of mass.

88. (a) Calculate the linear momentum, in British units, of Karl Malone (weight 265 pounds) moving at a speed of 15.0 ft/s.
(b) Determine the kinetic energy, in joules, of Karl Malone moving as in (a).
(d) Convert 787 ft-pounds to joules.
(e) A car weighing 3200 pounds is moving at 65.0 mi/hr. Calculate its kinetic energy in joules.

89. (a) A 2000 kg car going 60 km/hr hits a stopped car (also 2000 kg). Ignore friction. What is the total momentum after this collision?
(b) Determine the kinetic energy, in joules, of Karl Malone moving as in (a).
(d) Convert 787 ft-pounds to joules.
(e) A car weighing 3200 pounds is moving at 65.0 mi/hr. Calculate its kinetic energy in joules.

90. (c) A 1.00 kg air cart similar to the one used in class is moving horizontally at a velocity of 0.256 m/s to the left. The cart hits a second 0.500 kg cart moving at a speed of 0.128 m/s in the same direction. If the two carts stick together, find the final velocity (speed and direction).
(d) Find the internal kinetic energy of the system in part (c) before and after the collision, \( k_i \) and \( k_f \), respectively. If you have not solved part 9c), use \( v \) for the final velocity.
(e) A particle in space of mass \( m = 2.00 \text{ kg} \) is moving with velocity \( v = 8 \text{ m/s} \). The particle breaks up into two particles as shown in the diagram, where \( m_1 = 1.00 \text{ kg} \) and \( m_2 = 1.00 \text{ kg} \). There are no net external forces. Find \( \frac{v}{m_2} \) (magnitude of direction).

91. On a frictionless horizontal air track a cart of mass m and another of mass 3m collide. Initially the cart of mass 3m has a velocity of \( v_0 = 1.25 \text{ m/s} \) and the smaller cart has an initial velocity of zero. Take \( m = 1.75 \text{ kg} \).

(a) If they collide in a completely inelastic collision, calculate the final velocity.
(b) How much mechanical energy is lost in this collision?
(c) If they collide in a completely elastic collision, calculate the final velocity of each cart.
92. A mass \( M_1 \) rests with zero velocity on an ideal spring. The spring constant is 140 N/m. \( M_1 \) has the value 2.75 kg and the spring has a length of 1.25 m when \( M_1 \) is at rest on it. A mass \( M_2 = 4.75 \) kg falls from rest a distance of 0.115 m before striking number 1 and sticking to it.

(a) What is the length of the spring when it has its maximum compression?
(b) What is the length of the spring when all motion has ceased after the impact?

93. A mass \( m \) is attached to massless string that is wrapped around a solid cylinder that is on a frictionless axle. The system starts at rest. Mass \( m = 1.34 \) kg, cylinder mass \( M = 2.37 \) kg and radius is 0.15 m, and the coefficients of friction are 0.45 and 0.35.

(a) Calculate the speed of mass \( m \) after it has moved 1.25 m down the plane.
(b) Calculate the acceleration of mass \( m \) down the plane.

94. (a) Calculate the moment of inertia of a sphere of mass 7.35 kg and diameter of 0.123 m.
(b) The Earth rotates on its axis once every 24.0 hrs. Calculate its angular velocity (in rad/s).
(c) The speed of a point on the rim of a rotating wheel is 40.0 m/s. The wheel has a moment of inertia of 0.250 \( \text{kg} \cdot \text{m}^2 \) and a radius of 0.100 m. Calculate its rotational kinetic energy.
(d) Given a sphere of radius \( R \), and mass \( M \), calculate the moment of inertia about an axis parallel to the diameter at a distance \( R/3 \) from the center.
(e) The speed of a point on the equator of a rotating sphere is 17.0 m/s. The sphere has a mass of 1.25 kg and a diameter of 4.25 cm. Calculate its rotational kinetic energy.

95. (a) Given a uniform cylinder of mass 25.0 kg, radius 5.00 cm and length 20.0 cm, calculate its mass moment of inertia for rotation about an axis parallel to the long axis of the cylinder and halfway between the center and the outside of the cylinder.
(b) A wheel starting from rest accelerates uniformly. If it undergoes 475 complete revolutions in 6 min 35 s, what is the angular acceleration?
(c) A sphere of mass 8.00 kg and diameter 15.0 cm, is rolling without sliding. If its translational velocity is 17.0 m/s, find its rotational kinetic energy.
(d) For the sphere in problem (c), calculate its total kinetic energy.
(e) For the sphere in (c), calculate its angular momentum about the center of mass.
96. Given the Atwood machine shown. Mass 1 is 0.5 kg, and mass 2 is 1.0 kg. The moment of inertia of the pulley is 0.5 kg·m². The radius of the pulley is 0.1 m.

(a) Calculate the acceleration of the system. The rope does not slip on the pulley.
(b) Calculate the tension in each cord.

97. Two cars approach an intersection as shown. Car 1 weighs 4500 lbs and has a speed of 55.0 mi/hr. Car 2 weighs 3750 pounds with a speed of 60.0 mi/hr. They collide in a completely inelastic collision at the intersection.

(a) Calculate the direction the wreckage moves after the collision. Express this as an angle measured counterclockwise from the positive x-axis.
(b) If the coefficient of kinetic friction is 0.55 for the tires on this road, and the wheels of the car are locked (not rolling), calculate the distance the wreckage slides from the collision point.

