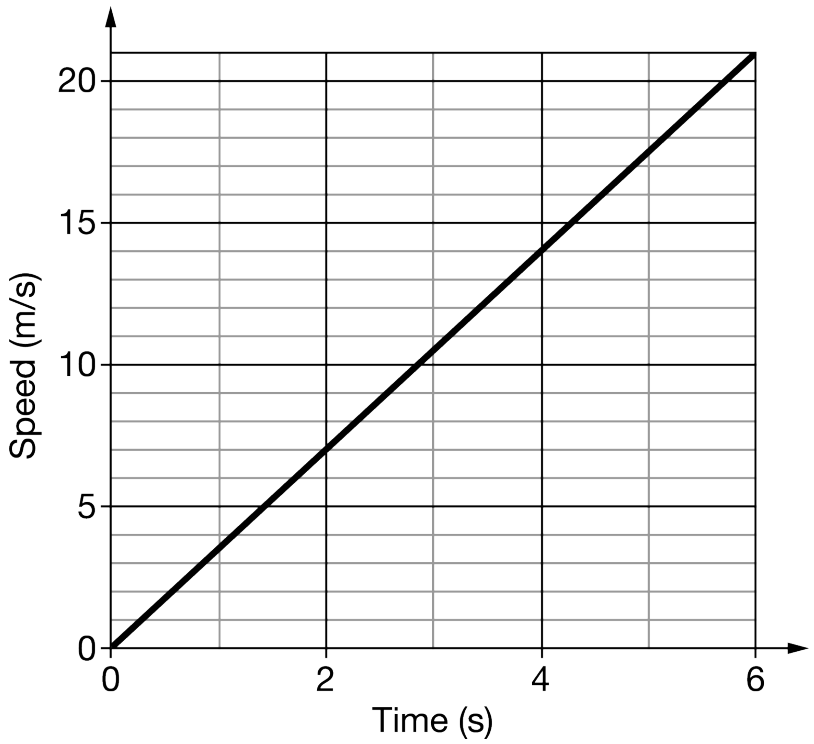
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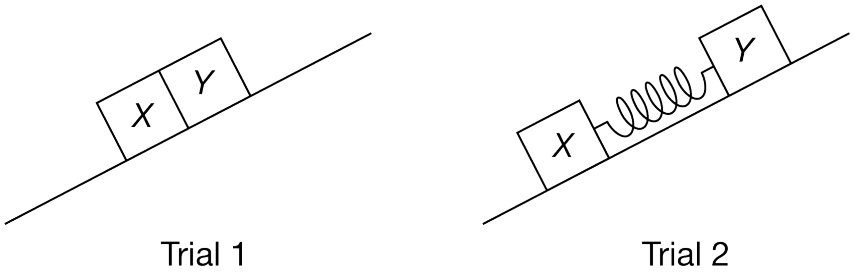
1.



An object of mass $10\ \text{kg}$ is released from rest above the surface of a planet such that the object's speed as a function of time is shown by the graph above. The force due to gravity exerted on the object is most nearly

(A) $3.5\ \text{N}$
(B) $7\ \text{N}$
(C) $35\ \text{N}$
(D) $70\ \text{N}$

2.



Blocks X and Y are glued together and released from rest on a ramp with negligible friction, as shown in trial 1. The blocks are then separated and connected by a light spring, as shown in trial 2. The spring is compressed and the blocks are again released from rest on the ramp. Immediately after the blocks are released, is the net force on the two-block system the same or different between trial 1 and trial 2? Immediately after the blocks are released, is the net force on block Y the same or different between trial 1 and trial 2?

chapter2

(A)

Force on System	Force on Block Y
Different	Different

(B)

Force on System	Force on Block Y
Different	The same

(C)

Force on System	Force on Block Y
The same	Different

(D)

Force on System	Force on Block Y
The same	The same

chapter2

3.

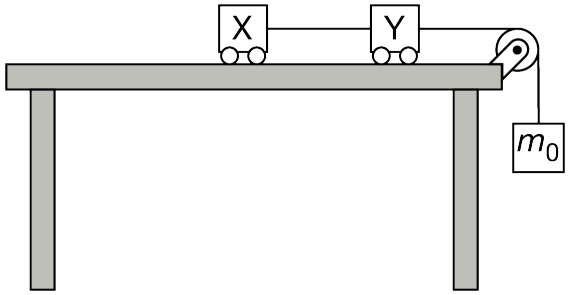


Figure 1

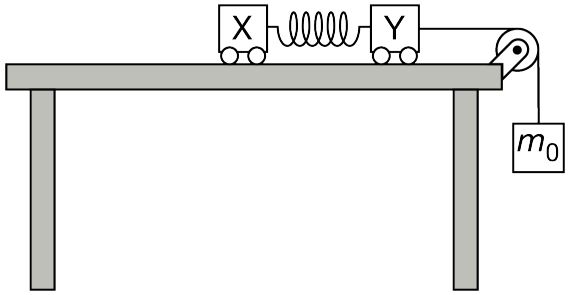


Figure 2

In Figure 1, cart Y is connected to cart X by a tight string and is also connected to the hanging block of mass m_0 by a light string that passes over a pulley. Figure 2 shows a system that is identical except for one change: cart Y and X are connected by a spring at its equilibrium length. Both systems are released from rest. Is the hanging block's acceleration as a function of time the same in both systems, and why or why not?

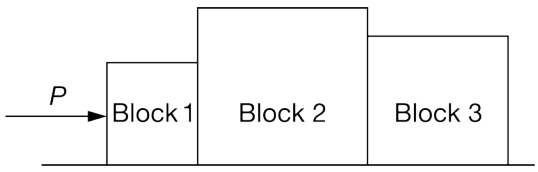
(A) Yes, because the net external force exerted on both systems is the same.

(B) Yes, because the tension in the string connecting the block to cart Y is determined by the masses of cart Y and the block.

(C) No, because the net external force exerted on each system is different.

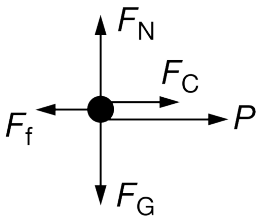
(D) No, because the tension in the string connected to the block is constant in one system but not in the other.

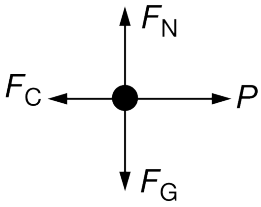
4.

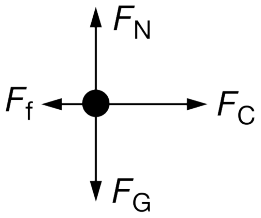


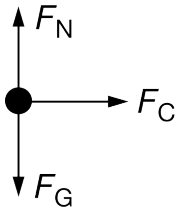
Three blocks are pushed along a rough surface by a force with magnitude P, as shown above. F_{C} is the magnitude of the contact force between blocks 2 and 3, and F_{f}, F_{N}, and F_{G} are the magnitudes of the friction, normal, and gravitational forces on block 3, respectively. Which of the following is a correct free-body diagram for block 3?

chapter2

(A) 

(B) 

(C) 

(D) 

5. A block moving to the right on a level surface with friction is pulled by an increasing horizontal force also directed to the right. As the applied force increases, which of the following is true of the normal force and the frictional force on the block?

chapter2

(A)

Normal Force	Frictional Force
Increases	Increases

(B)

Normal Force	Frictional Force
Increases	Remains constant

(C)

Normal Force	Frictional Force
Remains constant	Increases

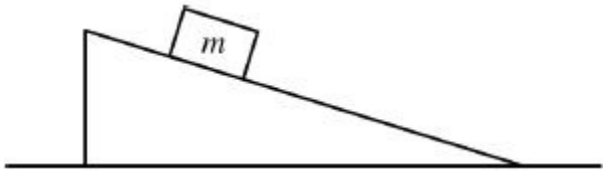
(D)

Normal Force	Frictional Force
Remains constant	Decreases

(E)

Normal Force	Frictional Force
Remains constant	Remains constant

6. Directions: For the question or incomplete statement below, two of the suggested answers are correct. For this question, you must select both correct choices to earn credit. No partial credit will be earned if only one correct choice is selected. Select the two that are best in each case.



