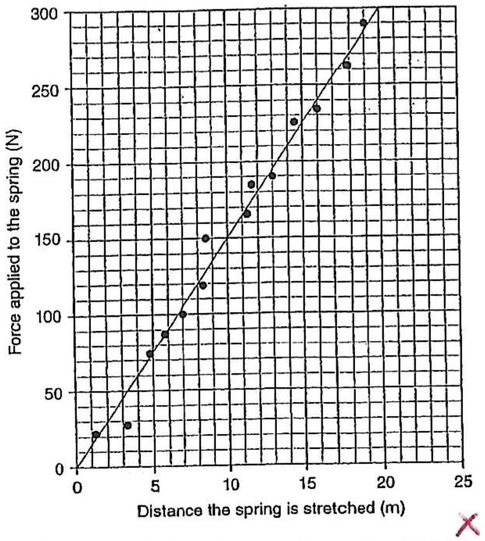
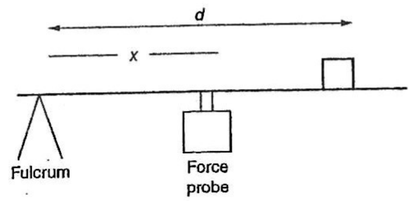


27. A force probe is used to stretch a spring by 20 cm. The graph of the force as a function of distance shown in the preceding figure is produced and used to determine the amount of work done in stretching the spring 20 cm. The experimenter reports the result as 3,000 J. Which of the following is a reasonable estimate of the experimental uncertainty on this measurement?

(A) 3,000 ± 3 J
(B) 3,000 ± 30 J
(C) 3,000 ± 300 J
(D) 3,000 ± 3,000 J

28. A string of fixed tension and linear mass density is attached to a vibrating speaker. It is observed that a speaker frequency of 60 Hz does not produce standing waves in the string. Which explanation for this phenomenon is correct?

(A) The string length is not a multiple of half the wavelength of the wave.
(B) The wave speed on the string is fixed.
(C) 60 Hz is in the lowest range of audible sound.
(D) The wavelength of the wave produced by the speaker is equal to the speed of waves on the string divided by 60 Hz.



29. In the laboratory, a long platform of negligible mass is free to rotate on a fulcrum. A force probe is placed a fixed distance x from the fulcrum, supporting the platform. An object of fixed mass is placed a variable distance d from the fulcrum. For each position d, the force probe is read. It is desired to determine the mass of the object from a graph of data. Which of the following can determine the object's mass?

(A) Plot the reading in the force probe times x on the vertical axis; plot the gravitational field times d on the horizontal axis. The mass is the slope of the line.
(B) Plot the reading in the force probe on the vertical axis; plot the distance d on the horizontal axis. The mass is the area under the graph.
(C) Plot the reading in the force probe on the vertical axis; plot the distance d multiplied by the distance x on the horizontal axis. The mass is the y-intercept of the graph.
(D) Plot the reading in the force probe times d on the vertical axis; plot the distance x on the horizontal axis. The mass is the slope of the line divided by the gravitational field.

30. In Collision A, two carts collide and bounce off each other. In Collision B, a ball sticks to a rigid rod, which begins to rotate about the combined center of mass. Which of the following statements about quantities in each collision is correct?

(A) Collision A: each cart experiences the same force, time of collision, and change in kinetic energy. Collision B: the ball and the rod each experience the same torque, time of collision, and change in rotational kinetic energy.

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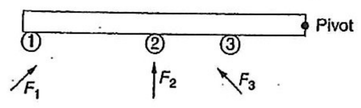
(B) Collision A: each cart experiences the same force, time of collision, and change in linear momentum. Collision B: the ball and the rod each experience the same torque, time of collision, and change in angular momentum.
(C) Collision A: each cart experiences the same force, time of collision, and change in kinetic energy. Collision B: the ball and the rod each experience the same torque, time of collision, and change in angular momentum.
(D) Collision A: each cart experiences the same force, time of collision, and change in velocity. Collision B: the ball and the rod each experience the same torque, time of collision, and change in angular velocity

31. It is known that a lab cart is moving east at 25 cm/s at time $t_1 = 0.10$ s, and then moving east at 15 cm/s at $t_2 = 0.20$ s. Is this enough information to determine the direction of the net force acting on the cart between t_1 and t_2?

