MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question. Some problems are conceptual, some you'll need to do some calculations. Circle your answer. Each question is worth 5 points.

1) A 4.0-kg object is moving with speed 2.0 m/s. A 1.0-kg object is moving with speed 4.0 m/s. Both objects encounter the same constant braking force, and are brought to rest. Which object travels the greater distance before stopping?
   A) the 1.0-kg object
   B) the 4.0-kg object
   C) both objects travel the same distance.
   D) it is impossible to know without knowing how long each force acts.

2) 97 J of work are needed to stretch a spring from 1.4 m to 2.9 m from equilibrium. What is the value of the spring constant?
   A) 30 N/m
   B) 31 N/m
   C) 32 N/m
   D) 33 N/m

3) Two identical balls are thrown directly upward, ball A at speed \( v \) and ball B at speed \( 2v \), and they feel no air resistance. Which statement about these balls is correct?
   A) At its highest point, ball B will have twice as much gravitational potential energy as ball A because it started out moving twice as fast.
   B) Ball B will go four times as high as ball A because it had four times the initial kinetic energy.
   C) The balls will reach the same height because they have the same mass and the same acceleration.
   D) Ball B will go twice as high as ball A because it had twice the initial speed.
   E) At their highest point, the acceleration of each ball is instantaneously equal to zero because they stop for an instant.

4) A tennis ball bounces on the floor three times. If each time it loses 15.0% of its energy due to heating, how high does it bounce after the third bounce provided we release it 1.0 m from the floor?
   A) 130 cm
   B) 110 cm
   C) 110 mm
   D) 11 cm

5) A steady horizontal force lasting for 2.30 s gives a 1.25 kg object an acceleration of 3.20 m/s\(^2\) on a frictionless table. What impulse does the force give to the object?
   A) 2.63 kg m/s
   B) 4.0 kg m/s
   C) 2.75 kg m/s
   D) 4.00 kg m/s
   E) 10.5 kg m/s

6) In a perfectly ELASTIC collision between two perfectly rigid objects
   A) the momentum of each object is conserved.
   B) the kinetic energy of each object is conserved.
   C) both the momentum and the kinetic energy of the system are conserved.
   D) the kinetic energy of the system is conserved, but the momentum of the system is not conserved.
   E) the momentum of the system is conserved but the kinetic energy of the system is not conserved.
7) When you ride a bicycle, in what direction is the angular velocity of the wheels? (Hint: Remember the right hand rule)
   a) to your left  b) to your right  c) backwards  d) up  e) forwards

8) A machine turns the power on to a grinding wheel, at rest, at time $t=0$. The wheel accelerates uniformly for 10 s and reaches the operating angular velocity of 38 rad/s. The wheel is run at that angular velocity for 30 s and then power is shut off. The wheel slows down uniformly at 2.1 rad/s$^2$ until the wheel stops. In this situation, the angular acceleration of the wheel between $t=0$ and $t=10$ s is closest to:
   A) $5.3 \text{ rad/s}^2$  B) $6.8 \text{ rad/s}^2$  C) $4.6 \text{ rad/s}^2$  D) $6.1 \text{ rad/s}^2$  E) $3.8 \text{ rad/s}^2$

9) A particular motor can provide a maximum of 1100 Nm of torque. Assuming that all of this torque is used to accelerate a solid, uniform flywheel of mass 810 kg and radius 3.00 m, how long will it take for the flywheel to accelerate from rest to 8.13 rad/s? (Hint: $I = \frac{1}{2} M R^2$)
   A) 4.03 s  B) 4.26 s  C) 3.33 s  D) 2.83 s

10) A potter's wheel, with rotational inertia 24 kgm$^2$, is spinning freely at 40 rpm. The potter drops a lump of clay onto the wheel, where it sticks a distance 1.2 m from the rotational axis. If the subsequent angular speed of the wheel and clay is 32 rpm, what is the mass of the clay?
   A) 3.7 kg  B) 2.8 kg  C) 4.6 kg

11) In Figure below, a mass of 35.30 kg is attached to a light string which is wrapped around a cylindrical spool of radius 10 cm and moment of inertia 4.00 kgm$^2$. The spool is suspended from the ceiling, and the mass is then released from rest a distance 3.50 m above the floor. How long does it take to reach the floor? (Hint: you may want to later this problem as the last one you do)
   A) 5.18 s  B) 4.92 s  C) 5.89 s  D) 2.97 s  E) 2.85 s
12) A disk is attached to a motor that provides a constant torque \( \tau = \tau_2 \). Assume no frictional losses in the system. \( \tau = 1.2 \text{ Nm} \).

a) What is the angular speed of the disk after 15 seconds of applied torque by motor?

b) The motor is shut off after 15 seconds and a brake is applied such that the disk comes to rest in 2.8 seconds. Find the magnitude of the angular acceleration.