A block of mass m is at rest on a rough incline, as shown in the figure above. Which of the following forces must have a magnitude equal to mg ? Select two answers.

chapter2

A The total force exerted on the block by the incline

B The normal force exerted on the block by the incline

C The force of friction exerted on the block by the incline

D The gravitational force exerted on Earth by the block

7. A toy doll and a toy robot are standing on a frictionless surface facing each other. The doll has a mass of $0.20\ \text{kg}$, and the robot has a mass of $0.30\ \text{kg}$. The robot pushes on the doll with a force of $0.30\ \text{N}$. The magnitude of the acceleration of the robot is

(A) zero

(B) $0.60\ \text{m/s}^2$

(C) $1.0\ \text{m/s}^2$

(D) $1.5\ \text{m/s}^2$

8. A ladder at rest is leaning against a wall at an angle. Which of the following forces must have the same magnitude as the frictional force exerted on the ladder by the floor?

(A) The force of gravity on the ladder

(B) The normal force exerted on the ladder by the floor

(C) The frictional force exerted on the ladder by the wall

(D) The normal force exerted on the ladder by the wall

9. A vehicle lands on Mars and explores its surface. The average gravitational field on the surface of Mars is 3.7 N kg . The weight of the vehicle is defined as the gravitational force exerted on it. Which of the following statements are true about the vehicle's weight? Select two answers.

A The vehicle's weight was constant until it reached the surface of Mars.

B The vehicle's weight increased while it was descending to the surface of Mars.

C The vehicle's weight always equals the normal force exerted by Mars on the vehicle while it is landing.

D The vehicle weighs less on the surface of Mars than on the surface of Earth.

10. An object starts from rest and slides with negligible friction down an air track tipped at an angle θ from the horizontal. A student records values of the object's position along the track at various times. The value of θ can best be determined from which of the following?

(A) The y-intercept of a graph of position as a function of time

(B) The y-intercept of a graph of position as a function of the square of time

(C) The slope of a graph of position as a function of time

(D) The slope of a graph of position as a function of the square of time

11. A person is running on a track. Which of the following forces propels the runner forward?

chapter2

(A) The normal force exerted by the ground on the person

(B) The normal force exerted by the person on the ground

(C) The force of friction exerted by the ground on the person

(D) The force of friction exerted by the person on the ground

12. An astronaut in deep space is at rest relative to a nearby space station. The astronaut needs to return to the space station. A student makes the following claim: "The astronaut should position her feet pointing away from the space station. Then, she should repeatedly move her feet in the opposite direction to each other. This action will propel the astronaut toward the space station." Is the student's claim correct? Justify your selection.

(A) Yes. The astronaut's feet exert a force away from the space station, creating an equal and opposite force that will accelerate the astronaut toward the space station.

(B) Yes. The astronaut's feet will have a velocity that is transferred to her center of mass, accelerating the astronaut toward the space station.

(C) No. The astronaut's feet are not exerting a force on another object, so there is no external force to accelerate the astronaut toward the space station.

(D) No. The astronaut would move away from the space station, not toward it, since her feet are pointed away from the space station.

13. A student wants to determine the coefficient of static friction μ between a block of wood and an adjustable inclined plane. Of the following, the minimum additional equipment the student needs to determine a value for μ is

(A) protractor only

(B) timer only

(C) protractor and timer

(D) meterstick and timer

(E) meterstick and string

14.

	Cart 1	**Cart 2**
Mass	$1\ \text{kg}$	$0.5\ \text{kg}$
Average force	$30\ \text{N}$	F_2
Average acceleration	$30\ \text{m/s}^2$	a_2

The incomplete data in the table above were recorded during an experiment in which two carts on a frictionless one-dimensional track collided head-on. What are the magnitudes of the average force F_2 exerted on cart 2 and the average acceleration a_2 of cart 2 during the collision?

chapter2

(A)

F_2	a_2
$15\ \text{N}$	$15\ \text{m/s}^2$

(B)

F_2	a_2
$30\ \text{N}$	$30\ \text{m/s}^2$

(C)

F_2	a_2
$30\ \text{N}$	$60\ \text{m/s}^2$

(D)

F_2	a_2
$60\ \text{N}$	$60\ \text{m/s}^2$

15. A tennis ball is thrown against a vertical concrete wall that is fixed to the ground. The ball bounces off the wall. How does the force exerted by the ball on the wall compare with the force exerted by the wall on the ball?

(A) The force exerted by the ball is greater.

(B) The forces exerted by the ball and the wall have the same magnitude.

(C) The force exerted by the ball is smaller.

(D) The relative magnitudes of the forces cannot be determined without knowing how long the ball and the wall are in contact.

16. A ball is moved from Earth to a planet that has a gravitational acceleration that is double that of Earth. How does the gravitational force on the ball when it is on the new planet compare to the gravitational force on the ball when it is on Earth?

(A) The gravitational force on the ball when it is on the new planet is double the force on the ball when it is on Earth.

(B) The gravitational force on the ball when it is on the new planet is half the force on the ball when it is on Earth.

(C) The gravitational force on the ball when it is on the new planet is the same as the force on the ball when it is on Earth.

(D) The gravitational force on the ball when it is on the new planet is one-fourth the force on the ball when it is on Earth.

chapter2

17. In one experiment, a student rolls a 2 kg ball such that it collides with a wall with a force of 10,000 N. In a second experiment, the student rolls a 5 kg ball such that it collides with the wall at a force of 5000 N. In both experiments, the balls bounce back from the wall and eventually come to rest. Which of the following statements is true regarding the force that the wall exerts on each ball?

(A) The wall exerts the same force on both balls since they both bounce back from the same wall in both experiments.

(B) The wall exerts a greater force on the 5 kg ball than on the 2 kg ball since a greater force is required to cause the heavier ball to bounce back from the wall.

(C) The wall exerts a greater force on the 2 kg ball than on the 5 kg ball since the force from the wall on each ball is equal to the force that each ball exerts on the wall.

(D) The answer cannot be determined without knowing the distance each ball rolls before coming to rest.

18. Block *A* and block *B* move toward each other on a level frictionless track. Block *A* has mass *m* and velocity $+v$. Block *B* has mass $2m$ and velocity $-v$. The blocks collide, and during the collision the magnitude of the net force exerted on block *A* is *F*. What is the magnitude of the net force exerted on block *B*, and why does it have that value?

