AP Physics 1: Algebra-Based
Summer Assignment - Document 2

The study of physics can be divided into some major areas: classical mechanics, relativity, thermodynamics, electromagnetism, optics and quantum mechanics. As mentioned in document 1, ***AP physics 1 deals with classical mechanics***, sometimes referred to as *Newtonian mechanics* or simply *mechanics* because important contributions were provided by Isaac Newton (1642–1727), who developed classical mechanics as a systematic theory and was one of the originators of calculus as a mathematical tool.

AP physics 1 is divided into 8 units. These units and their relevant weightings on the multiple-choice section of AP Exam (40 questions) are listed below.

Content outline	weighting for MCQ (40 Q's)	
Unit 1 Kinematics	10-15%	4 - 6 Q's
Unit 2 Force and Translational Dynamics	18-23%	7 - 9 Q's
Unit 3 Work, Energy, and Power	18-23%	7 - 9 Q's
Unit 4 Linear Momentum	10-15%	4 - 6 Q's
Unit 5 Torque and Rotational Dynamics	10-15%	4 - 6 Q's
Unit 6 Energy and Momentum of Rotating Systems	5-8%	2 - 3 Q's
Unit 7 Oscillations	5-8%	2 - 3 Q's
Unit 8 Fluids	10-15%	4 - 6 Q's

In addition to that, the course has five big ideas that serve as the foundation of it and allow you to create meaningful connections among concepts. They are often abstract concepts or themes that become threads that run throughout the course. Revisiting the big ideas and applying them in a variety of contexts allows you to develop deeper conceptual understanding. Below are the big ideas of the course and a brief description of each.

<u>BIG IDEAS</u>

1. **SYSTEMS (SYS)**: Objects and systems have properties such as mass and charge. Systems may have internal structure
2. **FIELDS (FLD):** Fields existing in space can be used to explain interactions.

3. **FORCE INTERACTIONS (INT):** The interactions of an object with other objects can be described by forces.
4. **CHANGE (CHA)**: Interactions between systems can result in changes in those systems.
5. **CONSERVATION (CON)**: Changes that occur as a result of interactions are constrained by conservation laws.

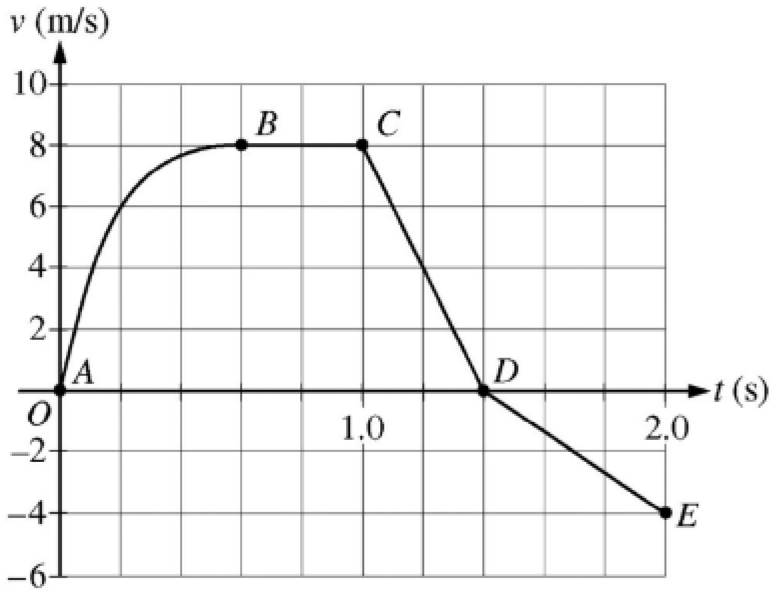
Document 2 has two parts: part 1 is related to kinematics and part 2 is related to dynamics. The questions will help you cover most of the concepts of units 1 and 2 in AP physics 1. These concepts will be revisited during the coming year, however, solving these questions independently paves the road toward understanding units 1 and 2 completely and speeds up the learning of the remaining units. **Document 2 needs to be completed and submitted on the first day of the coming academic year.**

DAY ONE OR ONE DAY, YOU DECIDE.

Part 1 - Kinematics

Question 1

The two questions below refer to the following information.



A cart is constrained to move along a straight line. A varying net force along the direction of motion is exerted on the cart. The cart's velocity v as a function of time t is shown in the graph above. The five labeled points divide the graph into four sections.

1. Which of the following correctly ranks the magnitude of the average acceleration of the cart during the four sections of the graph?

(A) $a_{CD} > a_{AB} > a_{BC} > a_{DE}$

(B) $a_{BC} > a_{AB} > a_{CD} > a_{DE}$

(C) $a_{AB} > a_{BC} > a_{DE} > a_{CD}$

(D) $a_{CD} > a_{AB} > a_{DE} > a_{BC}$

2. For which segment does the cart move the greatest distance?

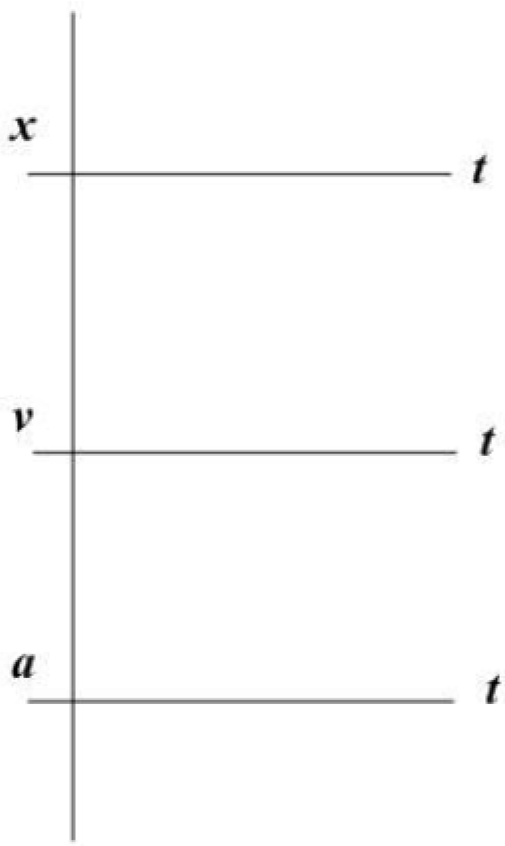
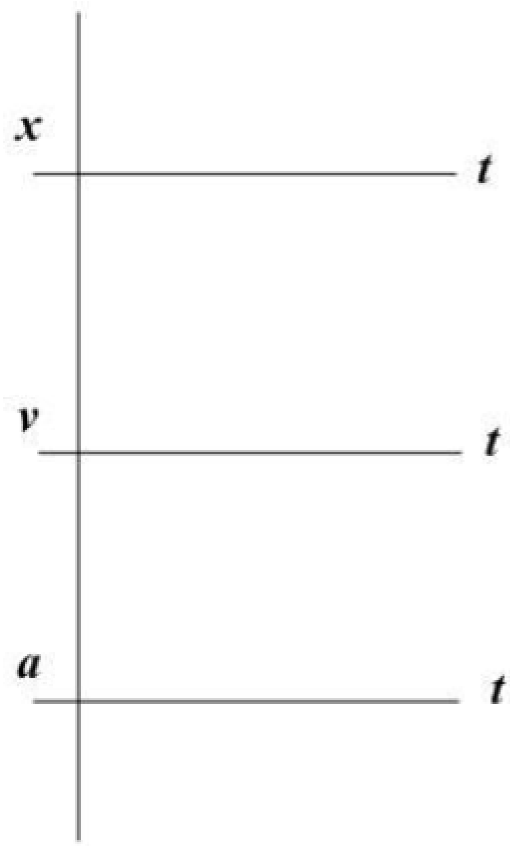
(A) AB (B) BC (C) CD (D) DE