98. A small mass $m_1$ slides in a completely frictionless spherical bowl. $m_1$ starts at rest at height $h = \frac{1}{2}$ R above the bottom of the bowl. When it reaches the bottom of the bowl it strikes a mass $m_2$, where $m_2 = 3m_1$, in a completely elastic collision.

(a) Calculate the height that $m_1$ moves up the bowl after the collision (measured vertically from the bottom of the bowl).
(b) Calculate the height that $m_1$ moves up the bowl after the collision.

99. (a) A wheel slows from 157 rev/min to 118 rev/min in a time of 43.0 s. Find its angular acceleration.
(b) A wheel starts at rest, with an angular acceleration of 2.50 rad/s². Through what angle has it turned at the end of 100 seconds?
(c) Calculate the moment of inertia for the object shown for rotation about an axis through A, 0.50 m from the right end.
(d) Calculate the moment of inertia of a sphere of mass $m$ and radius $R$, for rotation about an axis $R/2$ from the center of the sphere.
(e) The angular speed of a bicycle wheel is 25 rad/s. If the radius of the wheel is 0.50 m, find the velocity of a point on the rim.
100. (a) A wheel with radius $R = 0.370$ is rolling without sliding. The velocity of the center of mass is $27.5 \text{ m/s}$. Find the angular velocity of the wheel.

(b) A wheel on an axle has an angular acceleration of $-2.10 \text{ r/s}^2$, and an initial angular velocity of $17.5 \text{ r/s}$. How many revolutions does it undergo in $5.0 \text{ s}$?

(c) Two spheres touch each other. Each has a mass of $5.00 \text{ kg}$ and a radius of $4.25 \text{ cm}$. Calculate the moment of inertia for rotation about an axis through the point of contact and tangent to the two spheres, as shown.

(d) A rotating wheel with initial angular velocity of $175 \text{ r/s}$ coasts to a stop in $115 \text{ s}$. What is its TOTAL angular displacement during this time?

(e) Calculate the TOTAL kinetic energy of a bowling ball that is rolling without sliding. The ball weighs $16.0$ pounds, its radius is $4.00$ inches and the translational velocity of its center-of-mass is $35.0 \text{ ft/s}$.

(f) An object weighing $19.6 \text{ N}$ on Earth is given a velocity on the moon of $25.0 \text{ m/s}$. Calculate its kinetic energy on the moon.

101. A block of mass $M$ is on frictionless table. It is attached to the wall with a Hooke's law spring. The system is initially at rest at the equilibrium position of the spring. A bullet with mass $m$ is fired into the block and it stops there. If the initial position of the block is $x = 0$ and the maximum value of the displacement from equilibrium is $-6.25 \text{ cm}$, calculate the initial velocity of the bullet.

$$ M = 1.75 \text{ kg} \quad m = 2.45 \text{ g} \quad k = 85.0 \text{ N/m} $$

102. On the frictionless air track, a completely elastic collision occurs between $m_1$ and $m_2$. Initially, $m_1$ is moving at $1.35 \text{ m/s}$, and $m_2 (m_2 = 4 \ m_1)$ is at rest. Calculate the final velocities of $m_1$ and $m_2$ with proper signs.

103. A cannon is set up at the base of a hill. The hill can be represented by a parabola of the form $y = ax^2$, as shown. If the angle at which the gun is pointed is $\theta = 35.0^\circ$, calculate the value of the initial velocity if the shell is to strike the hill at point A, where A is a height $h$ above the horizontal. (Numerical answers.)

$$ a = 2.50 \times 10^{-6} \text{ m}^{-1} \quad h = 150 \text{ m} $$

105. A small mass, $3m$, slides without friction on the inside of a spherical bowl. It starts at rest at the position shown, and collides with a mass $m$ at the bottom. ($3m$ has three times the mass of $m$). The mass at the bottom is initially at rest. The two masses stick together.

(a) Calculate the maximum height, $h$, that the combined mass reaches. Express this as a fraction of $R$.

(b) Calculate the maximum angle, $\theta$, that the combined mass reaches.

(c) Calculate the mechanical energy lost as heat. Express this as $mgR$ times a number. Remember $m$ is the mass of the small block.
104. The length of the spring when unstretched and unsqueezed is 1.00 m. Block A is placed on the plane and the length of the spring is 0.75 m. Block B is launched down the plane with an initial speed \( v_0 = 4.00 \text{ m/s} \). The distance \( d \) is 1.500 m.

(a) Calculate the speed of block B just before its impact with block A.
(b) If block B strikes block A in a completely inelastic collision, what is the energy lost in the collision?
(c) Find the length of the spring at its maximum compression.

\[ \mu_k = 0.40; \ \mu_s = 0.50; \ m_A = 1.75 \text{ kg}; \ m_B = 2.45 \text{ kg}; \ k = 39.35 \text{ N/m} \]

105. In the drawing shown, A is a cylinder on a fixed axle. The mass B falls freely. The pulley is massless and frictionless.

(a) Determine the speed of B after B has fallen 1.65 m from rest using energy methods.
(b) Calculate the downward acceleration of B in this system using 2nd Law methods.

\[ m_A = 46.0 \text{ kg}; \ m_B = 9.5 \text{ kg}; \ R_A = 4.50 \text{ cm} \]

106. Two pendulums of mass \( m \) and \( 2m \) and length \( \ell \) are attached to the same point by strings. One of pendulums is moved such that it makes a 90° angle with the vertical and released. Describe the motion (velocities) after collision and calculate the maximum angle (angles are + to the right and − to the left) each of these will move with the vertical after the collision if the collision is

(a) completely inelastic;
(b) perfectly elastic.
(c) Find the fraction of the initial energy lost in the collision for both (a) and (b).