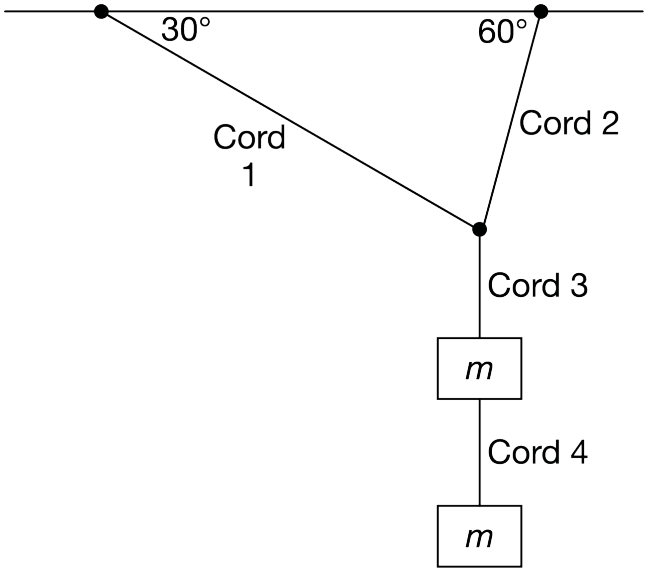
(A) $2F$, because the mass of block *B* is twice that of block *A* and the blocks have the same acceleration during the collision.

(B) $F/2$, because the mass of block *B* is twice that of block *A* and the blocks have the same acceleration during the collision.

(C) *F*, because the blocks have the same speed immediately before the collision.

(D) *F*, because the net force is equal to the mutual contact force between the blocks.

19.



The system shown above consists of two identical blocks that are suspended using four cords, each of a different length. Which of the following claims are true about the magnitudes of the tensions in the cords? Select two answers.

chapter2

A $T_1 > T_2$

B $T_1 \cos 30^\circ = T_2 \cos 60^\circ$

C $T_3 > T_4$

D $T_1 + T_2 = T_3$

20. On Earth, when a box slides across a horizontal board, the board exerts a frictional force of magnitude F_0 on the box. The board and the box are moved to a planet with twice the radius but one-third the mass of Earth. When the box slides across the board, the frictional force exerted by the board on the box is now

(A) $\frac{1}{12}F_0$

(B) $\frac{1}{6}F_0$

(C) $\frac{2}{3}F_0$

(D) F_0

21. A cart with an unknown mass is at rest on one side of a track. A student must find the mass of the cart by using Newton's second law. The student attaches a force probe to the cart and pulls it while keeping the force constant. A motion detector rests on the opposite end of the track to record the acceleration of the cart as it is pulled. The student uses the measured force and acceleration values and determines that the cart's mass is $0.4\ \text{kg}$. When placed on a balance, the cart's mass is found to be $0.5\ \text{kg}$. Which of the following could explain the difference in mass?

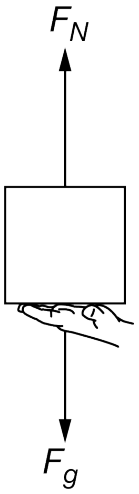
(A) The track was not level and was tilted slightly downward.

(B) The student did not pull the cart with a force parallel to the track.

(C) The wheels contain bearings that were rough and caused a significant amount of friction.

(D) The motion sensor setting was incorrect. The student set it up so that motion away from the sensor would be the negative direction.

22.



The diagram above represents the forces exerted on a box that a child is holding. F_N represents the force applied by the child's hand, and F_g represents the weight of the box. The child begins to raise the box with increasing speed. Which of the following claims is correct about force F_h that is exerted by the box on the child's hand as the box is being raised?

chapter2

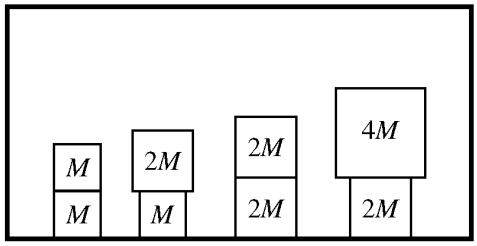
(A) $F_h = F_N$, where F_N does not change as the child raises the box.

(B) $F_h = F_N$, where F_N is larger as the box is being raised than when it was being held.

(C) $F_h = F_g$, where F_g does not change as the child raises the box.

(D) $F_h = F_g$, where F_g is larger as the box is being raised than when it was being held.

Refer to the following material to answer the questions.



The stacks of boxes shown in the figure above are inside an elevator that is moving upward. The masses of the boxes are given in terms of the mass *M* of the lightest box.

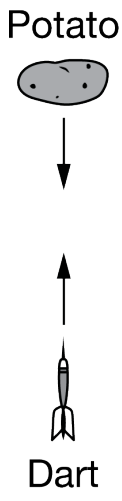
23. How does the magnitude of the force exerted by the top box on the bottom box compare with the magnitude of the force exerted by the bottom box on the top box for each of the stacks?

(A) The two magnitudes are always equal in each of the stacks.

(B) The two magnitudes are always different in each of the stacks.

(C) The two magnitudes are equal when the boxes have equal mass and different when the boxes have different masses.

(D) The two magnitudes are equal when the elevator is moving at constant speed and different when it is accelerating.



A potato falling vertically downward is struck by a dart that is traveling vertically upward, as shown above. The dart and potato then collide, stick together, and continue moving after the collision.

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chapter2

24. The weight of the dart is W. Which of the following claims best describes the magnitude of the net force on the dart immediately before, during, and immediately after the collision with the potato?

(A) It is equal to W just before the collision, and greater than W during and just after the collision.

(B) It is equal to W just before the collision, greater than W during the collision, and equal to W again after the collision.

(C) It is equal to W just before and during the collision, and greater than W just after the collision.

(D) It is equal to W just before, during, and just after the collision.

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25. 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?

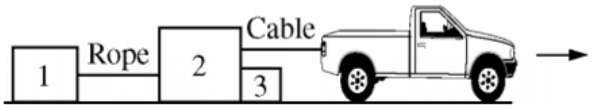
(A) The force exerted by A on B will be twice as great as the force exerted by B on A, because A has twice the mass of B.

(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.

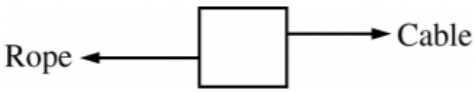
(C) The forces exerted by each object on the other are the same, because the product of mass and speed is the same for both objects.

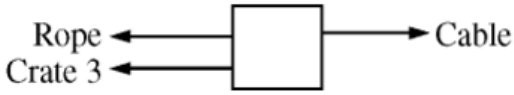
(D) The forces exerted by each object on the other are the same, because interacting objects cannot exert forces of different magnitude on each other.

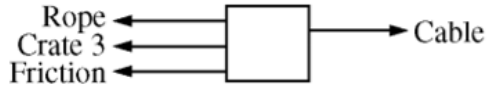
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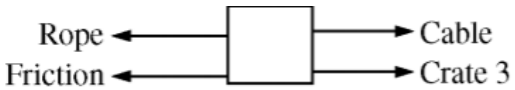


The figure above shows a truck pulling three crates across a rough road. Which of the following shows the directions of all the horizontal forces acting on crate 2 ?