**Given**

\[ \omega_0 = 0 \]
\[ \alpha = 0.65 \text{ rad/s}^2 \]

\[ \omega_2 = \omega_1 + \alpha t \]

\[ \omega_3 = \omega_2 + \alpha t \]

\[ \frac{-\omega_2}{t} = \alpha_{\text{dec.}} \]

\[ \omega_1 = 0.8 \text{ rad/s} \]

\[ \alpha_{\text{dec.}} = -3.5 \text{ rad/s}^2 \]
13) A disk of a radius $r = 0.10$ m with mass of 10 kg rolls without slipping down a slope that makes an angle of 30 degrees with the horizontal. The moment of inertia for a disk is $I = \frac{1}{2} MR^2$.

a) Find the acceleration of the center of mass down the inclined plane.

b) What is the magnitude and direction of frictional force on the sphere?

\[
\begin{align*}
\sum F &= ma \\
\sum F &= ma_x \\
\sum F &= ma_y \\
\sum F &= ma_z \\
I_a &= mgd \sin \theta \\
\end{align*}
\]

\[
\begin{align*}
x: & \quad \sum F_x = ma_x \\
y: & \quad \sum F_y = mg \sin \theta - ma_y = 0 \\
z: & \quad \sum F_z = I_a \\
R &= I \omega_x \\
R &= I \omega_y \\
R &= I \omega_z \\
\end{align*}
\]

b) Find the friction force:

\[
f_{\text{friction}} = \mu mg \cos \theta
\]

\[
f_{\text{friction}} = \frac{1}{3} mg \cos 30^\circ
\]

\[
f_{\text{friction}} = \frac{1}{3} (10 \text{ kg}) (9.8 \text{ m/s}^2) \cos 30^\circ = 14.933 \text{ N}
\]

\[
f_{\text{friction}} = 14.933 \text{ N}
\]

\[
of = \frac{1}{3} mg \cos 30^\circ = 14.933 \text{ N}
\]

\[
of = 14.933 \text{ N}
\]
14) In the figure below, a uniform ladder 12 meters long rests against a vertical frictionless wall. The ladder weighs 400 N and makes an angle of 61° with the floor. A man weighing 874 N climbs slowly up the ladder to a point 7.8 m up from the bottom. The ladder doesn’t slip.

a) What is \( \sum F = 0 \) the static frictional force the floor exerts on the ladder?

b) What is the normal force exerted by the floor on the ladder?

\[
\sum F = 0 \\
\sum T = 0
\]

\[
x: n_w - \sum F_x = 0 \\
y: \sum F_y = n_w - w_L = 0 \\
\gamma: \frac{(l \cos \theta) w_L + (l \sin \theta) w_m \cos \theta - l n_a \sin \theta}{\frac{L}{2} \sin \theta} = n_w
\]

\[
(n_w) = \frac{874 + 400}{12} = 774.17 \\
(\text{b) } n_w = 1274 \text{ N}
\]

\[
\text{(a) } 622 N = n_{x5}
\]
15) An engine is being used to raise an 89 kg crate vertically upward. If the power output of the engines is 1620 W assume that the friction in the system is negligible.

   a) How long does it take the engine to lift the crate a vertical distance of 18.7 m?
   b) Find the work done by gravity on the crate.

