11. The figure shows the time dependent velocity of an object.

a) (7 pts) During which interval does the object travel at constant velocity

b) (8 pts) What is the object’s displacement from 0 to 5 seconds?

1. A ball is thrown vertically upward with a speed of 25.0 m/s.
   (a) How high does it rise?
   (b) How long does it take to reach its highest point?
   (c) How long does the ball take to hit the ground after it reaches its highest point?
   (d) What is its velocity when it returns to the level from which it started?
5. A cannonball is fired horizontally from the top of a cliff. The cannon is at height $H = 80.0 \text{ m}$ above ground level, and the ball is fired with initial horizontal speed $v_0$. Assume acceleration due to gravity to be $g = 9.80 \text{ m/s}^2$.

(a) Assume that the cannon is fired at time $t = 0$. How long ($t_s$) does it take for the cannonball to hit the ground?
(b) Assume that the cannonball hits the ground at time $t_s$. What is the $y$-position of the cannonball at the time $t_s/2$?
(c) Given that the projectile lands at a distance $D = 160 \text{ m}$ from the cliff, as shown in the figure, find the initial speed of the projectile, $v_0$.
(d) What is the $y$ position of the cannonball when it is at distance $D/2$ from the hill?

Kinematic Equations:
1. $v_{fy} = v_{oy} + a_y t$
2. $\Delta y = v_{oy} t + \frac{1}{2} a_y t^2$
3. $v_{fy}^2 = v_{oy}^2 + 2a_y \Delta y$
4. $\Delta x = v_{ox} t$

$a_y = -g = -9.8 \text{ m/s}^2$
3. (4 pts) Which motion diagram correctly represents the graph on the left?

![Motion Diagram](image)

- a) 
- b) 
- c) 
- d) 
- e) 

8. (4 pts) For which of the following angles is the projectile in air for the longest time? Circle your choice.

(a) 15 deg  
(b) 30 deg  
(c) 45 deg  
(d) 60 deg  
(e) 70 deg  
(d) all are in air for the same time

![Projectile Motion](image)

10. (4 points) Which of the following graphs could correctly represent the motion of an object moving with a constant nonzero velocity?

- a) Graph I and IV only  
- b) Graphs III and V only  
- c) Graph II and V only  
- d) Graph I and V only  
- e) Graph II and VI only

![Graphs](image)
4. A ball is thrown straight upward and returns to the thrower's hand after 3.45 s in the air. A second ball thrown at an angle of 45.0° with the horizontal reaches the same maximum height as the first ball.
   (a) At what speed was the first ball thrown?
   (b) At what speed was the second ball thrown?

1. A fireman $d = 54.0$ m away from a burning building directs a stream of water from a ground-level fire hose at an angle of $\theta_i = 20.0^\circ$ above the horizontal as shown in the figure. If the speed of the stream as it leaves the hose is $v_i = 40.0$ m/s, at what height will the stream of water strike the building?
13. Two balls are on a frictionless horizontal surface being pulled by an applied force, $F$, and accelerating at $3 \text{ m/s}^2$.
   a) (7 pts) Draw a free body diagram for each of the two balls.
   b) (8 pts) Determine the tension in the rope between the two balls.

![Free Body Diagram]

5. When a 2.50-kg object is hung vertically on a certain light spring described by Hooke's law, the spring stretches 2.76 cm.
   a) What is the force constant of the spring?
   b) If the 2.50-kg object is removed, how far will the spring stretch if a 1.25-kg block is hung on it?
   c) How much work must an external agent do to stretch the same spring 3.00 cm from its unstretched position?
12. The graph shows the net force acting on a 4.0-kg block as it moves along a flat horizontal surface at an initial speed \( v_0 = 2.4 \text{ m/s} \).

a) (5 pts) What is the initial kinetic energy of the block?

b) (5 pts) Calculate the work done on the block from \( x = 0 \) to \( x = 40 \) m.

c) (5 pts) What is the speed of the block at \( x = 40 \) m?

d) (5 pts) Where does the block have maximum speed?
1. (4 pts) Your friend sitting on a sled and asks you to slide her across a flat, horizontal icy field. You push her from behind by applying a downward force on her shoulders at $30^\circ$ below the horizontal as shown in the figure. The normal force acting on your friend is:

a) greater than her total weight.

b) possibly greater than or less than the weight, depending upon the coefficient of kinetic friction.

c) equal to her weight since it is horizontal field.

d) less than her total weight

e) depends on the coefficient of static friction.