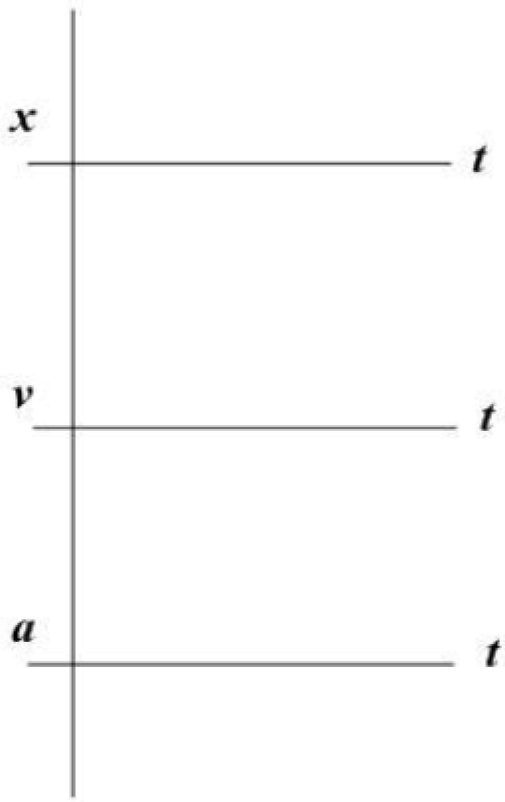
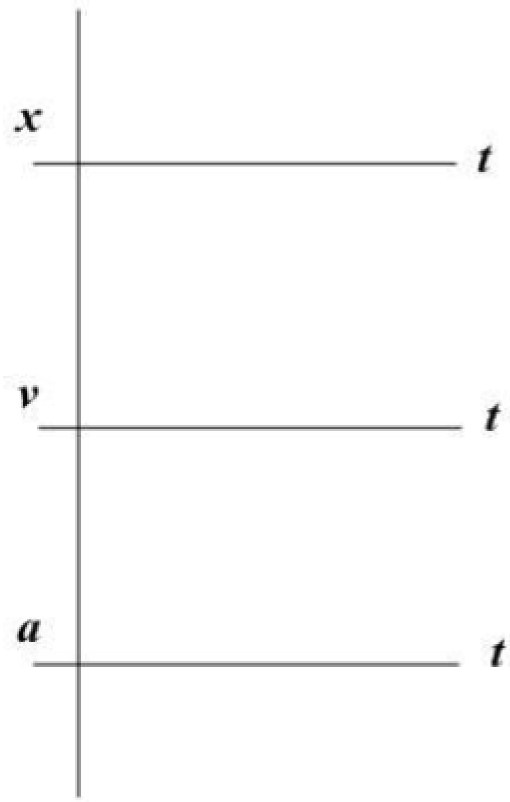
3. What is the acceleration of the cart at $t = 1.2\ s$?

(A) 20 m/s^2 (B) 3.3 m/s^2 (C) - 20 m/s^2 (D) - 3.3 m/s^2

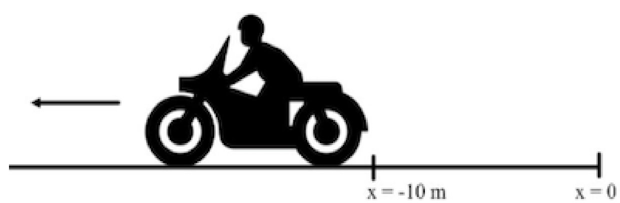
Question 2

Use the following link https://www.walter-fendt.de/html5/phen/acceleration_en.htm to go to a simulation about motion with constant acceleration. Enter the data of the four scenarios below in order to sketch the position vs. time, velocity vs. time and acceleration vs. time graphs.

Scenario one: moving to the left; $x_0 = 50\ m$; $v_0 = -2.0\ m/s$; $a = -1.0\ m/s^2$ 	Scenario two: moving to the right; $x_0 = 0\ m$; $v_0 = 0\ m/s$; $a = 1.0\ m/s^2$ 

Scenario three: moving to the left; $x_0 = 50\,m$; $v_0 = 0\,m/s$; $a = -\,1.0\,m/s^2$  	Scenario four: moving to the left; $x_0 = 50\,m$; $v_0 = -\,10\,m/s$; $a = 1.0\,m/s^2$ 

Question 3



A biker on a motorcycle is moving along a straight highway. At time $t = 0\,s$, the biker is at position $x = -\,10\,m$ as shown on the adjacent diagram. The biker is moving away from the origin and slowing down.

What are the signs of the initial position, initial velocity, and acceleration respectively?

