The next four questions pertain to the situation described below.

A ball with mass \( m = 1.8 \text{ kg} \) is thrown downward from the top of a building with height \( h = 16 \text{ m} \) and initial speed \( v_0 \) at an angle \( \theta \) with respect to the horizontal as shown in the figure. The \( x \)-component of the initial velocity \( v_{x0} = 23.4 \text{ m/s} \), and the ball hits the ground a distance \( d = 24 \text{ m} \) from the building as shown in the figure.

1) How long is the ball in the air?
   
   a. \( t = 1.81 \text{ s} \)  
   b. \( t = 1.03 \text{ s} \)  
   c. \( t = 4.78 \text{ s} \)

2) What is \( v_{y0} \), the \( y \) component of the ball's initial velocity?
   
   a. \( v_{y0} = -19 \text{ m/s} \)  
   b. \( v_{y0} = -13 \text{ m/s} \)  
   c. \( v_{y0} = -26 \text{ m/s} \)  
   d. \( v_{y0} = -11 \text{ m/s} \)  
   e. \( v_{y0} = 0 \text{ m/s} \)

3) If the ball is thrown at the same angle, but with a greater speed, the ball would be in the air
   
   a. a shorter time.  
   b. a longer time.  
   c. the same amount of time.

4) If the ball is thrown with the same speed, but horizontally (e.g. \( \theta = 0 \)), it would hit the ground with
   
   a. a faster speed than when it was thrown downward.  
   b. a slower speed than when it was thrown downward.  
   c. the same speed as when it was thrown downward.
The next two questions pertain to the situation described below.

![velocity-time graphs]

A ball's motion is represented by the velocity time-graph above.

5) Which of the velocity-time graphs best represents this statement?

An object has zero acceleration at t=2 s. At t=2.5 s, it is moving in the positive direction and slowing down.

a. A  
b. B  
c. C  
d. D  
e. E

6) Which of the velocity-time graphs best represents this statement?

The object is moving in the positive direction and speeding up at t=1.75 s. The object has negative acceleration at t=2.5 s.

a. A  
b. B  
c. C  
d. D  
e. E
The next three questions pertain to the situation described below.

A box of mass \( m_1 = 10 \text{ kg} \) is placed on a frictionless surface. A smaller box of mass \( m_2 = 3 \text{ kg} \) is placed on top of the larger box. The system of boxes is initially at rest. A horizontal force \( F \) is applied to the lower box, pulling it to the left as shown in the figure. The coefficients of static and kinetic friction between the two boxes are \( \mu_k = 0.25 \) and \( \mu_s = 0.29 \).

7) Initially, the two boxes are observed to move together (the small box remains on top of the large box). What is the direction of the friction force applied by the smaller box \( m_2 \) on the larger box \( m_1 \)?

a. to the left
b. to the right
c. there is no frictional force between the two boxes

8) What is the maximum force \( F_{\text{max}} \) that can be applied, before the small box begins to slide relative to the large box?

a. \( F_{\text{max}} = 37 \text{ N} \)
b. \( F_{\text{max}} = 7.4 \text{ N} \)
c. \( F_{\text{max}} = 32 \text{ N} \)
d. \( F_{\text{max}} = 28 \text{ N} \)
e. \( F_{\text{max}} = 24 \text{ N} \)

9) If the boxes start from rest, and a force \( F = 12 \text{ N} \) is applied until the boxes have moved a distance of 2.5 m, what is the work done by friction on the top box \( m_2 \)? (You may assume the two boxes move together.)

a. \( W_{\text{friction}} = 6.9 \text{ J} \)
b. \( W_{\text{friction}} = 0 \text{ J} \)
c. \( W_{\text{friction}} = 21 \text{ J} \)
d. \( W_{\text{friction}} = -6.9 \text{ J} \)
e. \( W_{\text{friction}} = -21 \text{ J} \)
The next two questions pertain to the situation described below.

A solid cubic box of mass \( m = 4 \) kg is pushed along a floor by a horizontal force \( F = 12 \) N. The box is observed to move with a constant velocity \( v = 0.3 \) m/s.