2. (4 pts) A treasure chest is resting on a rough floor. A force of $F = 15$ N is applied on the treasure chest as shown in the figure. The chest does not move because of static frictional force. What is true about the applied force $F$ and the frictional force, $f_s$?

a) $f_s$ is now $< 15$ N

b) $f_s$ is still $15$ N

c) $f_s$ is not $> 15$ N

d) $f_s$ may have changed. We need more information to draw a conclusion.

6. (4 pts) An elevator suspended by a cable is moving upward and slowing down. Which free-body diagram is correct?
1. A 144.0-N bird feeder is supported by three cables as shown in the figure below. Find the tension in each cable.

![Fig. 1](image)

4. A man pushing a crate of mass \( m = 92.0 \text{ kg} \) at a speed of \( v = 0.850 \text{ m/s} \) encounters a rough horizontal surface of length \( \ell = 0.65 \text{ m} \) as in the figure below. If the coefficient of kinetic friction between the crate and rough surface is 0.358 and he exerts a constant horizontal force of 277 N on the crate, find the following.

(a) Find the magnitude and direction of the net force on the crate while it is on the rough surface.

(b) Find the net work done on the crate while it is on the rough surface.

(c) Find the speed of the crate when it reaches the end of the rough surface.

![Diagram](image)
13. A car of mass 1,410 kg collides with a wall and rebounds as shown in the figure. Initial velocity of the car is \( v_0 = 15.1 \, \text{m/s} \) and the final velocity, \( v_f = -2.32 \, \text{m/s} \). The collision lasts for 0.141 sec.

a) What is the change in momentum of the car? Give magnitude and direction.

b) What is the magnitude of the impulse delivered to the car due to collision?

c) What is the direction of the average force exerted on the car by the wall?

d) (Extra Credit 2 pts) What is the magnitude of the average force exerted on the car by the wall?
Extra Practice Problem. A force of magnitude $F_x$ acting in the x-direction on a 2.25-kg particle varies in time as shown in the figure below. *(Indicate the direction with the sign of your answer.)*

a) Find the impulse of the force over the 5 second interval.

b) Find the final velocity of the object if it is initially at rest.

c) *(Extra Credit 2 pts)* Find the final velocity of the particle if it is initially moving along the x-axis with a velocity of $-2.15$ m/s.

---

12. A coin placed 0.30 m from the center of a rotating, horizontal turntable almost slips when its speed is 0.5 m/s.

a) What force causes the centripetal acceleration when the coin is stationary relative to the turntable? Choose one.
   - A. static friction
   - B. inertia
   - C. kinetic friction
   - D. centrifugal force

b) Draw a Free body diagram of the forces acting on the coin in the "side view".

c) What is the coefficient of static friction between coin and turntable?
7. A 0.30-kg rock is swung in a circular path and in a **vertical plane** on a 0.25-m-length string. At the **bottom of the path**, how does the tension in the string compare to the force of gravity on the rock?

   a) Tension is greater than mg  
   b) Tension is the same as mg  
   c) Tension is less than mg  
   d) Tension might be less, the same, or more than mg. It depends on how fast the rock is going around in the circular path.

**Conceptual problems**

**MC1:** The two workers in the figure below are carrying a long, heavy steel beam.

(i) Which one is exerting a larger force on the object?
   
   (A) The worker on the right  
   (B) The worker on the left  
   (C) Both exert equal force

(ii) How can you tell?
   
   (A) The worker is farthest from the center of mass.  
   (B) The worker is closest to the center of mass.  
   (C) The worker is closest to the end of the beam.

**MC 3:** WA student initially at rest on a frictionless frozen pond throws a 1 kg hammer in one direction. After the throw, the hammer moves off in one direction while the student moves off in the other direction. Which of the following correctly describes the above situation?

(A) The hammer will have the momentum with the greater magnitude  
(B) The student will have the momentum with the greater magnitude  
(C) The hammer will have the greater kinetic energy  
(D) The student will have the greater kinetic energy  
(E) The student and the hammer will have equal but opposite amounts of kinetic energy
5. A woman of mass \( m = 54.8 \) kg sits on the left end of a seesaw—a plank of length \( L = 4.0 \) m, pivoted in the middle as shown in the figure. (a) Where should a man of mass \( M = 78.5 \) kg sit if the system (seesaw plus man and woman) is to be balanced? (b) Find the normal force exerted by the pivot if the plank has a mass of \( m_{pl} = 13.1 \) kg.