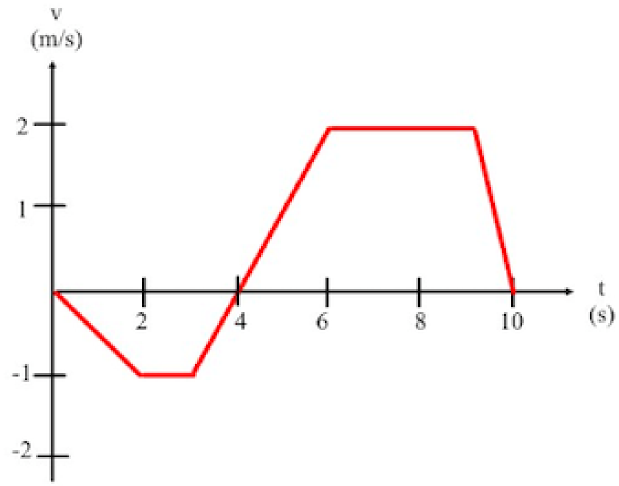
(A) positive, positive, negative

(B) negative, negative, negative

(C) negative, positive, negative

(D) negative, negative, positive

Question 4



The graph above describes the velocity of a toy car for 10 seconds as it moves across a level floor in a straight line.

1. The total displacement of the toy car for the entire 10 seconds is

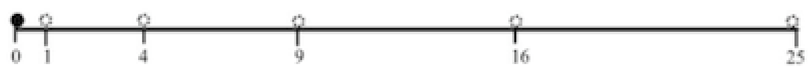
(A) 0 m (B) 6.5 m

(C) 9 m (D) 10 m

2. The acceleration of the toy car at $t = 4\,s$ is

(A) - 1 m/s^2 (B) 0 m/s^2 (C) 1 m/s^2 (D) 2 m/s^2

Question 5



The diagram above shows the motion of a ball rolling on a floor in a straight line. The position of the ball at time intervals of one second is indicated. Complete the verbal description of the motion by filling in a correct word or by choosing the appropriate response.

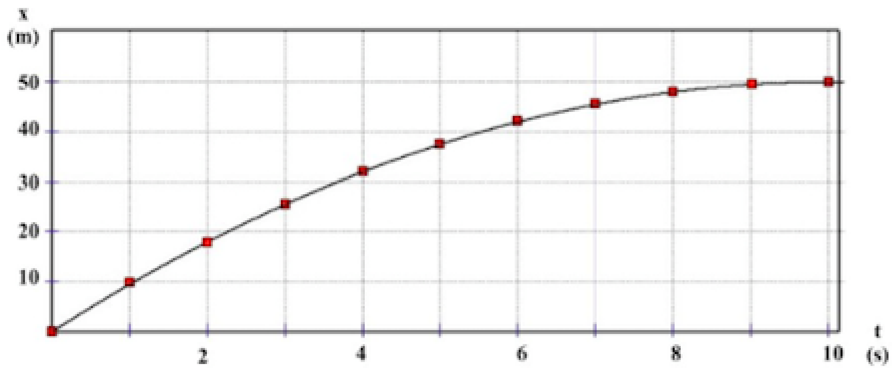
1. The ball starts at the ________________ and moves to the ***(right; left)***. The speed of the ball ***(stays the same; is increasing; is decreasing)***. The velocity is ***(zero; positive; negative)*** and the acceleration is ***(zero; positive; negative)***.

2. If the position is in centimeters and the ball starts from rest then its acceleration over the 5 s interval is

(A) 0.01 m/s^2 (B) 0.02 m/s^2 (C) 0.04 m/s^2 (D) 0.05 m/s^2

Question 6

The position vs. time graph of a car is shown below

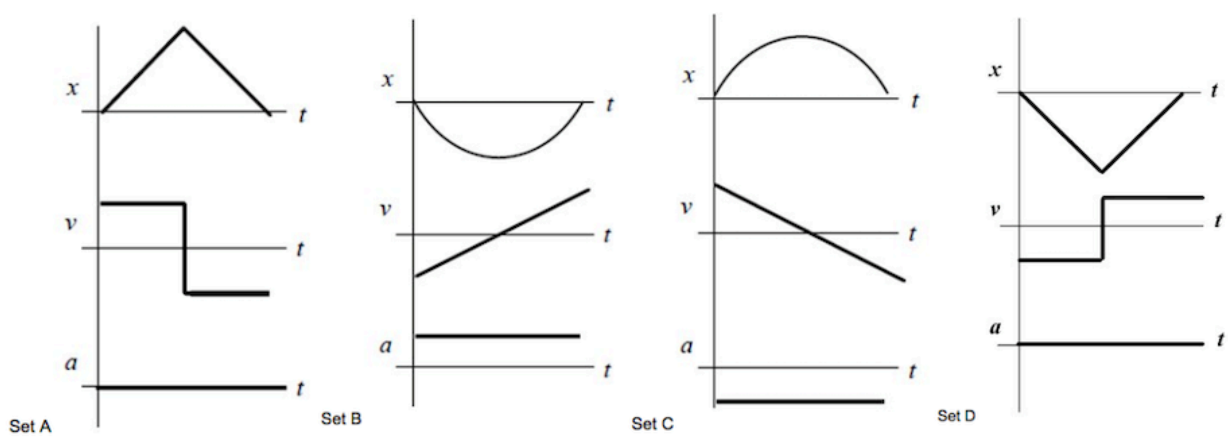


The average velocity of the car between 1.0 s and 9.0 s is

(A) 1.3 m/s (B) 2.5 m/s (C) 5 m/s (D) 6.3 m/s

Question 7

A tennis ball is thrown up and caught at the same height on its way down. Which set of graphs best describes the motion of the ball? Consider the upward direction to be positive.



(A) Sec A (B) Sec B (C) Sec C (D) Sec D

Question 8

It is observed that a car traveling toward the west on a straight highway is slowing down.

Which of the following statements must be true? There are two correct statements.

(A) The velocity and speed are both positive.

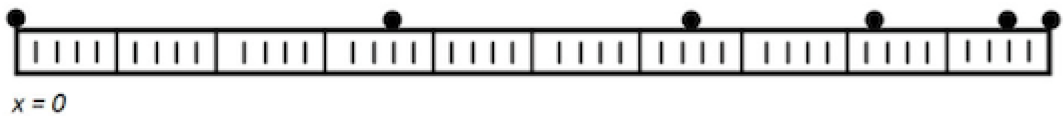
(B) The velocity vector is directed west.

(C) The acceleration vector is directed west.

(D) The acceleration vector is directed east.

Question 9

The drawing shows the motion diagram of a car that has been photographed at equal time intervals. The dot represents the position of the front of the car.



1. The description that could describe the motion of the car is

(A) The car is moving to the left, first speeding up then slowing down.

(B) The car is moving to the right, first speeding up then slowing down.

(C) The car is moving to the right and speeding up.

(D) The car is moving to the right and slowing down.

