The next two questions pertain to the situation described below.

![Graph showing velocity over time with points O, A, B, and C marked.]

A miniature racecar was placed onto a tabletop racetrack and released at time \( t = 0 \). The racecar's x-component of velocity is plotted above as a function of time.

1) What can be said about the x-component of the racecar's acceleration \( a_x \)?

- a. From \( O \) to \( A \), \( a_x \leq 0 \).
- \( \checkmark \) b. From \( A \) to \( B \), \( a_x \leq 0 \).
- c. From \( B \) to \( C \), \( a_x \geq 0 \).

2) How does the x-component of the racecar's position \( x_B \) at \( B \) compare to its position \( x_C \) at \( C \)?

- a. \( x_B < x_C \)
- b. \( x_B = x_C \)
- \( \checkmark \) c. \( x_B > x_C \)
An object starts from rest and begins to move along the $x$ axis at time $t = 0$. Its position is observed to be $x(t) = bt^4$, where $b$ is a constant.

3) Which of the following can be said about the object's position $x(t)$, velocity $v(t)$, or acceleration $a(t)$ when $t > 0$?

a. The object's velocity is given by $v(t) = bt^3$.
b. None of the other options.
c. If the object's acceleration is measured at some time $t$, then its velocity at that same time can be calculated using $v(t) = t a(t)$.
d. The object's position is related to its acceleration by $x(t) = \frac{t^2 a(t)}{2}$.
✓ e. The object's velocity is related to its acceleration by $v(t) = \frac{t a(t)}{3}$.

The next three questions pertain to the situation described below.

![Diagram of a cannon firing a cannonball](image)

A cannon fires a cannonball in an empty field. The cannonball spends 5.7 seconds in the air and lands a distance $D$ from the point from which it was shot. You should ignore air resistance.

4) What is the maximum height $h$ reached by the cannonball?

a. $h = 159.36$ m
b. There is not enough information given to determine this.
✓ c. $h = 39.84$ m
d. $h = 19.92$ m
e. $h = 79.68$ m

5) After being shot into the air, but before the cannonball lands, which of the following statements best describes the acceleration vector of the cannonball?

✓ a. It always points downward.
b. It points upward until the cannonball reaches its maximum height, then it points downward.
c. It always points toward the right.
6) Suppose the cannon fires another cannonball at the same initial angle but with twice the initial speed. What is the new horizontal distance $D_{\text{new}}$ travelled by the cannonball?

a. $D_{\text{new}} = \sqrt{2}D$

✓ b. $D_{\text{new}} = 4D$

c. $D_{\text{new}} = 2D$
The next two questions pertain to the situation described below.

Two rockets are initially at rest at position $x=0$. Rocket A begins to move with constant acceleration at time $t=0$. Rocket B remains at rest until time $t=3$ seconds, when it also begins to move with constant acceleration.

7) Suppose that both rockets accelerate at a constant $30 \text{ m/s}^2$. At $t=4 \text{ s}$ how is the distance between the two rockets changing?

a. decreasing  
b. remains the same  
**c. increasing**

8) Now suppose that rocket A accelerates at a constant $30 \text{ m/s}^2$ starting at $t=0$, while rocket B accelerates at a constant $40 \text{ m/s}^2$ starting at $t=3 \text{ s}$. At what time $t$ will rocket B catch up with rocket A?

a. 19.39 s  
b. rocket B will not catch rocket A  
**c. 22.39 s**  
d. 12 s  
e. 1.61 s
The next three questions pertain to the situation described below.

An amusement park ride consists of a set of chairs hanging from a rotating central hub by chains of length $L = 16$ m that are free to rotate about their attachment to the hub. The hub rotates at a constant angular velocity, causing the chairs to sweep out a circular path. Consider a passenger of mass $m = 90$ kg sitting in one of these chairs, swinging at an angle $\theta = 35^\circ$ from vertical as shown.

9) What is the tension in the chain?
   
   a. $T = 1260.91$ N  
   b. $T = 882.9$ N  
   ✓ c. $T = 1077.82$ N  
   d. $T = 1539.29$ N  
   e. $T = 38.64$ N

10) Let $T$ be the tension in the chain in the original problem above. Suppose the person is now swung in such a way that the angle of the chain is decreased. What is the new tension in the chain?
   
   ✓ a. $T_{\text{new}} < T$  
   b. $T_{\text{new}} = T$  
   c. $T_{\text{new}} > T$

11) Say the speed of the swinging person in the original problem is $V_0$. Suppose that we increase the mass of the person but keep the length of the chain the same. If we want the angle that the chain makes with the vertical to be the same as in the original problem, what would the new speed of the passenger have to be?
   
   a. $V_{\text{new}} < V_0$  
   b. $V_{\text{new}} > V_0$  
   ✓ c. $V_{\text{new}} = V_0$
A penguin of mass 7 kg takes his friends for a ride, pushing himself forward with a force of $F = 37 \text{ N}$. Penguin 2 has mass 21 kg, Penguin 4 has mass 9 kg, and the tension in the third rope is $T = 3.43 \text{ N}$.

12) What is the mass of the third penguin?

✓ a. 60 kg
b. 97 kg
c. 0 kg
d. 9 kg
e. 69 kg

The next two questions pertain to the situation described below.