   \[
   \begin{align*}
   & \text{Given:} \\
   & P = 1620 \text{ W} \\
   & m = 89 \text{ kg} \\
   & h = 18.7 \text{ m}
   \end{align*}
   \]

   \[
   \begin{align*}
   & \text{Physics:} \\
   & P = \frac{dW}{dt} \\
   & W = \int F \, dx
   \end{align*}
   \]

   \[
   \text{How long does it take:}
   \]

   \[
   W_{\text{net}} = mg(h_f - h_i)
   \]

   \[
   \text{by engine: } = (89 \text{ kg})(9.8 \text{ m/s}^2)(18.7 \text{ m})
   \]

   \[
   \Delta t = \frac{W_{\text{net}}}{P} = \frac{(89 \text{ kg})(9.8 \text{ m/s}^2)(18.7 \text{ m})}{1620 \text{ W}} = 10.0679
   \]

   \[
   \text{a) } \Delta t = 10.08 \text{ s}
   \]

   \[
   \begin{align*}
   & \text{b) } W_{\text{net}} = -116,000 \text{ [J]} \\
   & \text{by gravity}
   \end{align*}
   \]
16) Two cars of masses \( m_A = 10 \text{ kg} \) and \( m_B = 20 \text{ kg} \) collide at an intersection. Before the collision, car A was traveling eastward at a speed of \( v_{A1} = 8.0 \text{ m/s} \), and car B was traveling northward at a speed of \( v_{B1} = 9.0 \text{ m/s} \). After the collision, the two cars stick together and travel off in the same direction at an angle north of east. 

a) Find the magnitude of the velocity \( v_2 \) of the two cars after they collide.

b) Find the angle they make with the eastward direction.

\[ m_A = 10 \text{ kg} \]
\[ m_B = 20 \text{ kg} \]
\[ v_{A1} = 8.0 \text{ m/s} \]
\[ v_{B1} = 9.0 \text{ m/s} \]

\[ v_{A2} = v_{B2} \]

\[ \theta = 66.5 \degree \]
MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question. Some problems are conceptual; some you'll need to do some calculations. Circle your answer. Each question is worth 5 points.

1) A steady horizontal force lasting for 2.10 s gives a 1.25 kg object an acceleration of 3.20 m/s² on a frictionless table. What impulse does this force give to the object?
   A) 10.9 kg m/s
   B) 4.00 kg m/s
   C) 8.40 kg m/s
   D) 26.3 kg m/s
   E) 25.7 kg m/s

2) A particular motor can provide a maximum of 10.0 N⋅m of torque. Assuming that all of this torque is used to accelerate a solid, uniform flywheel of mass 15.0 kg and radius 3.00 m, how long will it take for the flywheel to accelerate from rest to 8.50 rad/s² (1069 rad/s²)?
   A) 4.11 s
   B) 2.89 s
   C) 4.45 s
   D) 3.40 s

3) A tennis ball bounces on the floor three times. If each time it loses 16.0% of its energy due to heating, how high does it bounce after the third time, provided we released it 2.8 m from the floor?
   A) 170 mm
   B) 17 cm
   C) 200 cm
   D) 50 cm

4) A potters wheel, with rotational inertia 25 kg⋅m², is spinning freely at 40.0 rpm. The potter drops a lump of clay onto the wheel, where it sticks a distance 1.2 m from the rotational axis. If the subsequent angular speed of the wheel and clay is 32 rpm, what is the mass of the clay?
   A) 4.7 kg
   B) 7.3 kg
   C) 5.3 kg
   D) 3.9 kg

5) A machinist turns the power on to a grinding wheel, at rest, at time t = 0 s. The wheel accelerates uniformly for 10 s and reaches the operating angular velocity of 74 rad/s. The wheel is run at this angular velocity for 30 s and then power is shut off. The wheel slows down uniformly at 2.2 rad/s² until the wheel stops. In this situation, the angular acceleration of the wheel between t = 0 s and t = 10 s is closest to:
   A) 10 rad/s²
   B) 8.9 rad/s²
   C) 13 rad/s²
   D) 4 rad/s²
   E) 2 rad/s²

6) In Figure below, a mass of 20.00 kg is attached to a light string which is wrapped around a cylindrical spool of radius 10 cm and moment of inertia 4.00 kg⋅m². The spool is suspended from the ceiling, and the mass is then released from rest a distance 4.70 m above the floor. How long does it take to reach the floor? (Hint: you may want to later this problem as a lab one, you do)
   A) 1.84 s
   B) 3.77 s
   C) 5.20 s
   D) 7.48 s
   E) 3.64 s
7) When you ride a bicycle, in what direction is the angular velocity of the wheels? (Hint: Remember the right hand rule)
   A) forwards   B) to your left   C) backwards   D) up   E) to your right

8) In a perfectly ELASTIC collision between two perfectly rigid objects
   A) the momentum of the system is conserved but the kinetic energy of the system is not conserved.
   B) the momentum of the system is conserved, but the kinetic energy of the system is not conserved.
   C) both the momentum and the kinetic energy of the system are conserved.
   D) the momentum of each object is conserved.
   E) the kinetic energy of each object is conserved.