2. Sketch the position vs. time that could match the motion of the car given above.

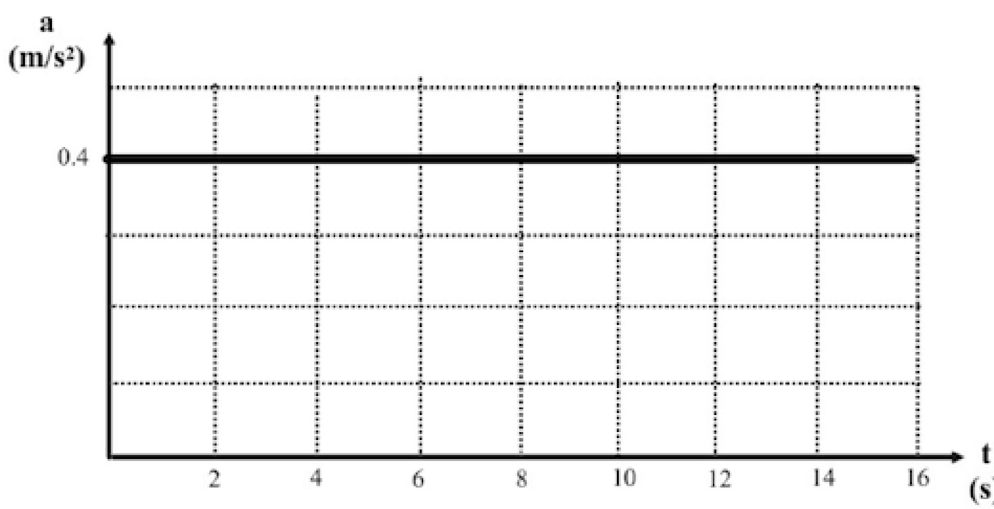
Question 10

A galloping horse has a speed of 12 m/s at t = 0. After 50 s, its speed is 8 m/s.

1. Draw a velocity-time graph to represent the motion of the horse.
2. Use your graph to calculate the displacement of the horse.
3. Use your graph to calculate the average acceleration of the horse.

Question 11

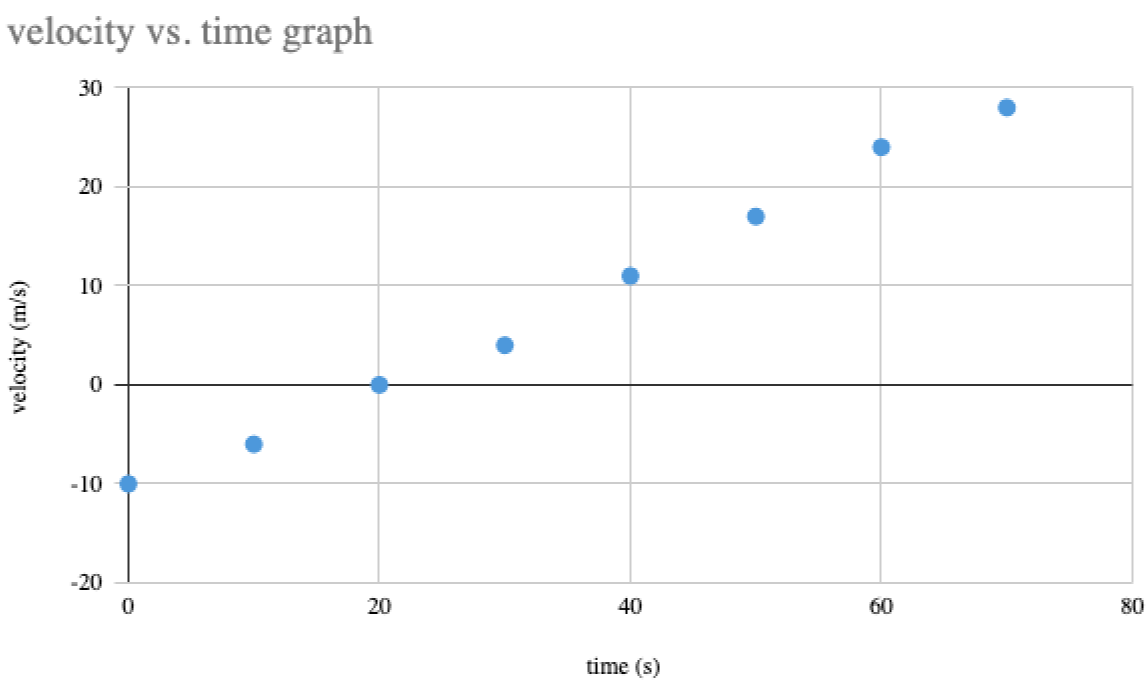
The acceleration vs. time graph represents the motion of a hockey player.



Use the graph to determine the change in velocity of the player from 2 to 16 s

Question 12

The velocity vs. time graph below was created with data from a virtual lab.



1. Use a ruler to draw a best fit line through the data.
2. Is the object speeding up, slowing down, or changing direction at each of the following times?

At 10 s, the object is ___________________________

At 20 s, the object is ___________________________

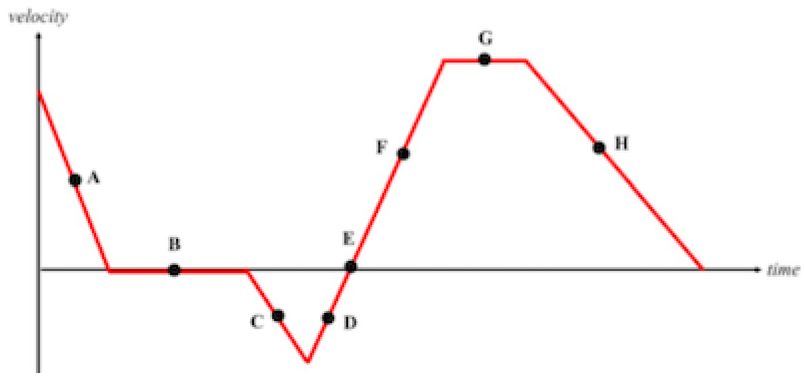
At 50 s, the object is ___________________________

3. Calculate the slope of the line and determine the appropriate units for the slope.On the graph,

circle the points on the best-fit line that were used to find the slope ____________________

4. What does the slope of the best fit straight line represent? ____________________

Question 13



The graph above represents the motion of a toy car. For each of the verbal descriptions below select the point or points at which the motion of the car matches the description.