(A)


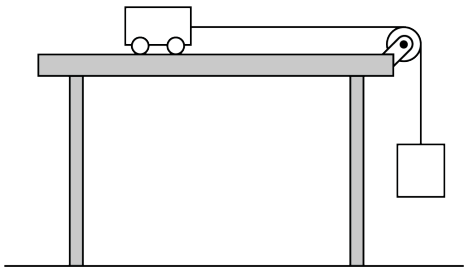
(B)


(C)


(D)


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chapter2



Students work together during an experiment about Newton's laws. The students use a setup that consists of a cart of known mass connected to one end of a string that is looped over a pulley of negligible friction, with its other end connected to a hanging mass. The cart is initially at rest on a horizontal surface and rolls without slipping when released. The inertia of the cart's wheels is negligible. Students have access to common laboratory equipment to make measurements of components of the system.

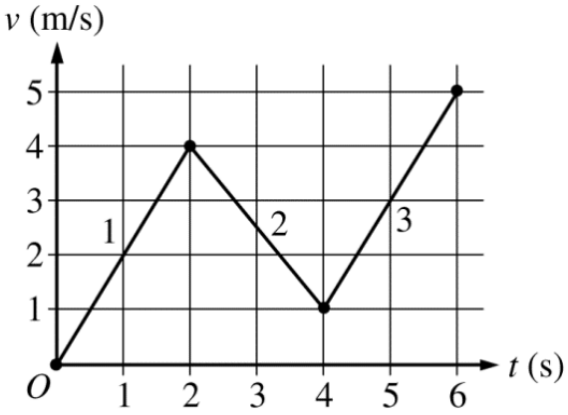
27. The students double the mass that hangs from the string. They also replace the original cart with a new cart that has double the mass. By doubling both masses, how will the tension in the string and the acceleration of the cart change?

(A) The tension and the acceleration will double.

(B) The tension will double, but the acceleration will stay the same.

(C) The tension will stay the same, but the acceleration will double.

(D) The tension and the acceleration will stay the same.



The graph above shows velocity v as a function of time t for a 0.50 kg object traveling along a straight line. The graph has three segments labeled 1, 2, and 3. A rope exerts a constant force of magnitude F_T on the object along its direction of motion the whole time. During segment 2 only, a frictional force of magnitude F_f is also exerted on the object.

28. Which of the following expressions correctly relates the magnitudes F_f and F_T?

chapter2

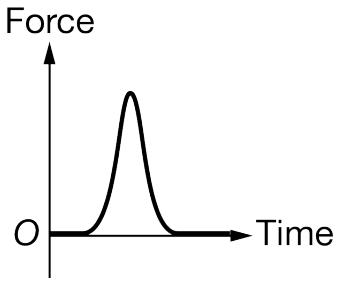
(A) $F_f < F_T$

(B) $F_f = F_T$

(C) $F_T < F_f < 2F_T$

(D) $F_f = 2F_T$

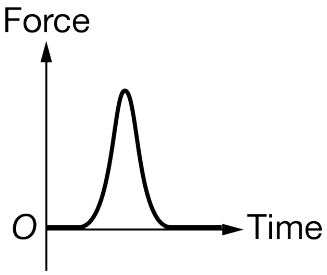
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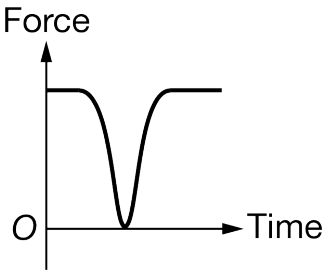
The graph shows the force exerted on a ball by the floor as a function of time as the ball bounces off the floor. If the positive direction is upward, which of the following graphs could represent the force exerted on the floor by the ball?

chapter2

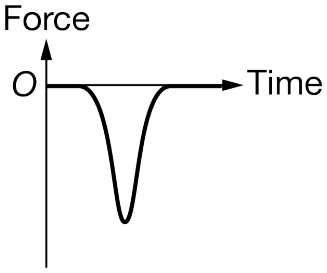
(A)



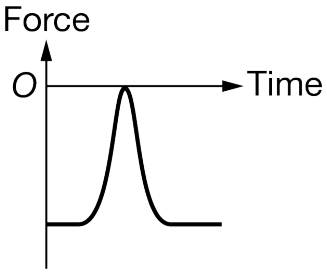
(B)



(C)



(D)



30. A ball is dropped onto the floor and bounces upward. Which of the following claims are correct about the force that the ball exerts on the floor compared to the force that the floor exerts on the ball when the ball and the floor are in contact?

(A) The ball exerts a greater force on the floor because the ball travels with a high speed, whereas the floor is at rest.

(B) The ball exerts a greater force on the floor because the ball is accelerating.

(C) The magnitude of the forces exerted by both objects is the same because the ball and the floor cannot exert forces of different magnitudes on each other.

(D) The magnitude of the forces exerted by both objects is the same because the gravitational force exerted by the ball on the floor and the gravitational force exerted on the floor by the ball must be the same.

chapter2



Figure 1



Figure 2

Note: Figures not drawn to scale.

The figures above show a small block of mass $0.20\ \text{kg}$ on a track in the shape of a circular arc. The block is released from rest at a height H above the floor, as shown in Figure 1. The block slides along the track with negligible friction and leaves it at a height of $0.40\ \text{m}$ above the floor and a speed of $3.0\ \text{m/s}$ at a 30° angle, as shown in Figure 2.

31. The magnitude of the gravitational force exerted on the block is F_g, and the magnitude of the normal force exerted by the track on the block is F_n. Which of the following correctly compares the magnitudes of these two forces when the block is at the lowest point on the track?

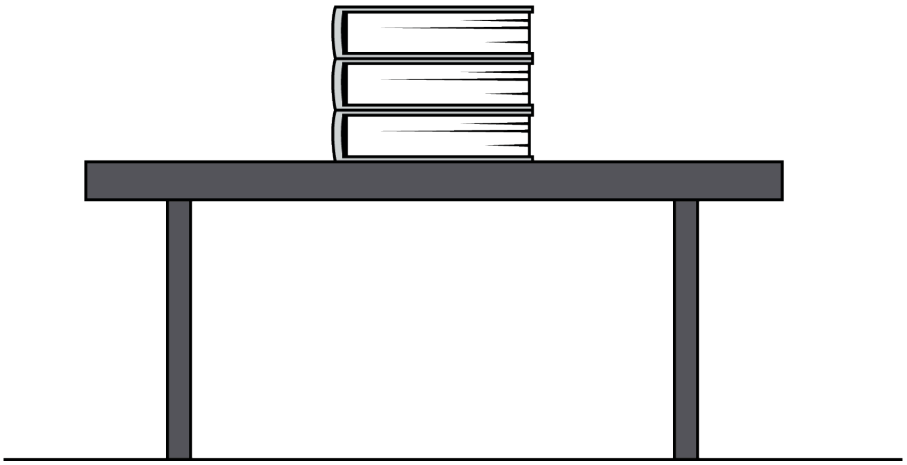
(A) $F_n > F_g$

(B) $F_n = F_g$

(C) $F_n < F_g$

(D) The magnitudes cannot be compared without knowing the radius of the arc of the track.

32.