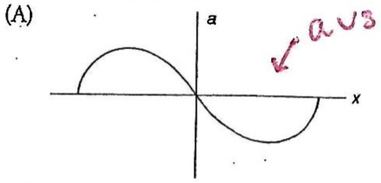
(A) Yes, since we know the cart is slowing down, its momentum change is opposite the direction of movement, and the net force is in the direction of momentum change.
(B) No, because we don't know whether forces such as friction or air resistance might be acting on the cart.
(C) No, because we don't know the mass of the cart.
(D) Yes, since we know the cart keeps moving to the east, the net force must be in the direction of motion.

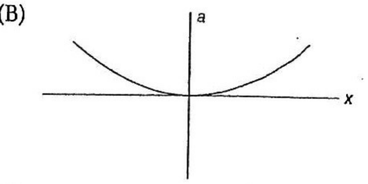


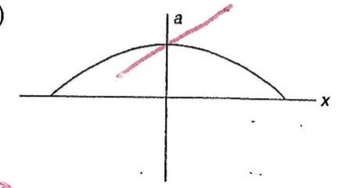
32. A rigid rod is pivoted at its right end. Three forces of identical magnitude but different directions are applied at the positions 1, 2, and 3 as shown. Which of the following correctly ranks the torques τ_1, τ_2, and τ_3 provided by the forces F_1, F_2, and F_3?

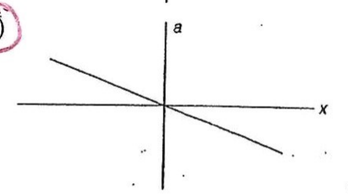
(A) $\tau_1 > \tau_2 > \tau_3$
(B) $\tau_3 > \tau_2 > \tau_1$
(C) $\tau_2 > \tau_1 > \tau_3$
(D) $\tau_2 > \tau_1 = \tau_3$

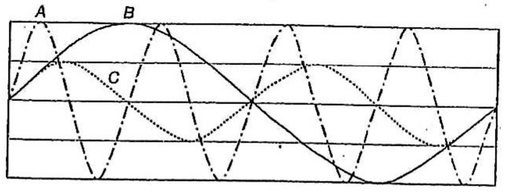
33. A block hanging vertically from a spring undergoes simple harmonic motion. Which of the following graphs could represent the acceleration a as a function of position x for this block, where $x = 0$ is the midpoint of the harmonic motion?

(A)


(B)


(C)


(D)




34. The preceding diagram represents a photograph of three transverse waves, each of which is moving to the right in the same material as the others. Which of the following ranks the waves by their amplitudes?

(A) A = B > C
(B) B > C > A
(C) A > C > B
(D) A = B ≠ C

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35. The mass of the Earth is 5.97×10^{24} kg. The Moon, whose center is 3.84×10^{8} m from the Earth's center, has mass 7.35×10^{22} kg. Which of the following is the best estimate of the gravitational force of the Earth on the Moon?

(A) 10^{39} N
(B) 10^{29} N
(C) 10^{19} N
(D) 10^{9} N

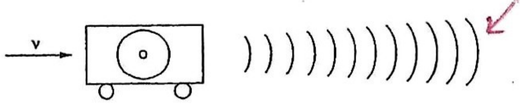
36. A children's toy consists of a cart whose very light wheels are attached to a rubber band. This rubber band can wind and unwind around the axle supporting the wheels.

This toy is given a shove, after which the toy rolls across a flat surface and up a ramp. It is observed that the toy does not go a consistent distance up the ramp—in some trials it ends up higher than in other trials, even though the shove imparts the same kinetic energy to the cart each time. Which of the following is a reasonable explanation for this phenomenon?

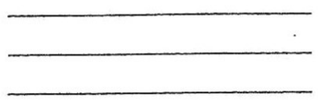
(A) Depending on how the rubber band is initially wound, more or less potential energy can be transferred from the rubber band to the kinetic energy of the car's motion.
(B) The normal force on the cart's wheels will be different depending on how much the rubber band winds or unwinds.
(C) How much energy is transferred from kinetic energy to gravitational potential energy depends on the vertical height at which the cart ends up.
(D) Some of the cart's initial kinetic energy will be dissipated due to work done by friction.

37. A man stands on a platform scale in an elevator. The elevator moves upward, speeding up. What is the action-reaction force pair to the man's weight?