107. On the frictionless air track a collision is arranged between two carts. The collision is completely elastic. The initial speed of each cart is \( v_0 \) with direction, as shown. Cart 1 has a mass of 3 times the mass of cart 2. Calculate the final velocities of carts 1 and 2 using the positive direction as shown.

108. The incline shown is frictionless. The mass \( M_1 \) (\( M_1 = 4.75 \text{ kg} \)) is attached to a rope that is wrapped around a cylinder. The cylinder is on a fixed axle. The cylinder has a mass \( M_2 \) (\( M_2 = 3.20 \text{ kg} \)) and a radius \( R \) of 6.05 cm.

(a) The block is released from rest. Calculate its acceleration down the incline.
(b) USE ENERGY METHODS: The block is released from rest. Calculate its velocity after it has traveled 1.39 m along the incline.
109. (a) Calculate the moment of inertia of an uniform cylinder of radius 0.35 m, length 0.75 m and a mass of 4.75 kg. The cylinder rotates about an axis through the center of mass and parallel to the cylinder axis.

(b) Given a sphere of radius \( R \), and mass \( M \), find its inertia for rotation about an axis that is a distance \( 2R/3 \) from the center of the sphere.

(c) Find the kinetic energy of a sphere (mass = 130.0 kg, radius = 0.60 m) rotating at 800 rev/minute about an axis through its center.

(d) A rotating wheel slows from 150 rev/minute to a stop in 57.0 sec. Determine its angular acceleration assuming it is uniform.

(e) A wheel starts at rest and accelerates uniformly with an angular acceleration of 3.30 rad/s\(^2\). Calculate its angular velocity after 15.0 s.

110. A mass \( m \) is attached to massless string that is wrapped around a solid cylinder that is on a frictionless axle. The system starts at rest. Mass \( m = 0.97 \) kg, cylinder mass \( M = 1.10 \) kg and radius is 0.20 m, and the coefficients of friction are \( \mu_s = 0.45 \) and \( \mu_k = 0.35 \).

(a) Calculate the speed of mass \( m \) after it has moved 1.37 m down the plane. (Use energy methods.)

(b) Calculate the acceleration of mass \( m \) down the plane.

111. A small mass \( m_1 \) slides in a completely frictionless spherical bowl. \( m_1 \) starts at rest at height \( h = \frac{3}{4} R \) above the bottom of the bowl. When it reaches the bottom of the bowl it strikes a mass \( m_2 \), where \( m_2 = 4m_1 \), in a completely elastic collision. The positive direction is shown on the drawing.

(a) Calculate the velocity of \( m_2 \) after the collision.

(b) Calculate the velocity of \( m_1 \) after the collision.

DO NOT USE canned equations from your card for the elastic collision. Use momentum and energy conservation properly to get the velocities.

112. A block, \( m_1 = 2.00 \) kg, is launched by a spring that has a spring constant of 250.0 N/m and an unsqueezed unstretched length of 3.00 m. The block travels a distance \( d = 1.20 \) m and hits a second block, \( m_2 = 4.00 \) kg, which is at rest. The blocks stick together in a completely inelastic collision. The coefficients of friction are \( \mu_s = 0.75 \) and \( \mu_k = 0.65 \). Calculate how far you would have to compress the spring to move the 2-mass system 0.500 m past the collision point before it stops.
113 Two 2.0 kg masses, A and B collide. The velocities before the collision are \( \vec{v}_A = 15\hat{i} + 30\hat{j} \) m/s and \( \vec{v}_B = -10\hat{i} + 5.0\hat{j} \) m/s. After the collision \( \vec{v}'_A = -5.0\hat{i} + 20\hat{j} \) m/s.

(a) What is the final velocity of B?
(b) How much kinetic energy was gained or lost in the collision?

114 A bullet of mass 4.5 g is fired horizontally into a 1.8 g wooden block at rest on a horizontal surface. The coefficient of kinetic friction between block and surface is 0.20. The bullet comes to rest in the block which moves 1.8 m. Find the speed of the bullet.

115 A block of wood of mass M is suspended on a string of length L. A bullet of mass m, strikes the block and sticks in it. The bullet is fired horizontally. As a result, the block describes a complete circle about the point of attachment of the string. At the top of the loop, the tension in the string is 2(M + m)g. Find the original velocity of the bullet.

116 A bullet of mass m strikes a block of wood of mass M on an inclined plane and is embedded in it. The coefficient of friction between the block and the plane is 0.55. The block slides up the plane a distance d. Find the original velocity of the bullet.

117 A block whose mass is 2.00 kg is at rest on the inclined plane shown. The coefficients of static and kinetic friction are 0.620 and 0.550, respectively. A bullet, traveling parallel to the plane in the direction of the arrow, strikes the block and passes through it, emerging with 1/3 of its original velocity. The mass of the bullet is 4.00 g and its velocity originally is 350 m/s.

(a) Does the block reach the bottom of the plane? Show why or why not.
(b) If it does, calculate its velocity at the bottom. If it does not, calculate its final displacement from its initial position.

118 Car A is traveling north as shown at 45.0 mi/hr. Car B is traveling in the direction given at 35.0 mi/hr. The mass of A is 2250 kg, and the mass of B is 3250 kg. They collide in a completely inelastic collision.