Two identical books are stacked on a table. A third identical book is then placed on top of the first two, causing an increase in the normal force exerted by the bottom book on the middle book. Which of the following is a correct explanation for the increase in this normal force?

chapter2

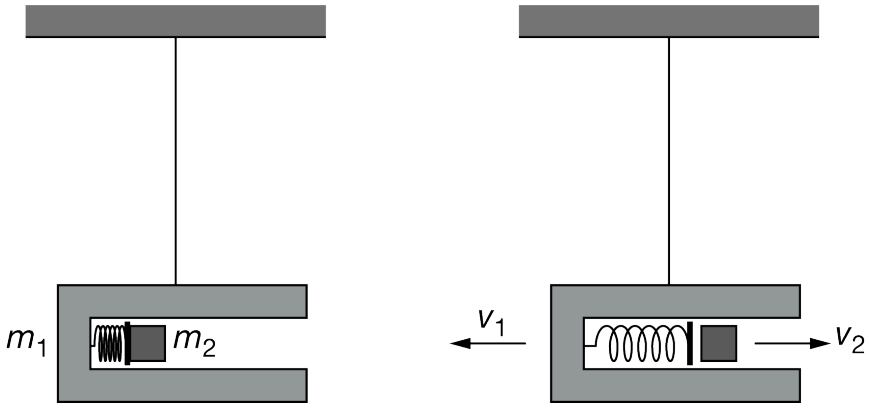
(A) The normal force on an object is equal in magnitude and opposite in direction to the force of gravity on that object.

(B) The addition of the top book causes the force of gravity on the table to increase.

(C) The forces of gravity on the bottom book and middle book increase because of the additional mass of the top book.

(D) The third book produces an additional downward force on the middle book, thus increasing the upward force exerted by the bottom book to maintain equilibrium.

33.



A launcher with mass m_1 is suspended from the ceiling by a string, as shown. A block with mass $m_2 < m_1$ is launched horizontally. At the moment of launch, the block has unknown speed v_2 and the launcher has unknown speed v_1 in the opposite direction. Which of the following is a true statement about the forces exerted between the launcher and block?

(A) The launcher exerts a greater force on the block than the block exerts on the launcher.

(B) The block exerts a greater force on the launcher than the launcher exerts on the block.

(C) The block and the launcher exert forces of equal magnitude on each other.

(D) The relative magnitude of the force exerted on the spring by the block and launcher cannot be determined without knowing v_1 and v_2.

34. A person stands in an elevator. The elevator starts from rest and travels from the first floor to the fifth floor of the building. Which of the following forces has a magnitude equal to the person's weight during the entire elevator ride?

(A) The gravitational force exerted by the elevator on the person

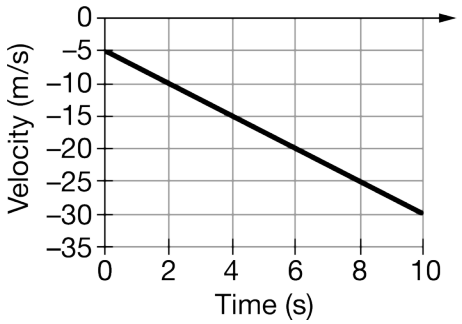
(B) The gravitational force exerted by the person on Earth

(C) The normal force exerted by the elevator on the person

(D) The normal force exerted by the person on the elevator

chapter2

35.



A $0.5\ \text{kg}$ object is in free fall as it falls downward near the surface of a planet. A graph of the object's velocity as a function of time is shown. What is the force due to gravity exerted on the object by the planet?

(A) $0.5\ \text{N}$

(B) $1.25\ \text{N}$

(C) $2.5\ \text{N}$

(D) $5\ \text{N}$

36. A ball of mass m is found to have a weight W_x on Planet X. Which of the following is a correct expression for the gravitational field strength of Planet X?

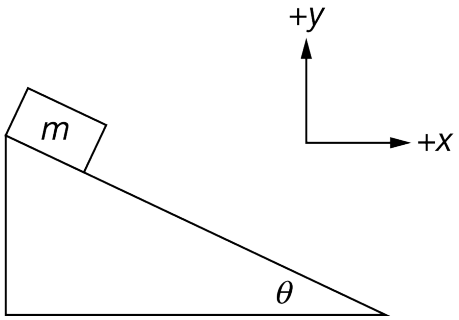
(A) The gravitational field strength of Planet X is mg.

(B) The gravitational field strength of Planet X is W_x/m.

(C) The gravitational field strength of Planet X is $9.8\ \text{N/kg}$.

(D) The gravitational field strength of Planet X is mW_x.

37.



A box of mass m is released from rest and accelerates down a ramp that is at an angle θ to the horizontal, as shown. The coefficient of kinetic friction between the box and the ramp is μ. As the box is sliding down the ramp, how are the magnitudes of the horizontal and vertical components of the box's velocity changing, if at all?

chapter2

(A)

Horizontal Component	Vertical Component
Not changing	Not changing

(B)

Horizontal Component	Vertical Component
Not changing	Increasing

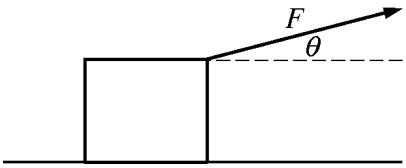
(C)

Horizontal Component	Vertical Component
Increasing	Not changing

(D)

Horizontal Component	Vertical Component
Increasing	Increasing

Refer to the following material for answering group of questions.



A crate is on a horizontal frictionless surface. A force of magnitude F is exerted on the crate at an angle θ to the horizontal, as shown in the figure above, causing the crate to slide to the right. The surface exerts a normal force of magnitude F_N on the crate. As the crate slides a distance d, it gains an amount of kinetic energy ΔK. While F is kept constant, the angle θ is now doubled but is still less than 90^o. Assume the crate remains in contact with the surface.

38. How does the new normal force exerted on the crate compare to F_N?

(A) The new normal force is greater than F_N.

(B) The new normal force is less than F_N.

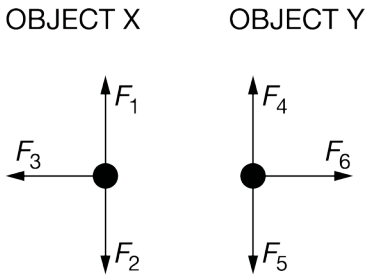
(C) The new normal force is equal to F_N.

(D) The new normal force is greater or less than F_N depending on the value of θ.

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chapter2

39.



Object X and object Y are at rest on a horizontal surface. Object X is in contact with object Y. The force diagrams for both objects are shown above. Which two forces make up an action-reaction pair?

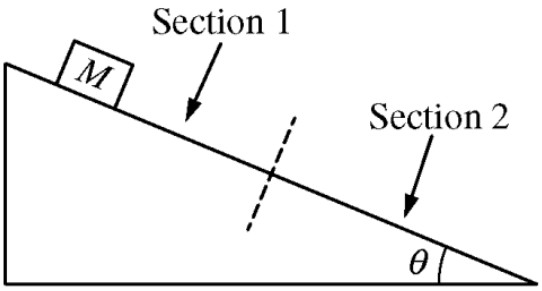
(A) F_1 and F_5, because both forces are exerted on different objects, have the same magnitude, and are in opposite directions.

(B) F_1 and F_2, because both forces are exerted on the same object, have the same magnitude, and are in opposite directions.