9) Two identical balls are thrown directly upward, ball A at speed \( v \) and ball B at speed 2\( v \), and they feel no air resistance. Which statement about these balls is correct?
   A) Ball B will go twice as high as ball A because it had twice the initial speed.
   B) Ball B will go four times as high as ball A because it had four times the initial kinetic energy.
   C) The balls will reach the same height because they have the same mass and the same acceleration.
   D) At its highest point, ball B will have twice as much gravitational potential energy as ball A because it started out moving twice as fast.
   E) At their highest point, the acceleration of each ball is instantaneously equal to zero because they stop for an instant.

10) A 4.0-kg object is moving with speed 2.0 m/s. A 1.0-kg object is moving with speed 4.0 m/s. Both objects encounter the same constant braking force, and are brought to rest. Which object travels the greater distance before stopping?
    A) the 1.0-kg object
    B) the 4.0-kg object
    C) Both objects travel the same distance.
    D) It is impossible to know without knowing how long each force acts.

11) 901 of work are needed to stretch a spring from 1.4 m to 2.9 m from equilibrium. What is the value of the spring constant?
    A) 55 N/m
    B) 27 N/m
    C) 36 N/m
    D) 39 N/m
12) A disk is attached to a motor that provides a constant torque \( T = 1.45 \text{ Nm} \). Assume no frictional losses in the system, \( I = 1.2 \text{ kgm}^2 \). \( \omega_0 = 0 \) rad/s, \( \alpha = \frac{1.45 \text{ rad/s}^2}{35 \text{ s}} \).

a) What is the angular speed of the disk after 35 seconds of applied torque by motor?

b) The motor is shut off after 35 seconds and a brake is applied such that the disk comes to rest in 3.8 seconds. Find the magnitude of the angular acceleration during this period.

\[ \begin{align*}
\text{Givens} & \\
\omega_0 &= 0 \\
\alpha &= \frac{1.45 \text{ rad/s}^2}{35 \text{ s}} \\
\end{align*} \]

\[ \begin{align*}
\omega_2 &= \omega_1 + \alpha t \\
\end{align*} \]

\[ \begin{align*}
a) \quad \omega_2 &= 0 + \alpha t \\
\omega_2 &= \alpha t \\
\omega_2 &= \left(\frac{1.45 \text{ rad/s}^2}{35 \text{ s}}\right)(35 \text{ s}) = 57.75 \text{ rad/s} \\
\omega_2 &= 58 \text{ rad/s} \\
\end{align*} \]

\[ \begin{align*}
b) \quad \omega_3 &= \omega_2 + \alpha t \\
\frac{-\omega_2}{t} &= \alpha_{\text{dec}}. \\
\frac{58 \text{ rad/s}}{35 \text{ s}} &= -\frac{1.45 \text{ rad/s}^2}{35 \text{ s}} \\
\alpha_{\text{dec}} &= -1.7 \text{ rad/s}^2 \\
\end{align*} \]
13) Two cars of masses $m_A = 15 \text{ kg}$ and $m_B = 25 \text{ kg}$ collide at an intersection. Before the collision, car A was traveling eastward at a speed of $v_{A1} = 18.0 \text{ m/s}$, and car B was traveling northward at a speed of $v_{B1} = 10.0 \text{ m/s}$. After the collision, the two cars stick together and travel off in the same direction at some angle north of east.

a) Find magnitude of the velocity $v_2$ of the two cars after they collide.

b) Find the angle they make with the eastward direction.

\[ \begin{align*}
\text{Physics} & \quad \text{Completely inelastic so mechanical energy is not conserved} \\
\text{Guess} & \quad \text{Conservative}
\end{align*} \]

\[ \begin{align*}
m_A &= 15 \text{ kg} \\
m_B &= 25 \text{ kg} \\
\vec{v}_{A1} &= 8\hat{i} + 3\hat{j} \\
\vec{v}_{B1} &= 2\hat{i} - 7\hat{j}
\end{align*} \]

\[ \begin{align*}
\vec{P}_i &= \vec{P}_f \\
0 + m_A v_{A1} &= (m_A + m_B) v \cos \theta \\
0 + m_B v_{B1} &= (m_A + m_B) v \sin \theta
\end{align*} \]