1. At rest _________

2. Constant velocity in the positive direction _________

3. Positive velocity with positive acceleration _________

4. Positive velocity with negative acceleration _________

5. Negative velocity with positive acceleration _________

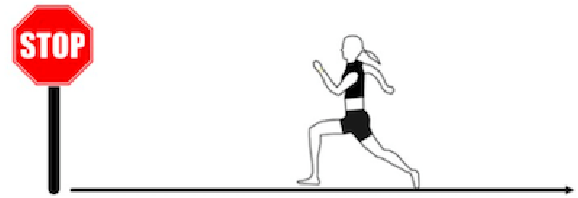
6. Negative velocity with negative acceleration _________

7. Zero velocity with positive acceleration _________

8. Zero velocity and negative acceleration _________

Question 14

A runner is moving to the left at 2.5 m/s approaching a stop sign 15 m away. The runner slows down at 0.3 m/s^2 and stops before she reaches the stop sign (which is considered to be at the origin).

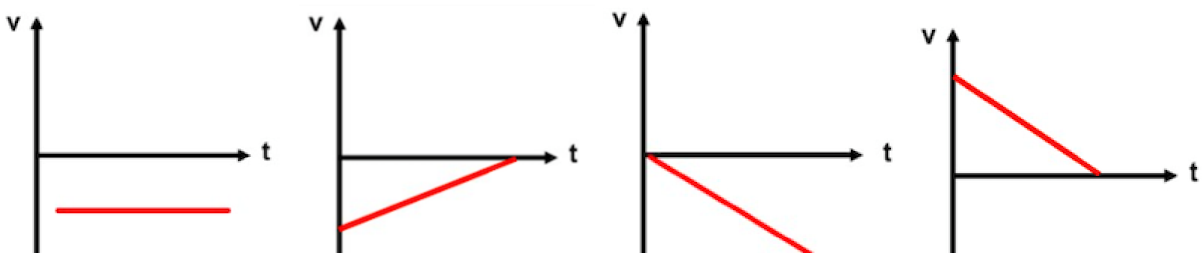


A student writes the data as follows: $t_0 = 0\,s\,;\ x_0 = +\ 15\,m\,;\ \ v_0 = -\ 2.5\,m/s\,;\ \ a = -\ 0.3\,m/s^2$

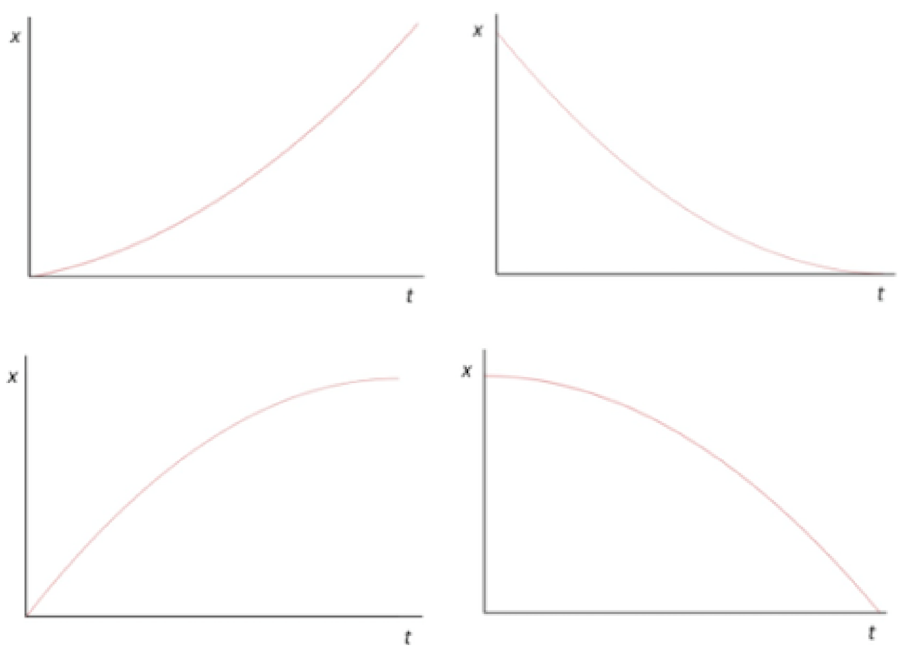
1. Which of the variables is incorrectly defined by the student?

(A) x_0 (B) v_0 (C) a (D) $a\ and\ v_0$

2. Which v-t graph best matches the motion of the runner?



3. Which x-t graph best matches the motion of the runner?



Question 15

A jet lands on an aircraft carrier at 63 m/s (226.8 km/h).

1. What is its acceleration (assumed constant) if it stops in 2.0 s due to an arresting cable that snags the airplane and brings it to a stop?

2. If the plane touches down at position $x_0 = 0$, what is the final position of the plane?

Question 16

A car traveling at a constant speed of 45.0 m/s passes a trooper hidden behind a billboard. One second after the speeding car passes the billboard, the trooper sets out from the billboard to catch it, accelerating at a constant rate of 3.00 m/s^2. How long does it take her to overtake the car?

Question 17

A ball is tossed straight up at 25 m/s. Estimate its velocity at 1-s intervals.

Question 18

A stone thrown from the top of a building is given an initial velocity of 20.0 m/s straight upward. The building is 50.0 m high, and the stone just misses the edge of the roof on its way down. Using $t = 0$ as the time the stone leaves the thrower's hand, determine

1. the time at which the stone reaches its maximum height
2. the maximum height
3. the time at which the stone returns to the height from which it was thrown
4. the velocity of the stone at this instant
5. the velocity and position of the stone at $t = 5.00\ s$

Question 19

A ladybug rests on a meter stick precisely at the 50.0 cm mark. She decides she wants a different view and walks on the meter stick until she reaches the 20.0 cm mark. She then turns immediately around and walks to the 30.0 cm mark where she decides to stay. What was the ladybug's displacement during this period?

(A) 20 cm (B) 40 cm (C) - 20 cm (D) - 40 cm

Question 20

A high school middle-distance athlete runs four and one-half times around the track during practice. Which of the following correctly describe the relationship between the distance the athlete runs and the athlete's displacement? There are two correct answers.

(A) the distance is larger than the magnitude of the displacement.

(B) the distance is exactly the same as the displacement.

(C) The displacement includes direction, but distance does not.

(D) The distance is a curved vector, but the displacement is a straight vector.