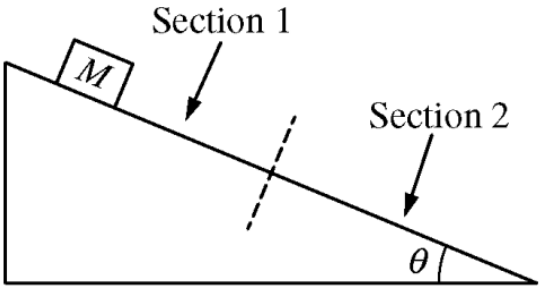
(C) F_2 and F_5, because both forces are exerted on different objects, have the same magnitude, and are in the same direction.

(D) F_3 and F_6, because both forces are exerted on different objects, have the same magnitude, and are in opposite directions.

chapter2



The inclined plane in the figure above has two sections of equal length and different roughness. The dashed line shows where section 1 ends and section 2 begins. A block of mass M is placed at different locations on the incline. The coefficients of kinetic and static friction between the block and each section are shown in the table below.



µs1). The second row reads Kinetic, µk, 2µk." height="91"

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40. If the block is at rest on section 1 of the incline, what is the magnitude of the force of static friction exerted on the block by the incline?

(A) $\mu_{s1} Mg\cos\theta$

(B) $\mu_{s1} Mg\tan\theta$

(C) $Mg \sin \theta$

(D) $Mg / \tan \theta$

41. If the block is sliding up section 2, what is the magnitude of the force of friction that is exerted on the block by the incline?

(A) $2\ \mu k\ Mg \cos \theta$

(B) $2\ \mu k\ Mg \tan \theta$

(C) $Mg \sin \theta$

(D) $Mg / \tan \theta$

chapter2

42. A student must determine the relationship between the inertial mass of an object, the net force exerted on the object, and the object's acceleration. The student uses the following procedure. The object is known to have an inertial mass of $1.0\ \text{kg}$.

Step 1: Place the object on a horizontal surface such that frictional forces can be considered to be negligible.

Step 2: Attach a force probe to the object.

Step 3: Hang a motion detector above the object so that the front of the motion detector is pointed toward the object and is perpendicular to the direction that the object can travel along the surface.

Step 4: Use the force probe to pull the object across the horizontal surface with a constant force as the force probe measures force exerted on the object. At the same time, use the motion detector to record the velocity of the object as a function of time.

Step 5: Repeat the experiment so that the object is pulled with a different constant force.

Can the student determine the relationship using this experimental procedure?

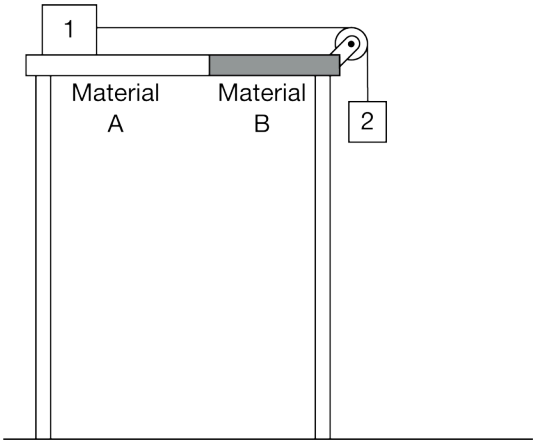
(A) Yes, because Newton's second law of motion must be used to determine the acceleration of the object.

(B) Yes, because the net force exerted on the object and its change in velocity per unit of time are measured.

(C) No, because the motion detector should be oriented so that the object moves parallel to the line along which the front of the motion detector is aimed.

(D) No, because knowing the net force exerted on the object and its change in velocity per unit of time is not sufficient to determine the relationship.

43.



Blocks 1 and 2 are connected by a light string that passes over a pulley with negligible mass and friction, as shown in the figure. Block 1 is on a table covered with two different materials, A and B. The two-block system is released from rest, and the speed of block 1 begins to increase. When block 1 reaches material B, its speed increases at a greater rate. Which of the following correctly compares the coefficient of kinetic friction μ between block 1 and the two materials and describes the change in the magnitude of the net force on block 2 as block 1 slides from material A to material B?

chapter2

(A)

Coefficients	Net Force
$\mu_A > \mu_B$	Decreases

(B)

Coefficients	Net Force
$\mu_A > \mu_B$	Increases

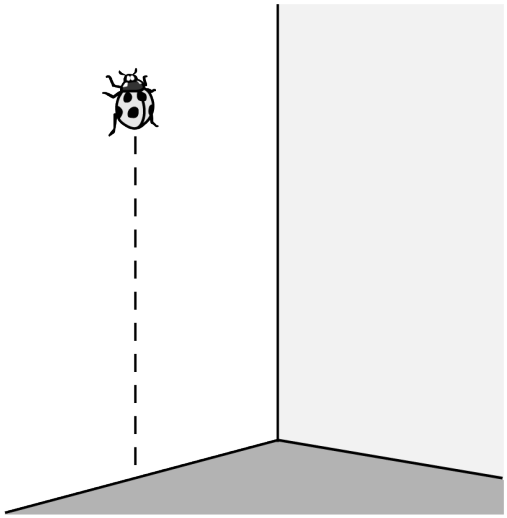
(C)

Coefficients	Net Force
$\mu_A < \mu_B$	Increases

(D)

Coefficients	Net Force
$\mu_A < \mu_B$	Decreases

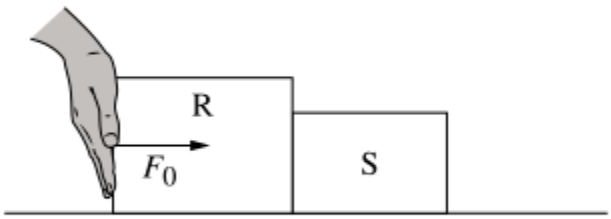
44.



A ladybug is crawling up a wall at constant speed, as shown above. Which of the following are correct justifications for how forces help the ladybug move up the wall? Select two answers.

chapter2

A	A constant nonzero net force acts on the ladybug as it moves up the wall.
B	The ladybug exerts a downward force on the wall to move itself up the wall.
C	The upward force of the wall on the ladybug moves the ladybug up the wall.
D	The ladybug exerts an upward force on itself to move it up the wall.



Box R of mass m_{R} and Box S of mass m_{S}, where $m_{\mathrm{R}} > m_{\mathrm{S}}$, are located on a horizontal surface, as shown. A constant horizontal force F_0 is exerted on Box R and causes the system to have an acceleration of magnitude a_0 to the right. The coefficient of kinetic friction between the surface and each box is μ_0.

45. When the force F_0 is exerted on Box R, a student measures the acceleration of the boxes to be $1\ \mathrm{m/s^2}$ to the right. Then the force is doubled to $2F_0$. Which of the following correctly describes the magnitude of the resulting acceleration of the boxes?

(A) $1\ \mathrm{m/s^2}$

(B) Between $1\ \mathrm{m/s^2}$ and $2\ \mathrm{m/s^2}$

(C) $2\ \mathrm{m/s^2}$

(D) More than $2\ \mathrm{m/s^2}$

chapter2

46.

Total Number	Distance from the Center of Disk (m)	Force of Friction (N)
1	0.2	0.6
2	0.5	1.5
3	0.7	2.1

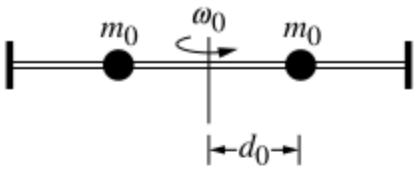
An object rotates at various distances from the center of a disk such that the object experiences a force of friction from the disk. Data collected from the experiment are shown in the table above. Each location of the disk rotates such that the tangential speed at that point remains constant. What is the magnitude of the force of friction exerted on the object if its mass is doubled and it is placed at a distance of $0.6\ \mathrm{m}$ from the disk's center?