(a) Find the velocity (magnitude and direction) just after the collision.
(b) If the coefficient of kinetic friction is 0.55, how far will the wreckage slide?
119. Car A is traveling east at 45.0 mi/hr. Car B is traveling north at 55.0 mi/hr. The masses of the cars are \( M_A = 2200 \text{ kg} \) and \( M_B = 3750 \text{ kg} \). They collide and the wreckage sticks together.

(a) Calculate the direction the wreckage moves (angle \( \theta \) in the diagram).

(b) If the coefficient of friction is taken to be 0.65, how far does the wreckage slide (in feet)?

120. (a) Convert 2.30 horsepower into watts.

(b) Convert 625 foot-pounds into joules. (You will have to work out the conversion factor from the definitions and the ones given.)

(c) A car is moving at 50.0 mi/hr. If it has a mass of 1750 kg, calculate its linear momentum in SI units (metric).

(d) A baseball is thrown at 45.0 m/s. The batter hits it directly back towards the pitcher at 65.0 m/s. If the mass is 0.300 kg, calculate the magnitude of the impulse given to the ball.

(e) A car of mass 2100 kg is traveling at 60.0 mi/hr. The brakes are put on and it skids to a stop in 418 ft. Find the power being dissipated as heat (in watts) after is has skidded 400 ft, assuming constant deceleration.

121. In a ballistic pendulum experiment a bullet is shot into a mass \( M \) and remains inside of it. If the pendulum swings to a maximum angle of \( \theta = 17.0^\circ \), calculate the initial velocity of the bullet. \( M = 2.50 \text{ kg} \), \( m_{\text{bullet}} = 0.12 \text{ kg} \), \( L = 1.10 \text{ m} \).

122. A bullet strikes the block \( M \) when the string is vertical and the block is motionless. The initial velocity of the bullet is \( v_u \), and it emerges from the block at a speed of \( 1/3 \, v_u \). The block is observed to swing to a maximum angle of \( 22^\circ \).

\[ M = 1.27 \text{ kg} \quad m = 0.050 \text{ kg} \]
\[ L = 1.00 \text{ m} \]

(a) Calculate \( v_u \).

(b) Calculate the mechanical energy lost to heat.

123. (a) A car weighing 6235 lbs is moving at 65.0 mi/hr. Find the momentum of the car in SI units.

(b) For the car in (a), calculate the energy in Joules.

(c) A ball of mass 1.20 kg moving with \( v = 5.70 \text{ m/s} \) hits the wall at an angle of \( 30^\circ \) and bounces off. If the collision lasted for 0.01 s, what is the average force exerted on the wall?
124. A bullet (mass \( m \)) hits a pendulum (mass \( M \) and length \( L \)) and remains in the pendulum. What would the initial velocity \( v_0 \) of the bullet have to be in order for the pendulum to barely complete the circle if:

(a) \( L \) is a string;
(b) \( L \) is a massless rod.

125. Given a uniform cylinder of mass 25.0 kg, radius 5.00 cm and length 20.0 cm, calculate its moment of inertia for rotation about an axis parallel to the long axis of the cylinder and halfway between the center and the outside of the cylinder.

(b) A wheel starting from rest accelerates uniformly. If it undergoes 475 complete revolutions in 6 min 35 s, what is the angular acceleration?

(c) Calculate the moment of inertia of a sphere of mass 7.35 kg and diameter of 0.123 m.

(d) The speed of a point on the rim of a rotating wheel is 40.0 m/s. The wheel has a moment of inertia of 0.250 kg\( \cdot \)m\(^2\) and a radius of 0.100 m. Calculate its rotational kinetic energy.

(e) A baseball is thrown at 45.0 m/s. The batter hits it directly back towards the pitcher at 65.0 m/s. If the mass is 0.300 kg, calculate the magnitude of the impulse given to the ball.

126. A bullet strikes the block \( M \) when the string is vertical and the block is motionless. The initial velocity of the bullet is \( v_0 \), and it emerges from the block at a speed of \( 1/3 \) \( v_0 \). The block is observed to swing to a maximum angle of 22°.

\[ M = 1.27 \text{ kg}; \quad m = 0.050 \text{ kg}; \quad L = 1.00 \text{ m} \]

(a) Calculate \( v_0 \).

(b) Calculate the mechanical energy lost to heat.

127. A solid flywheel has a mass of \( 7.7 \times 10^4 \) kg and a radius of 2.4 m. The flywheel is rotating at 360 rpm. Consider the flywheel to be a solid disk of constant mass density. If a frictional force of 34 kN acts tangentially on the shaft, which is 0.41 m in diameter, how long will it take to stop the rotational motion of the flywheel?

128. (e) A golf ball of mass 100 g, initially at rest, is given a velocity of 35 m/s. Calculate the impulse delivered by the golf club.
129. (c) Calculate the kinetic energy, in joules of the truck in (b).

(e) An object of mass 3.75 kg is traveling at 1.50 m/s in the positive x-direction. A second object of mass 1.25 kg, travels at 4.50 m/s in the negative x-direction. They collide in a completely inelastic collision. Calculate the kinetic energy lost.

130. Cylinder A of mass 0.50 kg, is dropped 2.50 m onto cylinder B of mass 3.25 kg, which is resting (v = 0) on a spring whose spring constant is 4.25 kN/m (4.25 × 10^3 N/m). (Assume a Hooke’s law spring.) When A strikes B, they stick together.