Suppose a 32.0-kg child sits 0.99 m to the left of center on the same seesaw. A second child sits at the end on the opposite side, and the system is balanced. (c) Find the mass of the second child.

6. An Atwood's machine consists of blocks of masses \( m_1 = 12.0 \) kg and \( m_2 = 19.0 \) kg attached by a cord running over a pulley as in the figure below. The pulley is a solid cylinder with mass \( M = 9.20 \) kg and radius \( r = 0.200 \) m. The block of mass \( m_2 \) is allowed to drop, and the cord turns the pulley without slipping. (a) Why must the tension \( T_2 \) be greater than the tension \( T_1 \)? (b) What is the acceleration of the system, assuming the pulley axis is frictionless? (c) Find the tensions \( T_1 \) and \( T_2 \).
Set 4

AE 13.04 (Question): A 0.455 kg object connected to a light spring with a spring constant of 20.5 N/m oscillates on a frictionless horizontal surface.
(a) Calculate the total energy of the system and the maximum speed of the object if the amplitude of the motion is 3.00 cm.
(b) What is the velocity of the object when the displacement is 2.00 cm?
(c) Calculate the kinetic and potential energies of the system when the displacement is 2.00 cm.
(d) For what values of x is the speed of the object 0.11 m/s?

P13.08: A block of mass $m = 2.00$ kg is attached to a spring of force constant $k = 4.15 \times 10^2$ N/m that lies on a horizontal frictionless surface as shown in the figure below. The block is pulled to a position $x_i = 5.05$ cm to the right of equilibrium and released from rest.
(a) Find the work required to stretch the spring.
(b) Find the speed the block has as it passes through equilibrium.
P 13.15: A horizontal block-spring system with the block on a frictionless surface has total mechanical energy $E = 39.2$ J and a maximum displacement from equilibrium of 0.244 m.

(a) What is the spring constant?

(b) What is the kinetic energy of the system at the equilibrium point?

(c) If the maximum speed of the block is 3.45 m/s, what is its mass?

(d) What is the speed of the block when its displacement is 0.160 m?

(e) Find the kinetic energy of the block at $x = 0.160$ m.

(f) Find the potential energy stored in the spring when $x = 0.160$ m.

(g) Suppose the same system is released from rest at $x = 0.244$ m on a rough surface so that it loses 13.0 J by the time it reaches its first turning point (after passing equilibrium at $x = 0$). What is its position at that instant?
Q: The drawing shows identical springs that are attached to a box in two different ways. Initially, the springs are unstrained. The box is then pulled to the right and released. In each case the initial displacement of the box is the same. At the moment of release, which box, if either, experiences the greater net force due to the springs?

Q: Which one of the following graphs correctly represents the restoring force \( F \) of an ideal spring as a function of the displacement \( x \) of the spring from its unstrained length?

(a)  
(b)  
(c)  
(d)  
(e)  

Q5: When an object moving in simple harmonic motion is at its maximum displacement from equilibrium, which of the following is at a maximum?

1. Velocity
2. Acceleration
3. Kinetic energy

Q: You have two springs. One has a greater spring constant than the other. You also have two objects, one with a greater mass than the other. Which object should be attached to which spring, so that the resulting spring–object system has the greatest possible period of oscillation?

(a) The object with the greater mass should be attached to the spring with the greater spring constant.
(b) The object with the greater mass should be attached to the spring with the smaller spring constant.
(c) The object with the smaller mass should be attached to the spring with the smaller spring constant.
(d) The object with the smaller mass should be attached to the spring with the greater spring constant.
1 mile = 5280 ft
1 m = 3.28 ft
\[ 2\pi \text{ radians} = 360^\circ \]
\[ G = 6.67 \times 10^{-11} \frac{\text{N} \cdot \text{m}^2}{\text{kg}^2} \]
\[ R_E = 6.38 \times 10^6 \text{ m} \]
\[ g = 9.8 \text{ m/s}^2 \]