A group of hungry penguins has caught an unusually large fish of mass $10^5 \text{ kg}$. Each penguin can apply a force of 37 N. The coefficient of static friction between the fish and the ice is 0.02 and the coefficient of kinetic friction is 0.005.

13) What is the minimum number of penguins needed to move the fish from rest?

a. 26514
b. 1
c. 55
d. 133
✓ e. 531
14) Once the penguins manage to move their prey, how many penguins does it take to achieve an acceleration of $0.2 \, m/s^2$?

✓ a. 673
b. 408
c. 133
d. 1
e. 14
The next two questions pertain to the situation described below.

A tribometer is a device used to measure coefficients of friction. Two simple tribometers are shown above.

15) If we want to measure the coefficient of kinetic friction between mass 2 and surface A (left diagram), we should:

a. adjust \( m_1 \) until \( m_2 \) first begins to move, then take the ratio \( m_1/m_2 \)
✓ b. adjust \( m_1 \) so that \( m_2 \) moves with constant velocity, then take the ratio \( m_1/m_2 \)
 c. adjust \( m_1 \) until \( m_2 \) first begins to move, then take the ratio \( m_2/m_1 \)
 d. adjust \( m_2 \) so that \( m_1 \) moves with constant velocity, then take the ratio \( m_1/(m_1 + m_2) \)
 e. adjust \( m_1 \) so that \( m_2 \) moves with constant velocity, then take the ratio \( m_2/m_1 \)

16) If we want to measure the coefficient of static friction between mass 1 and surface B (right diagram), we could:

a. None of the other choices are correct.
 b. adjust \( \theta \) so that the mass moves with constant velocity, then compute \( \tan(\theta) \)
✓ c. adjust \( \theta \) until the mass first begins to move, then compute \( \tan(\theta) \)
 d. adjust \( m_1 \) until the mass first begins to move, then compute \( \tan(\theta) \)
 e. adjust \( m_1 \) until the mass moves with constant velocity, then compute \( \tan(\theta) \)
A small satellite with a mass of 2 kg has been set into a stable circular orbit around the Earth. The radius of the satellite's orbit (distance between the center of the Earth and the center of the satellite) is $R_{se} = 7 \times 10^6$ m. The satellite completes an orbit every 1.62 hours. Air resistance is negligible at the satellite's altitude.

17) What is the magnitude of the centripetal force on the satellite due to its gravitational interaction with the Earth?

a. 19.6 N  
✓ b. 16.3 N  
  c. 2.94 N

18) What is the total work done by the centripetal force (from the preceding question) as the satellite completes one full orbit around the Earth?

✓ a. 0 J  
  b. $7.16 \times 10^8$ J  
  c. $1.37 \times 10^8$ J
The next two questions pertain to the situation described below.

The free body diagram below depicts the various forces acting on a block of mass 7 kg that is pulled up an inclined plane by a small vehicle. The block is acted on by gravity \( F_g \), the normal force \( F_N \), a rope tension \( T \), and at times a frictional force \( F_f \) that is present only over a bumpy part of the plane. The plane's surface makes an interior angle \( \theta = 45 \) degrees with the horizontal plane, as shown.

On the lower part of the plane, where the block sits in the figure below, there is zero friction between the block and the plane. Above this, where the surface becomes bumpy, there is a coefficient of kinetic friction \( \mu_k = 0.1 \).

19) The block is initially being pulled up the smooth section of the ramp, where there is no friction. In this region, what magnitude of the rope's tension, \( T \), would be required to keep the box moving up the plane at a constant velocity of 10 m/s?

✓ a. 48.56 N  
b. 34.34 N  
c. 68.67 N  
d. 36.07 N  
e. 0.69 N

20) Higher up the plane, as the box is pulled across a rough part of the plane's surface, it slows down to a stop due to friction. What total work would be done on the box as it slowed from 10 m/s to rest?

a. 350 J  
b. 0 J  
✓ c. -350 J
A box sits on the horizontal bed of a truck accelerating to the left. Static friction between the box and the truck keeps the box from sliding around as the truck drives.

21) The work done on the box by the static frictional force as the truck moves a distance D to the left is:

   a. Zero
   b. Negative
   c. Positive

22) What is the y-component of the normal force of the ground acting on the penguin?

   a. -191.98 N
   b. -161.18 N
   c. 191.98 N
   d. 176.58 N
   e. 161.18 N

A crested penguin of mass 18 kg is standing on the ground, and is connected to the ceiling by a spring of spring constant k=14 N/kg. The spring is stretched downward by a distance of Δy = 1.1 m from its equilibrium length, as shown in the figure above.
A penguin on the south shore of a river has a fish dinner to bring home to its baby. The baby is on the northern shore of the river, directly north of its parent. Unfortunately the two are on islands separated by a distance of $D=250 \text{ m}$. The water between the two is flowing to the east at a rate of $v_w = 6 \text{ m/s}$, parallel to the shores. The penguin parent can swim at a speed of $v = 6.5 \text{ m/s}$

23) At what angle $\theta$ west of north should the penguin swim so that they reach their baby?

a. No such angle  
b. 52.9 degrees  
c. 42.7 degrees  
✓ d. 67.4 degrees  
e. 22.6 degrees