(A) $0.9\ \mathrm{N}$

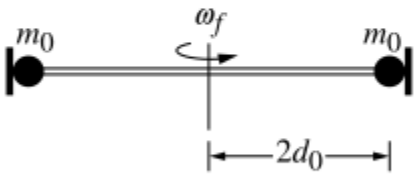
(B) $1.8\ \mathrm{N}$

(C) $3.6\ \mathrm{N}$

(D) The answer cannot be determined without knowing the original mass of the object.



Initial State



Final State

Note: Figures not drawn to scale.

Consider a system that consists of two beads and a thin rod of negligible mass. In the initial state, the beads, each of mass m_0, are attached with their centers a distance d_0 from the center of the rod. The rod is freely rotating with angular speed ω_0 about a fixed vertical axis through the center of the rod, as shown. Then, an internal mechanism releases the beads and they slide with negligible friction outward until the beads hit the end stops. In the final state, the centers of the beads are a distance $2d_0$ from the center of the rod, which is rotating with an angular speed ω_f, as shown. The curved arrows in the figures indicate the directions only, not the magnitudes, of the angular speeds.

47. The tangential speed v of the beads can be represented by $v = \omega r$, where ω is the angular speed and r is the distance of the bead from the vertical axis. Which of the following correctly compares the magnitude of the net force exerted on one of the beads in the initial state to the magnitude of the net force exerted on the same bead in the final state?

(A) The magnitude of the net force is the same and zero in both states.

(B) The magnitude of the net force is the same and nonzero in both states.

(C) The magnitude of the net force is less in the final state.

(D) The magnitude of the net force is greater in the final state.

---

48. A book is at rest on the top of a table. A student makes the following claim: “An attractive electromagnetic force is exerted on the book from the table, and this force can also be classified as the normal force.” Which of the following statements correctly justifies the student's claim?

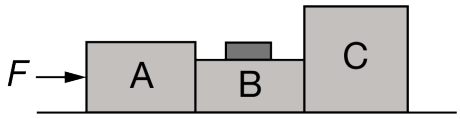
(A) The claim is correct because the charged particles of the table exert a downward attractive force on the charged particles of the book.

(B) The claim is correct because the charged particles of the table exert a downward repulsive force on the charged particles of the book.

(C) The claim is incorrect because the charged particles of the table exert an upward repulsive force on the charged particles of the book.

(D) The claim is incorrect because the charged particles of the table exert an upward attractive force on the charged particles of the book.

49.



Three blocks, A, B, and C, are pushed by a constant force F that is applied on block A as shown. There is negligible friction between the blocks and the surface. When a small object is attached to the top of block B, the normal force between blocks A and B is F_{AB} and the normal force between blocks B and C is F_{BC}. How will the values of F_{AB} and F_{BC} change if the small object is moved to the top of block C and the experiment is repeated?

chapter2

(A)

F_{AB}	F_{BC}
Increases	Stays the same

(B)

F_{AB}	F_{BC}
Decreases	Increases

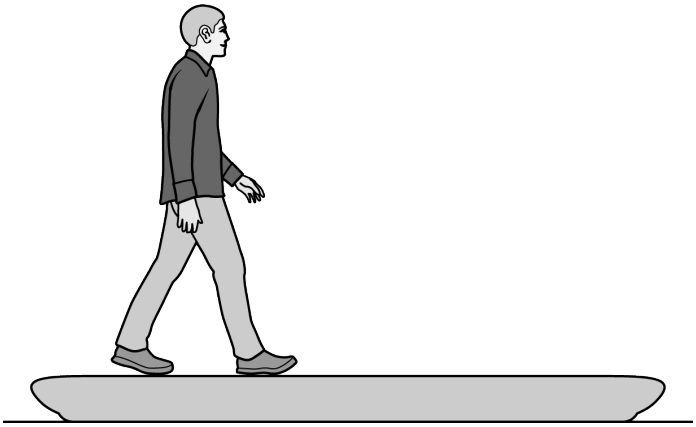
(C)

F_{AB}	F_{BC}
Stays the same	Decreases

(D)

F_{AB}	F_{BC}
Stays the same	Increases

50.



A person of mass $60\ \text{kg}$ is initially standing at one end of a small raft that has a mass of $40\ \text{kg}$. The raft is in the middle of a lake, and the drag force between the raft and the water is negligible. The person begins to walk to the right, as shown above, at a speed v relative to the water. As a result, the raft will

(A) remain at rest

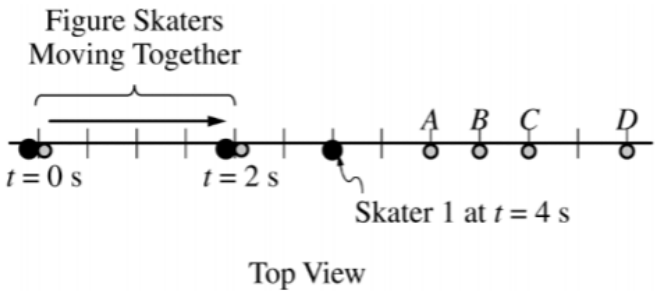
(B) move to the left at a speed less than v

(C) move to the left at a speed equal to v

(D) move to the left at a speed greater than v

chapter2

51.



At time $t = 0$ two figure skaters are moving together over ice with negligible friction, as shown above. Skater 1, represented by the large black dot, is twice as massive as skater 2, represented by the gray dot. At $t = 2$ s the skaters push off of one another. The location of skater 1 is shown at $t = 4$ s . At $t = 4$ s , skater 2 is located at which of the labeled points?

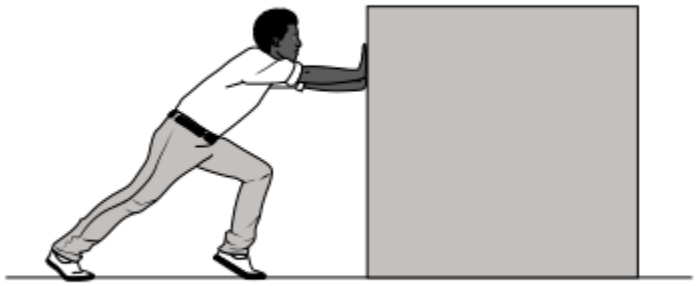
(A) Point *A*

(B) Point *B*

(C) Point *C*

(D) Point *D*

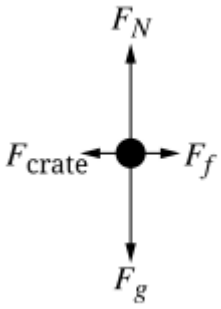
52.