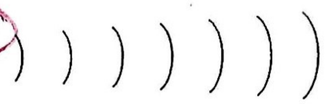
(A) The force of the elevator cable on the man
(B) The force of the man on the scale
(C) The force of the elevator cable on the elevator
(D) The force of the man on the Earth

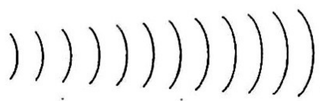


38. The preceding diagram shows a speaker mounted on a cart that moves to the right at constant speed v. Wave fronts for the constant-frequency sound wave produced by the speaker are indicated schematically in the diagram. Which of the following could represent the wave fronts produced by the stationary speaker playing the same note?

(A)


(B)


(C)


(D)


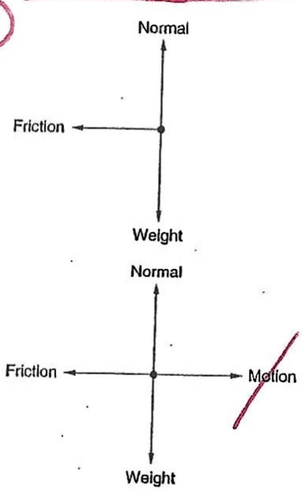
39. A table supports a wooden block placed on the tabletop. Which fundamental force of nature is responsible for this interaction, and why?

(A) The electric force, because the protons in the nuclei of the top atomic layer of the table repel the nuclei in the bottom atomic layer of the wood.
(B) The gravitational force, because by $F = GMm/r^2$, the force of the table on the wood at that close range is sufficient to balance the force of the Earth on the wood.
(C) The electric force, because the outer electrons in the top atomic layer of the table repel the outer electrons in the bottom atomic layer of the wood.
(D) The strong nuclear force, because the protons in the nuclei of the top atomic layer of the table repel the nuclei in the bottom atomic layer of the wood.

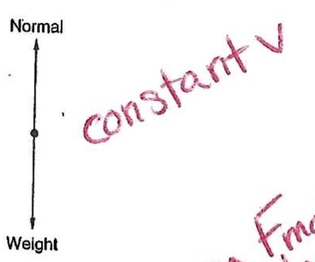
40. A solid sphere ($I = 0.06$ kg·m²) spins freely around an axis through its center at an angular speed of 20 rad/s. It is desired to bring the sphere to rest by applying a friction force of magnitude 2.0 N to the sphere's outer surface, a distance of 0.30 m from the sphere's center. How much time will it take the sphere to come to rest?

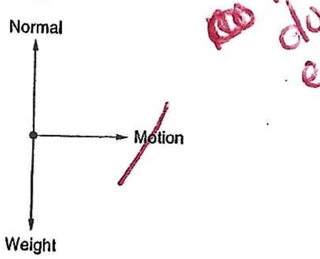
(A) 4 s
(B) 2 s
(C) 0.06 s
(D) 0.03 s

41. Which of the following force diagrams could represent the forces acting on a block that slides to the right while slowing down?

(A)


(B)

(C)


(D)


42. Standing waves are produced by a 100-Hz generator in a string of fixed length. The tension in the string is increased until a new set of standing waves is produced. Will the wavelength of the new standing waves be greater than or less than the wavelength of the original standing waves?

(A) Less, because the tension in the string varies directly with the wave speed, which varies inversely with the wavelength.
(B) Greater, because the tension in the string varies directly with the wave speed, which varies inversely with the wavelength.
(C) Greater, because the tension in the string varies directly with the wave speed, which varies inversely with the wavelength.
(D) Less, because the tension in the string varies directly with the wave speed, which varies inversely with the wavelength.

43. Two electrically charged balls are separated by a short distance, producing a force of 50 μN between them. Keeping the charge of each ball the same, the mass of one of the balls but not the other is doubled. What is the new electric force between the balls?

(A) 50 μN
(B) 100 μN
(C) 200 μN
(D) 400 μN

44. A block of mass m is attached to a spring of force constant k. The mass is stretched a distance A from equilibrium and released from rest. At a distance x from the equilibrium position, which of the following represents the kinetic energy of the block?

(A) $\frac{1}{2}kA^2 - \frac{1}{2}kx^2$
(B) $\frac{1}{2}mA\sqrt{k/m}^2$
(C) $\frac{1}{2}kA^2 + \frac{1}{2}kx^2$
(D) $\frac{1}{2}kx^2$

45. A man with his hands to his sides on a frictionless platform that is rotating. Which of the following could change the angular momentum of the man-platform system?