\[ \begin{align*}
v_{A2} &= \frac{m_A v_{A1} + m_B v_{B1}}{m_A + m_B} \\
\tan \left( \frac{v_{A2}}{v_{B2}} \right) &= \frac{v_{A2}}{v_{B2}} = 60.33 \%
\end{align*} \]

\[ \begin{align*}
\theta &= 60^\circ \\
\tan \left( \frac{38.5^\circ}{15^\circ} \right) &= 2.53
\end{align*} \]
14) In the figure below, a uniform ladder 12 meters long rests against a vertical frictionless wall. The ladder weighs 480 N and makes an angle 6° with the floor. A man weighing 740 N climbs slowly up the ladder to a point 7.8 m up from the bottom. The ladder doesn’t slip.

a) What is the frictional force the floor exerts on the ladder?

b) What is the normal force exerted by the floor on the ladder?

\[ \sum F = 0 \]
\[ \sum T = 0 \]

\[ X: n_x - \frac{F}{5} = 0 \]
\[ y: \theta = - \frac{n_y - w_1}{w_2} \]
\[ \gamma: \frac{\frac{1}{2} (\theta \cos \theta) w_1 + (\theta \sin \theta \sin \theta)}{\theta \cos \theta} - \left( \frac{\theta \sin \theta \cos \theta}{\theta \cos \theta} \right) = 0 \]
\[ n_x = \frac{w_1}{0.99} \]

\[ n_x = 1100 \text{ N} \]

\[ s_{90} \quad \text{and} \quad n_x = \frac{w_1}{0.99} \]

\[ n_y = 740 \text{ N} - 480 \text{ N} \]

\[ 591.9 \text{ N} = n_y = \frac{w_1}{0.99} \]
15) A disk of a radius \( r = 0.25 \text{ m} \) with mass of 20.00 kg rolls without slipping down a slope that makes an angle of 30.0 degrees with the horizontal. The moment of inertia for a disk is \( I = \frac{1}{2} MR^2 \).

a) Find the acceleration of the center of mass down the inclined plane.

b) What is the magnitude and direction of frictional force on the sphere?

\[ \sum F_x = ma_x \]
\[ \sum F_y = ma_y \]
\[ \sum T = I \alpha \]

Since \( \alpha \) is CCW, \( f \) is up ramp +x

\[ \sum F_x = ma_x \]
\[ N - mg \sin \theta = -ma_x \]
\[ I \alpha = ma_x \]
\[ \frac{I \alpha}{2} + m \frac{dx}{dt} = mg \sin \theta \]

b) Find the frictional force acting on the disk.

\[ f = \frac{1}{2} mg \sin \theta \]
\[ f = \frac{1}{2} \times 20.00 \times 9.8 \times \sin 30^\circ \]
\[ f = 19.6 \times 0.5 \]
\[ f = 9.8 \text{ N} \]

Substitute \( \alpha = 2 \times 9.8 \times \sin 30^\circ = 32.66 \text{ m/s}^2 \)

\[ a_x = 32.66 \text{ m/s}^2 \]

\[ a_y = \frac{1}{2} (g) \sin 30^\circ = 32.66 \text{ m/s}^2 \]

\[ a_y = 16.33 \text{ m/s}^2 \]

\[ a_y = \frac{1}{2} (g) \times 0.5 = 16.33 \text{ m/s}^2 \]
14) An engine is being used to raise an 45 kg crate vertically upward. If the power output of the engines is 1520 W assume that the friction in the system is negligible.

a) How long does it take the engine to lift the crate a vertical distance of 13.5 m?

b) Find the work done by gravity on the crate.

\[ P = \frac{dW}{dt} \]

- **Given**
  - \( P = 1520 \text{ W} \)
  - \( m = 45 \text{ kg} \)
  - \( h = 13.5 \text{ m} \)

- **Physics**
  - \( W = \int F \, dx \)

\[ \Delta t = \frac{W_{\text{done}}}{P} = \frac{(45 \text{ kg})(98 \text{ m/s}^2)(13.5 \text{ m})}{1520 \text{ W}} = 3.91478 \text{ s} \]

\( \Delta t \approx 3.9 \text{ s} \)

b) \( W_{\text{done}} = -6000 \text{ [J]} \)

\[ W_{\text{gravity}} = -W_{\text{engine}} \]

\[ mgh = -59635 \text{ J} \]