Part 2 - Dynamics

Question 1

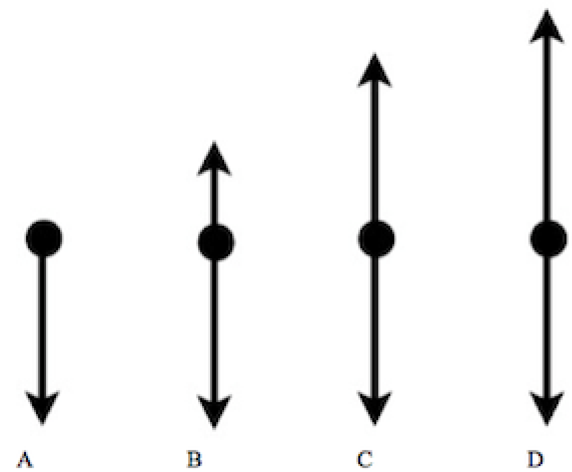
Consider dropping, from the same height above the earth surface, the following objects:
tennis ball, crumpled A4 paper, non-crumpled coffee filter, and a foam cup.

By analyzing the effect of the forces on the acceleration of the falling objects, you can notice the presence of two forces that are exerted on each object.

1. Which object, do you think, will fall with nearly zero acceleration?

(A) tennis ball (B) crumpled A4 paper (C) non-crumpled coffee filter (D) foam cup

2. For the object you have just selected, which of the following adjacent free body diagrams best represents the relative magnitude of the gravitational and air drag forces exerted on the object?



3. For the object that will fall with the greatest acceleration, how would the magnitudes of the gravitational force and the drag force compare for that object?

(A) air drag larger

(B) air drag a little smaller

(C) air drag half the size

(D) air drag negligible

4. Let F_{air} represent the magnitude of the drag force and F_{grav} represent the magnitude of the gravitational force. Taking up as the positive direction, from the free body diagrams above, the combination of the forces or the net force ΣF on any of the falling objects could be equal to which expression:

(A) $F_{air} + F_{grav}$ (B) $F_{air} - F_{grav}$ (C) $F_{grav} - F_{air}$ (D) F_{air} / F_{grav}

5. The general equation of Newton's second law can be written as

(A) $F_g = mg$ (B) $a = F_{net}/ m$ (C) $F_{net} = a/ m$ (D) $a = F_{net} \times m$

6. Our equation for the local gravitational force is

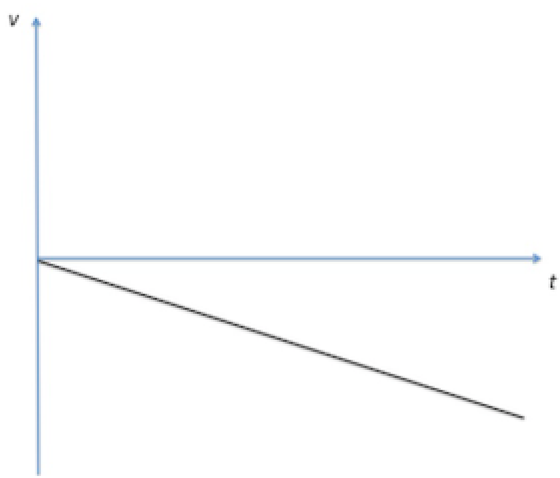
(A) $F_g = mg$ (B) $a = F_{net}/ m$ (C) $F_{net} = a/ m$ (D) $a = F_{net} \times m$

7. Using the correct equations in numbers 5 and 6 above and the expression for force due air resistance F_{air}, we can derive an equation to calculate the acceleration of an object as it falls through the air. Assuming up is the positive direction, this equation is:

(A) $a = m/ (mg)$ (B) $a = g$ (C) $a = m/ (F_{air} - mg)$ (D) $a = (F_{air} - mg)/m$

Question 2

The figure below shows the velocity vs. time graph for an object that is moving in a straight line along the x-axis.



Which of the following statements most correctly describes the net force on the object?

(A) the net force is constant and points in the +x direction.

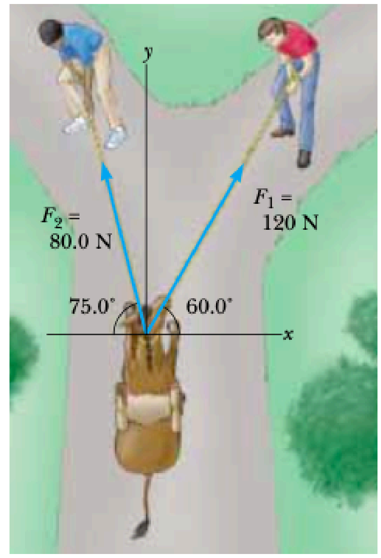
(B) the net force is constant and points in the -x direction.

(C) you cannot tell anything about the net force if you do not have an acceleration vs. time graph.

(D) the net force is decreasing over time

Question 3

The helicopter view in the adjacent figure shows two people pulling on a stubborn mule by two forces that are measured in newtons (N).



1. Which of the following represent true statements about the mule? Select two correct answers.

(A) the mule will remain stationary.

(B) the mule would experience a net force.

(C) the mule would accelerate.

(D) the mule would move with constant velocity.

2. Suppose F_1 in the adjacent figure was rotated so that it pointed in exactly the opposite direction as F_2. Assume F_2 is unchanged in direction and assume both forces are unchanged in magnitude.

How would rotating F_1 change the net force?

(A) it would change only the direction of the net force; its magnitude remains unchanged.

(B) it would change only the magnitude of the net force; its direction would remain unchanged.

(C) it would make the magnitude of the net force smaller since the forces will no longer be partially aligned.

(D) the net force would have a magnitude of zero since the forces are now pulling in opposite directions.

3. Suppose you know that two forces acting on the mule create a net force: i.e. $\mathbf{F}_{net} = \mathbf{F}_1 + \mathbf{F}_2$. How would you use this information to add another force, F_3, to the figure so that $\mathbf{F}_1 + \mathbf{F}_2 + \mathbf{F}_3$ yields a zero net force?

(A) $\mathbf{F}_3$ would need to have the same magnitude and direction as $\mathbf{F}_{net}$.

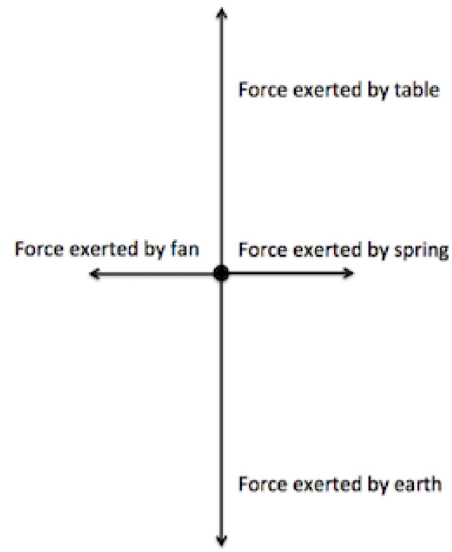
(B) $\mathbf{F}_3$ would need to have the same magnitude and opposite direction as $\mathbf{F}_{net}$.