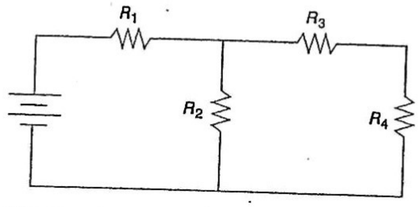
(A) The man catches a baseball thrown to him by a friend.
(B) The man thrusts his arms out away from his body
(C) The man thrusts his arms out away from his body, and then quickly brings his arms back to his side again.
(D) The man jumps straight up in the air and lands back on the platform.

Questions 46–50: Multiple-Correct Items

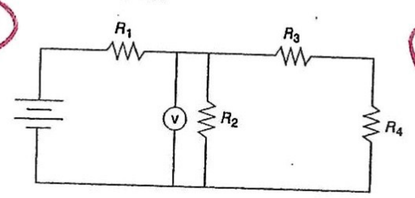
Directions: Identify ***exactly two*** of the four answer choices as correct and grid the answers with a pencil on the answer sheet. No partial credit is awarded; both of the correct choices, and none of the incorrect choices, must be marked for credit.

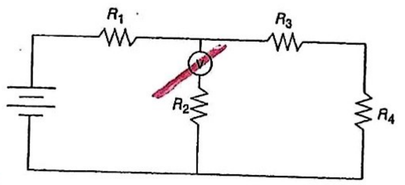
46. The distance between the centers of two objects is d. Each object has identical mass m and identical charge $-q$. Choose all of the correct statements about the similarities and differences between the electric and gravitational force between the two objects. Choose two answers.

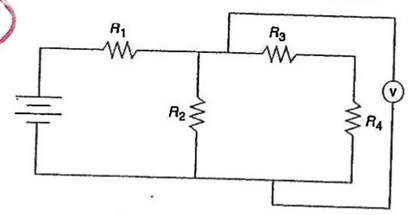
(A) Both the electric and the gravitational force depend inversely on the square of the distance d.
(B) Just as the gravitational force depends on the sum of the two masses m and m, the electric force depends on the sum of the two charges $-q$ and $-q$.
(C) For any measureable m and q in the laboratory, the electric force is many orders of magnitude larger than the gravitational force.
(D) Both the electric and gravitational forces are attractive.

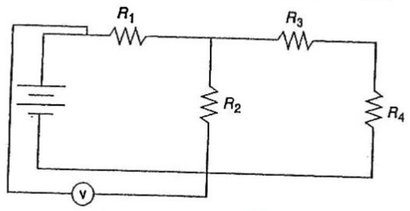


47. Which placement of voltmeters will allow for determination of the voltage across resistor R_2 in the circuit diagrammed in the preceding figure? Choose two answers.

(A)


(B)


(C)


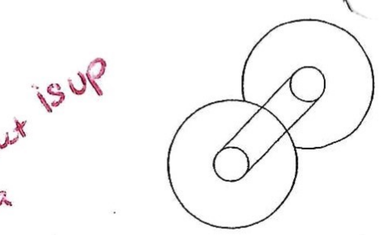
(D)


48. A student of mass 50 kg stands on a scale in an elevator. The scale reads 800 N. Which of the following could describe how the elevator is moving? Choose two answers.

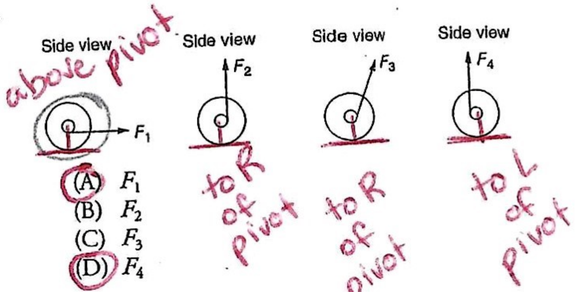
(A) Moving downward and slowing down
(B) Moving downward and speeding up
(C) Moving upward and speeding up
(D) Moving upward and slowing down

49. A 1-m-long pipe is closed at one end. The speed of sound in the pipe is 300 m/s. Which of the following frequencies will resonate in the pipe? Choose two answers.

(A) 75 Hz
(B) 150 Hz
(C) 225 Hz
(D) 300 Hz



50. The device shown in the preceding figure consists of two wheels connected by a thick axle. A force can be applied to the axle by pulling a rope at several positions along the axle. Which of the pictured applied forces would cause forward rotation of the device's wheels? Choose two answers.



(A) F_1
(B) F_2
(C) F_3
(D) F_4