(a) Determine the maximum displacement of B from its original position.

(b) Find the energy lost during impact.

131. A block of mass m slides from rest down a frictionless circular track as shown. It strikes a second block of mass 3m exactly at the bottom, and they stick together.

(a) Find the largest value of $\theta$, the angular position after the collision.

(b) When $\theta$ is at its largest value as in (a), find the normal force the track exerts on the block.

132. Mass 1 rests on a frictionless inclined plane supported by a Hooke’s law spring of constant k = 111.2 N/m. Mass 2 slides down the plane and collides with 1 and sticks to it. If the maximum compression of the spring is 35.0 cm from its length just before impact, calculate the distance 2 moves from rest before colliding with 1. $M_1 = 1.25$ kg, $M_2 = 0.75$ kg.

(a) Calculate the maximum value of the angle $\theta$ that the pendulum achieves.

(b) Calculate the tension in the string when $\theta = \theta_{\text{max}/2}$.

133. A bullet of mass 28 g is fired into a block of mass 1.35 kg. The velocity of the bullet is 275 m/s and it stops inside the block. The block M is part of a pendulum of pendulum length L = 2.00 m as shown.

(a) Calculate the maximum value of the angle $\theta$ that the pendulum achieves.

(b) Calculate the tension in the string when $\theta = \theta_{\text{max}/2}$.

134. A mass $m_1$ is attached to the ceiling by a Hooke’s law spring with spring constant k. It is initially at rest. A second mass, $m_2$, is given an initial velocity $v_0$. It strikes $m_1$ and sticks to it after $m_2$ has moved a distance h vertically. Calculate the maximum vertical distance traveled by $m_2$ after the collision. (Numerical answer.)
135. When mass A is placed on a long Hooke’s law spring and allowed to come to rest, the spring is squeezed 21.0 cm from its equilibrium length. A mass B is given an initial velocity \( v_0 = 3.75 \text{ m/s} \) above A. When B strikes A they stick together. Use energy methods where appropriate.

(a) How much kinetic energy is lost in the collision of A and B (numerical answer)?

(b) Calculate the maximum displacement of the spring from the point labeled \( y = 0 \) after the collision (numerical answer).

\[
m_A = 4.12, \quad m_B = 1.75 \text{ kg}, \quad v_0 = 6.20 \text{ m/s}
\]

136. (d) A car of mass 1000 kg is traveling west at 15.0 m/s. A second car of mass 1500 kg is traveling east at 20.0 m/s. If they collide head-on and stick together, calculate the kinetic energy lost in the collision.

137. A mass of \( m = 2.55 \text{ kg} \) is suspended at rest by a massless spring as shown. When the mass is attached to the unstretched spring it stretches the spring by 1.45 cm. A bullet is fired from below so that it strikes the mass and remains in it. If the mass of the bullet is 23.0 grams and the velocity of the bullet when it enters the block is 285 m/s, calculate the maximum height of the block from \( y = 0 \) in the drawing.

\[
m_B = 4.12, \quad m_B = 1.75 \text{ kg}, \quad v_0 = 6.20 \text{ m/s}
\]

138. On the frictionless, horizontal air track we have used in class, are two carts. Cart 1 has an initial velocity of \( v_1 \), and cart 2 is initially at rest. They collide in a completely elastic collision. Take \( 3M_1 = 2M_2 \) \( (M_1 = \frac{3}{2} \text{ kg}) \). For full credit on this problem you must derive any equation used starting with first principles, i.e., conservation laws, as appropriate.

(a) Calculate the final velocities of \( M_1 \) and \( M_2 \) after the collision in terms of numbers and \( v_1 \).

(b) How much energy is lost in this collision?

139. The spring shown has an unstretched length of 1.25 m. When mass \( m_2 \) is placed on it, and all oscillations have died out, its length is 1.10 m. Block \( m_1 \) is dropped on \( m_2 \) from a height of 6.25 m. It lands on top of \( m_2 \) and stays there. \( m_1 = 1.10 \text{ kg}; \quad m_2 = 3.27 \text{ kg} \)

(a) Calculate the length of the spring at maximum compression.

(b) Determine the energy lost to heat.

(c) Find the length of the spring with both masses on it after all oscillations have died out.

140. (e) A mass \( m \) on the frictionless air track is moving with speed \( v_0 \). It collides with, and stick to, a mass \( 3m \). Calculate the fraction of the original kinetic energy that is lost as heat.
141. The spring shown has an unstretched length of 0.475 m. When \( m_2 \) is placed upon it, and all oscillation has died out, the length is 0.400 m. The mass \( m_1 \) is dropped 3.57 m and lands on top of \( m_2 \).

\[
m_1 = 1.50 \text{ kg} \\
m_2 = 2.50 \text{ kg}
\]

(a) Calculate the length of the spring at its maximum compression.
(b) Calculate the energy lost to heat.

142. (e) Convert 4750 J to ft-pounds of energy.

143. (e) An object of \( M = 3.50 \text{ kg} \) is traveling at 1.20 m/s in the positive x direction. A second object of \( m = 1.25 \text{ kg} \) is traveling at 4.5 m/s in the negative direction. The two masses collide in a completely inelastic collision (they stick together). Calculate the energy lost.

\[
v_f = v_i + v_{ex} \frac{m_1}{M_f}
\]

144. A rocket cylinder of initial mass \( 10^3 \text{ kg} \) is bolted to the ground (see figure). The rocket cylinder exhausts gas at 1 kg/s which hits a vertical shield at 100 m/s. Assume the gas molecules move only parallel to the shield after striking it. Ignore air resistance.