10) What is the coefficient of kinetic friction between the box and the floor?

a. \( \mu = 0.0092 \)
b. \( \mu = 0.15 \)
c. \( \mu = 0.31 \)

11) A second box is made of the same material as the first box but is half the size of the first box in every dimension. Subject to the same force \( F = 12 \) N, the second box:

a. Moves with the same constant velocity as the first box.
b. Moves with a constant acceleration
c. Moves with a constant velocity eight times that of the first box.
The next three questions pertain to the situation described below.

A box of mass $M = 0.4 \text{ kg}$ is moving along a stationary ramp upward (+$x$ direction) as shown in the figure. The box's initial speed $V = 1.4 \text{ m/s}$. The angle between the ramp and the horizontal plane $\theta = 24 \text{ degrees}$, and the coefficient of friction between the box and the ramp is $\mu_k = 0.32$.

12) What is the magnitude of the box's acceleration as it is moving up the ramp?

   a. $|a_{\text{up}}| = 6.9 \text{ m/s}^2$
   b. $|a_{\text{up}}| = 7.7 \text{ m/s}^2$
   c. $|a_{\text{up}}| = 1.1 \text{ m/s}^2$
   d. $|a_{\text{up}}| = 0.85 \text{ m/s}^2$
   e. $|a_{\text{up}}| = 4 \text{ m/s}^2$

13) What is the direction of the box's acceleration as it moves up the ramp?

   a. $+x$
   b. $-x$
   c. $0$

14) Eventually the box is observed to slide back down the ramp with constant acceleration $a_{\text{down}}$. Compare the magnitude of the acceleration of the box going up and down the ramp.

   a. $|a_{\text{down}}| < |a_{\text{up}}|$
   b. $|a_{\text{down}}| = |a_{\text{up}}|$
   c. $|a_{\text{down}}| > |a_{\text{up}}|$
The next two questions pertain to the situation described below.

The width of a river is \( d = 90 \text{ m} \), the water flows with a constant speed \( v_{w,g} \) with respect to its banks. An athletic swimmer can swim at a speed \( v_{s,w} = 6 \text{ m/s} \) in still water. Although she heads directly across the river toward the opposite bank with her maximum effort, she arrives at point \( C \) on the opposite bank a distance \( L = 60 \text{ m} \) downstream.

15) The speed of the water, relative to the ground is:

a. \( v_{w,g} = 7.2 \text{ m/s} \)
b. \( v_{w,g} = 3 \text{ m/s} \)
c. \( v_{w,g} = 6 \text{ m/s} \)
d. \( v_{w,g} = 4 \text{ m/s} \)
e. \( v_{w,g} = 10 \text{ m/s} \)

16) If instead she chose a heading that would get her directly across the river (point B), how long would it take her to get to the other side?

a. \( t = 45 \text{ s} \)
b. \( t = 20 \text{ s} \)
c. \( t = 15 \text{ s} \)
The next two questions pertain to the situation described below.

A ball of mass mass \( m = 1.5 \) kg is suspended from a rope of length \( L \) and travels in a horizontal circle of radius \( R = 1.8 \) m at a constant speed \( v = 3 \) m/s, as shown in the figure.

17) What is the horizontal component of the tension in the rope \( T_{\text{horizontal}} \)?

a. \( T_{\text{horizontal}} = 15 \) N
b. \( T_{\text{horizontal}} = 7.5 \) N
c. \( T_{\text{horizontal}} = 8.3 \) N

18) What is the length \( L \) of the rope?

a. \( L = 2.02 \) m
b. \( L = 3.96 \) m
c. \( L = 2.42 \) m
The next two questions pertain to the situation described below.

For the following problems assume the earth is a sphere with radius \( R_E = 6.4 \times 10^6 \) m, and mass \( M_E = 6 \times 10^{24} \) kg.

19) If a person weighs 120 pounds on the surface of the Earth, how much would the person weigh on the surface of a planet that has 1/2 of the mass of the earth and 1/2 of the Earth's radius?

   a. 120 pounds
   b. 60 pounds
   c. 240 pounds

20) What is the speed of a 128 kg satellite in a circular orbit around the earth at a distance of \( R_{\text{orbit}} = 1.92 \times 10^7 \) m from the center of the earth?

   a. 0.00808 m/s
   b. 4570 m/s
   c. 1250 m/s
   d. 7910 m/s
   e. 1.12 \times 10^5 m/s