**Circumference = 2\pi r**

**Area = \pi r^2**

### Kinematic Equations for Constant Acceleration:

- Velocity:
  \[ v = v_0 + at \]

- Position:
  \[ x = x_0 + v_0 t + \frac{1}{2} at^2 \]
  \[ \Delta x = x - x_0 \]

- Velocity Squared:
  \[ v^2 = v_0^2 + 2a(x - x_0) \]

### Kinematic Equations for Rotational Motion for Constant Angular Acceleration:

- Angular Velocity:
  \[ \omega = \omega_0 + at \]

- Angular Position:
  \[ \theta = \theta_0 + \omega_0 t + \frac{1}{2} \alpha t^2 \]
  \[ \Delta \theta = \theta - \theta_0 \]

- Angular Velocity Squared:
  \[ \omega^2 = \omega_0^2 + 2\alpha \Delta \theta \]

### For Forces and Newton’s Laws

\[ \vec{a} = \frac{\vec{F}_{\text{net}}}{m} \]

\[ \vec{F}_{\text{net}} = \sum \vec{F} \]

\[ f_k = \mu_k F_N \]

\[ f_S \leq \mu_s F_N \]

\[ F_G = \frac{G m_1 m_2}{r^2} \]

\[ F_g = mg \]

### Work, Energy, Power

\[ W_{\text{net}} = \Delta KE \]

\[ W_{nc} = \Delta KE + \Delta PE = (KE_f + PE_f) - (KE_0 + PE_0) \]

\[ W = Fd \cos \theta \quad d = |\Delta x| \]

\[ KE = \frac{1}{2} mv^2 \]

\[ PE_g = mgh \]

\[ PE_{\text{spring}} = \frac{1}{2} k(x)^2 \]

\[ ME = KE + PE \]

\[ P = \frac{W}{t} = \frac{\Delta E}{t} = F_{\text{ave}} v \]

### Momentum and Impulse

\[ F_{\text{ave}} \Delta t = \Delta p \]

\[ P_f = P_i \]

\[ I = F_{\text{ave}} \Delta t \]

\[ p = mv \quad \Delta p = p_f - p_i \]

### Relationship Between Linear and Rotational Terms and Other Useful Equations for Circular Motion:

\[ s = r\theta \quad v_t = r\omega \quad a_t = r\alpha \]

\[ v_t = \frac{2\pi r}{T} \]

\[ a_c = \omega^2 r = \frac{v_t^2}{r} \]

\[ a_{\text{total}} = \sqrt{a_t^2 + a_c^2} \]

### Equations for Rotational Dynamics:

\[ \alpha = \frac{\tau_{\text{net}}}{I} \]

\[ \tau_{\text{net}} = \sum \tau \]

\[ \tau = rF_\perp = rF \sin \theta \]

\[ I = \sum (mr^2) \]

\[ I_{\text{hoop}} = MR^2 \quad I_{\text{disk}} = \frac{1}{2} MR^2 \]

\[ I_{\text{hollow sphere}} = \frac{2}{3} MR^2 \quad I_{\text{solid sphere}} = \frac{2}{5} MR^2 \]

\[ I_{\text{rod, center}} = \frac{1}{12} ML^2 \quad I_{\text{rod, end}} = \frac{1}{3} ML^2 \]

\[ x_{CM} = \frac{\sum m_i x_i}{\sum m_i} \quad y_{CM} = \frac{\sum m_i y_i}{\sum m_i} \]

### Angular Momentum Considerations

\[ \tau \Delta t = \Delta L \]

\[ L = I\omega \]

### Energy Considerations:

\[ KE_{\text{rot}} = \frac{1}{2} I \omega^2 \]

### Spring Force, Energy and Simple Harmonic Motion:

\[ x = A \cos(\omega t) \quad v = -A \omega \sin(\omega t) \quad a = -A \omega^2 \cos(\omega t) \]

\[ v = \pm \frac{k}{m} \sqrt{A^2 - x^2} \]

\[ F_{\text{spring}} = k \Delta x \quad \Delta x = \text{displacement from equilibrium} \]

\[ PE_{\text{spring}} = \frac{1}{2} k(x)^2 \]

\[ f = \frac{1}{T} \quad \omega = 2\pi f = \frac{2\pi}{T} \quad \omega = \frac{k}{\sqrt{m}} \]