(a) Find the horizontal force on the shield.
(b) Now assume the rocket cylinder is unbolted and lies on a frictionless horizontal surface. Find the horizontal force on the shield from the gas that is ejected when the mass of the rocket (plus gas) has decreased to 900 kg.

145. (a) Calculate the moment of inertia about the center axis of a solid cylinder of diameter 0.125 m and length 2.05 m. The mass of the cylinder is 2.75 kg.
(b) If a wheel rotates three times on its axle in 12.5 hours, calculate its angular velocity in rad/s.
(c) Calculate the torque that a force of \( F = 10 \text{ N} \) exerts on a nut as shown in the figure. The force is applied a distance \( r = 0.200 \text{ m} \) from the center of the nut.
(d) A saw blade running at 12.5 revolutions per second slows to a stop in 13.4 s with a constant acceleration (deceleration). Find the acceleration in rad/s^2.
(e) A thin solid disk of mass \( M = 2.00 \text{ kg} \) and radius \( R = 0.500 \text{ m} \) rolls on level ground without slipping. The angular velocity of the disk is \( \omega = 4.05 \text{ rad/s} \). Find the total kinetic energy of the disk.

146. Assume the “dumbbell” shown in the figure can be approximated as two identical solid spheres of mass \( M \) and radius \( R \) connected by a thin rod of mass \( m \) and length \( \ell \). [A line down the center of the rod passes through the center of each sphere.]

(a) Find the moment of inertia about an axis perpendicular to the rod and passing through its center (labeled A).
(b) Find the moment of inertia about an axis perpendicular to the rod and passing through one end (labeled B).
(c) Assume the rod has a radius \( r \) (the rod is not thin). Find the moment of inertia about an axis tangent to the two spheres and parallel to the long axis of the rod (labeled C).
147. The length of the spring when unstretched and unsqueezed is 2.00 m. Block A is placed on the plane and the spring is compressed by block A. Block B is launched down the plane with an initial speed \( v_0 = 2.00 \text{ m/s} \). The distance \( d \) is 1.500 m.

(a) Find the compressed length of the spring due to block A.
(b) Calculate the speed of block B just before its impact with block A.
(c) If block B strikes block A in a completely inelastic collision, what is the energy lost in the collision?
(d) Find the length of the spring at its maximum compression.

\[ \mu_s = 0.40; \mu_k = 0.50; m_A = 1.75 \text{ kg}; m_B = 2.45 \text{ kg}; k = 39.35 \text{ N/m} \]

148. A pot is spinning on a potter’s wheel when it breaks into pieces. Figure A shows a top view of the pot just before it breaks. Figures 1, 2, and 3 show possible velocities of the fragments as they fly out after the pot breaks. Which figure (1, 2, or 3) represents a realistic situation? Which physics principle, or principles, have you used to reach your conclusion?

![Image](https://via.placeholder.com/150)

B. A 2-kg particle has position vector \( \mathbf{r} = 4\mathbf{i} + 3t^2\mathbf{j} \), where distances are in meters and the time \( t \) is in seconds. Compute the following vectors at time \( t \):

(a) the particle’s linear momentum,
(b) the particle’s angular momentum about the origin,
(c) the torque acting on the particle about the origin.

149. A 4.0 kg block moving in the +x direction at 2.0 m/s collides with a 3.0 kg block moving in the +y direction at 5.0 m/s. The two blocks stick together and move away from the point of impact with the same velocity.

(a) With what speed are they moving and what angle does their velocity vector make with the +x direction after the collision?
(b) What percentage of the initial kinetic energy of these blocks is lost in the collision? This percentage is given by the formula \[ \left( \frac{K_\text{f} - K_\text{i}}{K_\text{i}} \right) \times 100\% \].

150. Two thin disks A and B of identical mass but different radii (\( r_A = 20 \text{ cm} \) and \( r_B = 10 \text{ cm} \)) are spinning on frictionless bearings at the same angular speed \( \omega_0 = 10 \text{ rad/s} \) but in opposite directions, A clockwise and B counterclockwise (see Figure). The two disks are brought slowly together. The resulting frictional force between the surfaces eventually brings them to a common angular velocity.

(a) What is the magnitude of that final angular velocity?
(b) In which direction are the disks spinning when they stick together?
151. A uniform rod of mass \( M = 200 \) g and length \( L = 1.0 \) m is nailed at its center to a frictionless table. An \( m = 100 \) g pellet slides on the table at a speed of \( v = 3.0 \) m/s, and hits the rod perpendicularly at a distance \( d = 20 \) cm from the nail (see Figure). The pellet sticks in the rod. The rod and pellet turn together around the nail.

(a) Find the angular speed of the rod plus pellet system after the collision.
(b) What is the linear momentum of the pellet before and after the collision? What is the linear momentum of the rod before and after the collision?
(c) If it takes \( \Delta t = 0.030 \) s for the pellet to get stuck in the rod, what is the average force the nail exerts on the rod plus pellet system during the collision?

152. A circular turntable rotates at constant angular speed about a vertical axis. There is no friction and no driving torque. A circular pan rests on the turntable and rotates with it (see figure). The bottom of the pan is covered with a layer of ice of uniform thickness, which is, of course, also rotating with the pan. The ice melts but none of the water escapes from the pan. As it spins, the water surface curves downward into its characteristic concave shape. Is the angular speed now (a) greater than, (b) the same as, or (c) less than the original speed? Give reasons for your answer.