(C) the only way to get a zero net force is to remove all forces.

(D) you must add two forces - one to counteract $\mathbf{F}_1$ and one to counteract $\mathbf{F}_2$.

Question 4

Suppose a system is defined as a laboratory cart and anything attached to or inside of it. The system is stationary on a horizontal and frictionless table being pulled one way by a horizontal spring scale and pushed the other way by a battery-operated fan. The free body diagram shown aside for the system illustrates forces exerted on it from the earth, table, fan, and spring.



Forces on the system

1. Now suppose mass is added to the system, but nothing else is changed. Which of the following correctly describe changes to the free body diagram made necessary by the introduction of the mass, assuming the cart remains stationary after the mass is added? Check ALL that apply.

(A) the vector representing the force by the fan would be longer.

(B) the vector representing the force by the spring scale would be longer.

(C) the vector representing the force by the earth would be longer.

(D) the vector representing the force by the table would be longer.

2. Now suppose the speed of the fan is increased, but nothing else is changed. Which of the following correctly describes changes to the free body diagram made necessary by the higher speed of the fan, assuming the cart remains stationary after the speed of the fan is increased? Check ALL that apply.

(A) the vector representing the force by the fan would be longer.

(B) the vector representing the force by the spring scale would be longer.

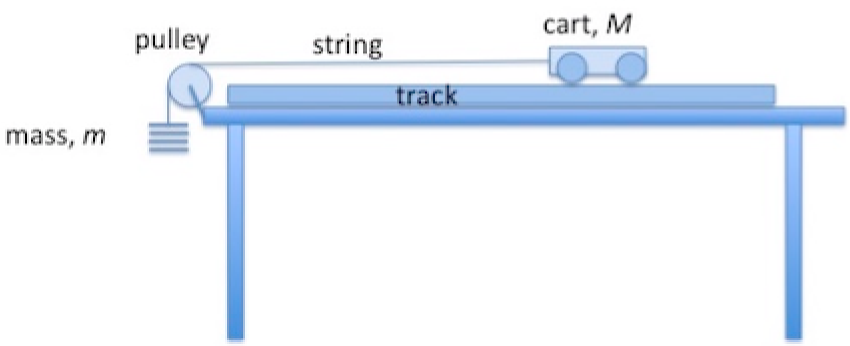
(C) the vector representing the force by the earth would be longer.

(D) the vector representing the force by the table would be longer.

Question 5

A student holds a cart of *mass M* stationary on a level track. The cart is attached to a string, which loops over a pulley of negligible mass and is attached to a hanging weight of *mass m* as shown below. Assume that the friction in the system is negligible. The student lets go of the cart, which then begins to accelerate.

Based on what you know about the forces, complete the paragraph below by selecting the appropriate words from the options provided.



There are ***(one; two; three; four)*** forces on the cart. The net force on the cart is due to the force exerted by the ***(earth; pulley; string; mass m)*** and is pointed ***(leftward; rightward; downward; upward)***. The acceleration of the cart is calculated by ***(adding; subtracting; multiplying; dividing)*** the net force on the cart by ***(M; m; g)***.

There are ***(one; two; three; four)*** forces exerted on the weight. The net force on the weight is pointed ***(leftward; rightward; downward; upward)***. The magnitude of the net force can be calculated by ***(adding; subtracting; multiplying; dividing)*** the acceleration by ***(M; m; g)***.

Question 6

complete the paragraph below by selecting the appropriate words from the options provided.

Suppose a system is defined as a stationary glass placed on a level table by a student. A correct free body diagram representing forces on the system (the glass) will have a downward vector representing a ***(normal; gravitational; tension; friction)*** force and an upward vector representing a ***(normal; gravitational; tension; friction)*** force. Because the glass is at rest with respect to the table, its acceleration is ***(constant; zero; unknown)***. Newton's ***(first; second; third)*** law implies that the forces in the free body diagram should be of equal ***(direction; magnitude)*** and opposite ***(direction; magnitude)***.

Newton's ***(first; second; third)*** law, which can be illustrated by a force diagram but not a free body diagram, can be used to describe the action-reaction pairs of forces between the glass and the ***(earth; table; student)*** and between the ***(earth; glass; student)*** and the table. For each action-reaction pair, the forces should be of ***(equal; unequal)*** magnitude and ***(opposite; same)*** direction.

The student accidently knocks the glass off the table. While the glass is falling, Newton's ***(first; second; third)*** law applies. The glass will experience a ***(zero; net; balanced)*** force, which can be used to predict the magnitude and direction of the glass's ***(speed; acceleration; mass)***.

Question 7

A monkey hangs by his two hands from a vine tied to the branch of a tree. Which of the following are examples of appropriate action-reaction pairs of forces pertaining to this situation? Select two answers.

(A) an upward force on the monkey by the vine and a downward force on the vine by the monkey.

(B) an upward force on the monkey by the vine and a downward force on the monkey by the earth.

(C) an upward force on the earth by the monkey and a downward force on the vine by the monkey.

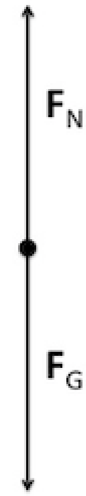
(D) an upward force on the earth by the monkey and a downward force on the monkey by the earth.

Question 8

A system consists of three objects: a car, a person seated in the car, and the earth. How many action-reaction pairs can you identify involving those three objects?

(A) two (B) three (C) five (D) six

Question 9



A student draws the following diagram to represent Newton's third law action-reaction pair of forces on a glass of water sitting on a table. The student intends $\mathbf{F_G}$ to represent the gravitational force and $\mathbf{F_N}$ to represent the normal force.

Which of the following statements offers the best analysis of the student's diagram? Select two answers.

(A) the normal force is a reaction force in response to the action force of gravity pulling the glass into the table.

(B) the figure illustrates an action-reaction pair because the forces have equal magnitude and opposite direction.

(C) the figure illustrates external forces on the glass and not an action-reaction pair.

(D) force diagrams for Newton's third law must illustrate two interacting objects and one type of force.