B. A dog weighing 25.8 lb is standing on a flatboat so that he is 21.4 ft from the shore. He walks 8.50 ft on the boat toward shore and then halts. The boat weighs 46.4 lb, and one can assume there is no friction between it and the water.
(a) Does the center of mass of boat+dog move? Explain your reasoning.
(b) How far is the dog from the shore at the end of his walk?

C. [6 points] The disk in the figure is spinning about its axle in the direction indicated by the arrow. The position of the center of mass of disk+axle+counterweight is marked CM. In which direction does the axle precess when viewed from above? (a) Clockwise, (b) counterclockwise, or (c) does not precess.

153. A ball (hollow sphere) of mass 0.56 kg and radius 0.13 m is dropped from a height of 0.98 m (it starts from rest). The ball bounces on the floor to a height of 0.72 m.

A. What is the speed of the ball just before it hits the floor? What is its speed just after?
B. If the ball is in contact with the floor for 15 milliseconds, what is the average force the ball exerts on the floor? Give magnitude and direction.

154. The figure shows a thin uniform aluminum bar of length 25.2 cm and mass 2.14 g, pivoted at the center, and a small blob of putty of mass 1.43 g. The system is supported by a frictionless horizontal surface. The putty moves to the right at 53.0 cm/s, strikes the bar at a distance of 10.6 cm from the pivot, and sticks to the bar at the point of contact.

A. Find the angular velocity of the system after the putty sticks to the bar.
B. Find the amount of kinetic energy lost in the “collision.”
155. A vessel at rest explodes, breaking into three pieces. Two pieces, one twice the mass of the other, fly off perpendicular to one another with the same speed of 31.4 m/s. The third piece has three times the mass of the lightest piece. Find the magnitude and direction of the velocity of the heaviest piece immediately after the explosion. (Specify the direction by giving the angle $\theta$ from the line of travel of the least massive piece.)

156. (a) Find the center of mass of the system shown.

157. (b) Calculate the x-coordinate of the center of mass of the system shown.

158. (b) Find the x coordinate of the center of mass of the system shown.

159. (b) For the system shown, and the coordinate system given, calculate the x-coordinate of the center of mass.

160. (d) Find the center of mass for the system shown.
161. (a) Find the x-coordinate of the center of mass of the system shown.

(b) Find the center of mass of the system shown. [Hint: Show your coordinate system and choose it to take advantage of symmetry.]

(c) In the drawing, \( m_1 = 7.25 \text{ kg} \), \( m_2 = 6.00 \text{ kg} \), \( m_3 = 4.25 \text{ kg} \). Calculate the x-coordinate of the center of mass of this system.

162. (a) Find the maximum altitude of a rocket launched vertically from the earth's surface at an initial speed of 4.05 km/s.

(b) Find the center of mass of the system shown. Use the coordinate system given, and express your answer as a vector in \( \hat{i} \), \( \hat{j} \) notation.

163. (d) Find the center of mass for the system shown.

164. (a) The space shuttle is moving in a circular orbit with a speed of 7.8 km/s and takes 87 min to complete one orbit. In order to return to Earth, the shuttle fires its retro engines opposite to its direction of motion. The engines provide a deceleration of 6 m/s\(^2\) that is constant in magnitude and direction.

(a) Compute the angular velocity of the shuttle while in the circular orbit and the radius of the orbit.

(b) Find the tangential and centripetal acceleration of the shuttle at the instant the engines are turned on.

(c) What is the total acceleration (magnitude and direction) at the same instant? Give the direction as an angle from the shuttle’s direction of motion and specify if inward or outward of the circular orbit.
167. A. The three square-shaped objects shown in the figure below (A-a square frame, B-a solid square, and C-a square frame with a cross in the middle) have sides of equal length and have equal total mass. Rank them in the order of their moment of inertia about an arbitrary axis (from lowest to highest). Answer this question by explaining how the distribution of mass affects the moment of inertia. You do not need to calculate the moments of inertia.

B. A puck is spinning in a circle on the end of a string nailed to a frictionless table (see diagram). What is the force experienced by the nail? Explain.

C. A fellow student states that forces cause an object to move. Critique this statement.

168. A. A block of mass \(m\) is sliding on a wedge of mass \(M\) that is free to roll on a table. The figure shows the free-body diagram for the block, which includes its weight \(mg\) and the normal \(N\) and friction \(f\) forces from its contact with the wedge. Draw the free-body diagram for the wedge and identify each force. Make sure you include all forces (neglect air resistance and friction with the table). Only clearly drawn diagrams will receive full credit.

B. A dumbbell with balls of unequal mass is made to rotate about three different axes as shown in the figure. Rank cases A, B, and C in order of increasing moment of inertia (from smallest to largest). Explain your reasoning.

C. The koma is a traditional Japanese toy that children spin like a top by pulling a string they wrap around it. It is a wooden cone attached to a disk with an axle through the middle (see figure). The child who makes the koma spin faster wins. To try and win, should a child wrap the string around (a) the disk or (b) the cone? Explain your reasoning.