Question 10

You and your lab partner are seated in a stationary passenger train at a train station. The train's engine begins to pull the train from rest down the track, accelerating it at about 1.0 m/s^2. Your friend remarks that until the train reaches a constant velocity, Newton's Third Law does not apply, since the forward force the engine exerts on the passenger car must necessarily be larger than the backward force the passenger car exerts on the engine.

Which of the following answers most correctly addresses your lab partner's statement?

(A) your lab partner is correct. Newton's Third Law only applies for systems that are not accelerating.

(B) your lab partner is correct. Newton's Third Law only applies for systems that are completely stationary.

(C) your lab partner is incorrect. A corollary to Newton's Third Law provides for different force magnitudes during acceleration as long as the force directions are opposite.

(D) your lab partner is incorrect. The acceleration is due to other forces external to the engine-passenger car system.

Question 11

1. An object experiences no acceleration. Which of the following *cannot* be true for the object?
(A) A single force acts on the object.
(B) No forces act on the object.
(C) Forces act on the object, but the forces cancel.

2. An object experiences a net force and exhibits an acceleration in response. Which of the following statements is *always* true?
(A) The object moves in the direction of the force.
(B) The acceleration is in the same direction as the velocity.
(C) The acceleration is in the same direction as the force.
(D) The velocity of the object increases.

3. You push an object, initially at rest, across a frictionless floor with a constant force for a time interval Δt, resulting in a final speed of v for the object. You repeat the experiment, but with a force that is twice as large. What time interval is now required to reach the same final speed v?
(A) $4\Delta t$ (B) $2\Delta t$ (C) Δt (D) $\Delta t/2$ (E) $\Delta t/4$.

4. A baseball of mass m is thrown upward with some initial speed. A gravitational force is exerted on the ball
(A) at all points in its motion
(B) at all points in its motion except at the highest point
(C) at no points in its motion.

Question 12

1. If a fly collides with the windshield of a fast-moving bus, which object experiences an impact force with a larger magnitude?
(A) the fly (B) the bus (C) the same force is experienced by both.

2. If a fly collides with the windshield of a fast-moving bus, which object experiences the greater acceleration:
(A) the fly (B) the bus (C) the same acceleration is experienced by both.

3. Which of the following is the reaction force to the gravitational force acting on your body as you sit in your desk chair?

(A) The normal force ex- erted by the chair

(B) The force you exert downward on the seat of the chair

(C) Neither of these forces.

4. In a free-body diagram for a single object, you draw

(A) the forces acting on the object and the forces the object exerts on other objects, or

(B) only the forces acting on the object.

Question 13

Two blocks of masses m_1 and m_2, with $m_1 > m_2$, are placed in contact with each other on a frictionless, horizontal surface, as in figure below. A constant horizontal force F is applied to m_1 as shown.

(A) Suppose a system is defined as the two blocks together, m_1 and m_2. Draw the free body diagram of this system.

(B) Suppose a system is defined as block m_1 ONLY. Draw the free body diagram of this system.

(C) Suppose a system is defined as block m_2 ONLY. Draw the free body diagram of this system.

Question 14

The systems shown below are in equilibrium. Two objects, m_1 and m_2, are connected by a light string that passes over a frictionless pulley, as in figure 1 below, and one object (5.00 kg) is connected by a scale to a fixed wall, as in figure 2 below. Draw free-body diagrams of all objects, m_1, m_2 and 5.00 kg, assuming the inclined planes are frictionless.

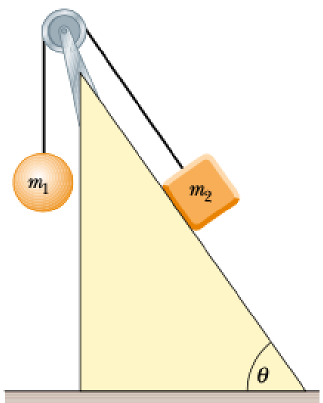


Figure 1

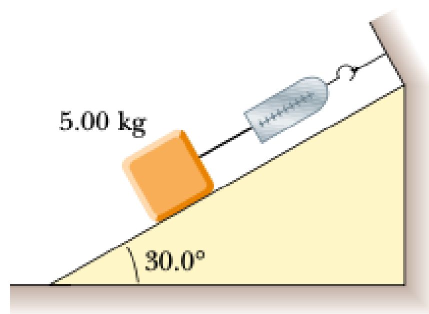


Figure 2

Question 15

A hockey puck on a frozen pond is given an initial speed of 20.0 m/s. If the puck always remains on the ice and slides 115 m before coming to rest, determine the coefficient of kinetic friction between the puck and ice.

Question 16

Two objects, A and B, move toward one another. Object A has twice the mass and half the speed of object B. Which of the following describes the forces the objects exert on each other when they collide and provides the best explanation?

(A) The force exerted by A on B will be twice as great as the force exerted by B on A, because A has twice the mass of B.

(B) The force exerted by A on B will be half as great as the force exerted by B on A, because A has half the speed of B.

(C) The forces exerted by each object on the other are the same, because the product of mass and speed is the same for both objects.

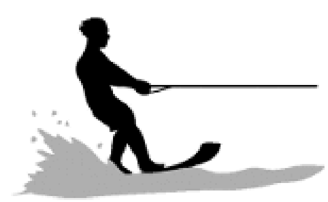
(D) The forces exerted by each object on the other are the same, because interacting objects cannot exert forces of different magnitude on each other.

- Which Newton's law supports your answer to the question above? ________________

Question 17

For the following question, <u>two</u> of the suggested answers will be correct. You must select both correct choices to earn credit. No partial credit will be earned if only one correct choice is selected.

A water-skier with weight $F_g = mg$ moves to the right with acceleration a. A horizontal tension force T is exerted on the skier by the rope, and a horizontal drag force F_d is exerted by the water on the ski. The water also exerts a vertical lift force L on the skier. Which of the following are correct relationships between the forces exerted on the skier-ski system? Select two answers.



(A) $T - F_d = ma$

(B) $L - F_g = ma$

(C) $L - F_g = 0$

(D) $T - F_d = 0$

Question 18

1. Express the joule, the unit of work, in terms of the base units of mass, length and time.

2. Newton's law of universal gravitation is represented by $F = G\frac{mM}{r^2}$

Here *F* is the magnitude of the gravitational force exerted by one object on another, *M* and *m* are the masses of the objects, and *r* is a distance.

What are the SI units of the proportionality constant *G*? Show your work