169. In a competition on survival skills, Ann hoists a bucket full of water up an old-fashioned well with a pulley and a handle (see figure). Ann applies a constant force \(F\) at the far end of the handle at 90 degrees from it. It takes Ann 2.0 s to raise the bucket 10. m, starting from rest. The pulley is a uniform disk of mass \(M = 2.0\) kg and radius \(R = 0.10\) m, and the combined mass of bucket and water is \(m = 1.0\) kg. The handle is \(L = 0.20\) m long, has negligible mass, and is attached to the center of the pulley. Neglecting friction and air resistance, find

A. the acceleration of the bucket,
B. the tension in the rope holding the bucket,
C. the force \(F\) Ann exerts to hoist the bucket.
A thin non-uniform rod of mass \( M = 0.050 \) kg, length \( L = 0.20 \) m, and radius \( R = 3.0 \) mm, is allowed to rotate about an axis \( A \) through its \( x = 0 \) end (see figure). The mass density of the rod is

\[
\rho = \frac{3Mx^2}{\pi R^2 L^3}
\]

A braking system exerts a constant torque of magnitude \( \tau_A = 3.0 \times 10^{-4} \) m and brings the rod from an initial angular velocity \( \omega_0 = 0.95 \) rad/s to rest.

A. Show by integration that the moment of inertia of the rod about the rotation axis \( A \) is

\[
I_A = \frac{3}{5} ML^2.
\]

(As a reference, the volume of an infinitesimal cylinder of radius \( R \) and length \( dx \) is \( dV = \pi R^2 dx \).)

B. Find the magnitude of the angular acceleration of the rod as it is slowing down.

C. Find the time the brakes have been applied.
Data: Use these constants (where it states for example, 1 ft, the 1 is exact for significant figure purposes).

1 ft = 12 in (exact)
1 m = 3.28 ft
1 mile = 5280 ft (exact)
1 hour = 3600 sec = 60 min (exact)
1 day = 24 hr (exact)

$g_{\text{earth}} = 9.80 \text{ m/s}^2$
$= 32.2 \text{ ft/s}^2$
$g_{\text{moon}} = 1.67 \text{ m/s}^2$
$= 5.48 \text{ ft/s}^2$

1 year = 365.25 days
1 kg = 0.0685 slug
1 N = 0.225 pound
1 horsepower = 550 ft-pounds/s
(exact) $M_{\text{earth}} = 5.98 \times 10^{24} \text{ kg}$

$R_{\text{earth}} = 6.38 \times 10^3 \text{ km}$
$M_{\text{sun}} = 1.99 \times 10^{30} \text{ kg}$
$R_{\text{sun}} = 6.96 \times 10^8 \text{ m}$
$M_{\text{moon}} = 7.35 \times 10^{22} \text{ kg}$
$R_{\text{moon}} = 1.74 \times 10^3 \text{ km}$
$G = 6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2$
$m_{\text{electron}} = 9.11 \times 10^{-31} \text{ kg}$
Data: Use these constants (where it states for example, 1 ft, the 1 is exact for significant figure purposes).

1 ft = 12 in (exact)
1 m = 3.28 ft
1 mile = 5280 ft (exact)
1 hour = 3600 sec = 60 min (exact)
1 day = 24 hr (exact)

\[ g_{\text{earth}} = 9.80 \text{ m/s}^2 \]

\[ = 32.2 \text{ ft/s}^2 \]

\[ g_{\text{moon}} = 1.67 \text{ m/s}^2 \]

\[ = 5.48 \text{ ft/s}^2 \]

1 year = 365.25 days
1 kg = 0.0685 slug
1 N = 0.225 pound
1 horsepower = 550 ft-pounds/s (exact)

\[ M_{\text{earth}} = 5.98 \times 10^{24} \text{ kg} \]

\[ R_{\text{earth}} = 6.38 \times 10^7 \text{ km} \]

\[ M_{\text{sun}} = 1.99 \times 10^{30} \text{ kg} \]

\[ R_{\text{sun}} = 6.96 \times 10^8 \text{ km} \]

\[ M_{\text{moon}} = 7.35 \times 10^{22} \text{ kg} \]

\[ R_{\text{moon}} = 1.74 \times 10^3 \text{ km} \]

\[ G = 6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2 \]

\[ m_{\text{electron}} = 9.11 \times 10^{-31} \text{ kg} \]
Data: Use these constants (where it states for example, 1 ft, the 1 is exact for significant figure purposes).

1 ft = 12 in (exact)

1 m = 3.28 ft

1 mile = 5280 ft (exact)

1 hour = 3600 sec = 60 min (exact)

1 day = 24 hr (exact)

$g_{\text{earth}} = 9.80 \text{ m/s}^2 = 32.2 \text{ ft/s}^2$

1 year = 365.25 days

1 kg = 0.0685 slug

1 N = 0.225 pound

1 horsepower = 550 ft-pounds/s (exact)

$M_{\text{earth}} = 5.98 \times 10^{24} \text{ kg}$

$R_{\text{earth}} = 6.38 \times 10^3 \text{ km}$

$M_{\text{sun}} = 1.99 \times 10^{30} \text{ kg}$

$R_{\text{sun}} = 6.96 \times 10^8 \text{ m}$

$M_{\text{moon}} = 7.35 \times 10^{22} \text{ kg}$

$R_{\text{moon}} = 1.74 \times 10^3 \text{ km}$

$G = 6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2$

$k = 9.00 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2$

$\varepsilon_0 = 8.85 \times 10^{-12} \text{ F/m}$

$e_{\text{electron charge}} = -1.60 \times 10^{-19} \text{ C}$

$m_{\text{electron}} = 9.11 \times 10^{-31} \text{ kg}$