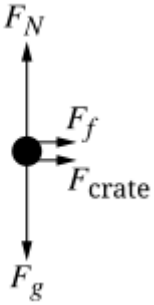


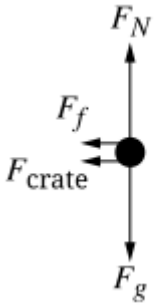
A person exerts a force of magnitude F_{crate} on a crate, as shown in the figure, causing the crate to move with a constant velocity. There is nonnegligible friction between the crate and the floor and between the person's shoes and the floor. F_g is the magnitude of the weight of the person, F_N is the magnitude of the force exerted by the floor on the person, and F_f is the magnitude of the frictional force exerted by the floor on the person. Which of the following diagrams could represent the forces exerted on the person?

chapter2

(A) 

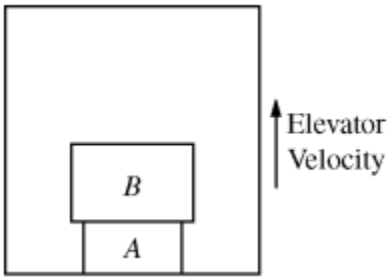
(B) 

(C) 

(D) 

chapter2

53.



Box A of mass m sits on the floor of an elevator, with box B of mass 2m on top of it, as shown in the figure above. The elevator is moving upward and slowing down. F_A is the magnitude of the force exerted on box A by box B, F_B is the magnitude of the force exerted on box B by box A, and F_g is the magnitude of the gravitational force exerted on box B. Which of the following ranks the forces in order of increasing magnitude?

(A) $F_B = F_A = F_g$

(B) $(F_B = F_A) < F_g$

(C) $F_B < (F_A = F_g)$

(D) $F_g < F_B < F_A$

54.

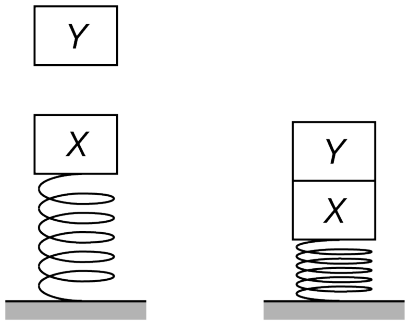


Figure 1 Figure 2

Block Y with mass m_Y falls onto and sticks to block X, which is attached to a vertical spring, as shown in Figure 1. A short time later, as shown in Figure 2, the blocks are momentarily at rest. At that moment, block Y exerts a force of magnitude F_{down} on block X, and block X exerts a force of magnitude F_{up} on block Y. Which of the following correctly relates F_{up}, F_{down}, and $m_Y g$ at the instant shown in Figure 2 ?

(A) $(F_{\text{up}} = F_{\text{down}}) > m_Y g$

(B) $(F_{\text{up}} = m_Y g) > F_{\text{down}}$

(C) $m_Y g > F_{\text{up}} > F_{\text{down}}$

(D) $F_{\text{up}} = F_{\text{down}} = m_Y g$

55. A student must design an experiment to determine the relationship between the mass of an object and the resulting acceleration when the object is under the influence of a net force. Which of the following experiments should the student conduct in order to determine the relationship between all three quantities?

chapter2

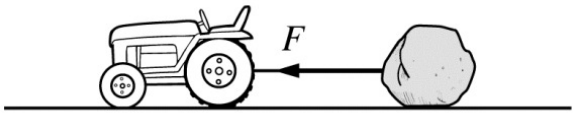
(A) Drop objects of different masses from a known height above the ground for multiple trials such that they reach their respective terminal speeds. Use a stopwatch to measure the time it takes each object to reach the ground, and record the mass of each object by using a mass scale.

(B) Slide objects of different masses across the same rough surface so that each object travels at a constant speed while under the influence of the force of kinetic friction. Then measure the force required to keep each object at a constant speed by using a force sensor, and record the mass of each object by using a mass scale. Perform this experiment multiple times with objects of different masses.

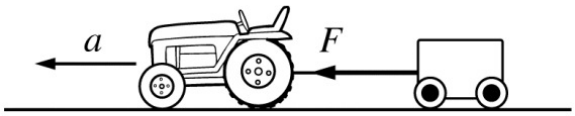
(C) Place an object on a rough surface so that the object is at rest. Use a force sensor to exert a force on the object until just after the object overcomes the force of static friction. Record this force. Repeat the experiment for objects of different masses.

(D) Slide an object of known mass across a rough surface, using a constant applied force that can be measured by a force sensor. Place a motion detector behind the object so that its speed can be measured as it slides across the surface. Repeat the experiment for different applied forces.

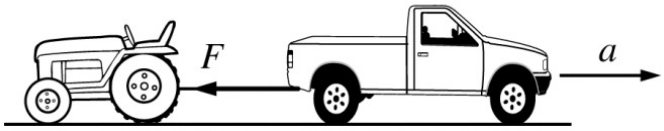
56.



Boulder: Force F to the left
No acceleration



Wagon: Force F to the left
Acceleration a to the left



Truck: Force F to the left
Acceleration a to the right

Each of the figures above shows a tractor attached to an object. The tractor exerts the same constant force F on each object in every case. Which of the following is a true statement about an object and the relative magnitude of the force exerted by the object on the tractor?

(A) The magnitude of the force exerted by the truck on the tractor is greatest, because the resulting motion is in the direction opposite the tractor's pull.

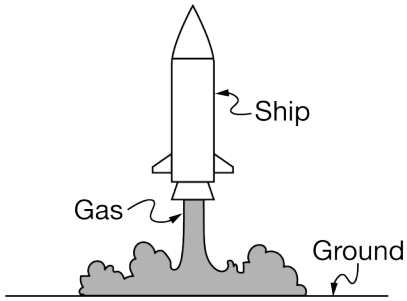
(B) The magnitude of the force exerted by the boulder on the tractor is least, because no motion results.

(C) The magnitude of the force exerted by the wagon on the tractor is least, because the resulting motion is in the direction of the tractor's pull.

(D) The magnitude of the force exerted by each object on the tractor is equal, because the tractor exerts an equal force on each object.

chapter2

57.



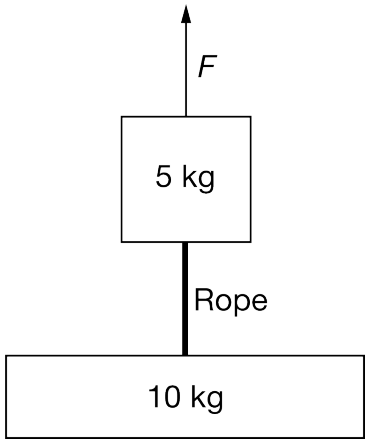
When a rocket-propelled ship launches from the ground, it expels exhaust gas from the bottom of the ship, as shown above. Which of the following explains why the ship is able to leave the ground?

(A) The ship exerts a force on the ground, and the ground exerts a force of equal magnitude and in the opposite direction on the ship.

(B) The gas exerts a force on the ground and a force of equal magnitude in the opposite direction on the ship.

(C) The gravitational potential energy of the ship-Earth system decreases as the ship moves up, so the kinetic energy of the ship must increase.

(D) The ship exerts a downward force on the gas, and the gas exerts an upward force on the ship.



Two blocks are connected by a rope, as shown above. The masses of the blocks are $5\ \text{kg}$ for the upper block and $10\ \text{kg}$ for the lower block. An upward applied force of magnitude F acts on the upper block.

58. The system is moving and accelerating upward. A pair of scissors cuts the rope. Which of the following describes the motion of the $10\ \text{kg}$ block immediately after the rope has been cut?

(A) The block continues to move upward and to accelerate upward.

(B) The block begins to move downward but continues to accelerate upward.

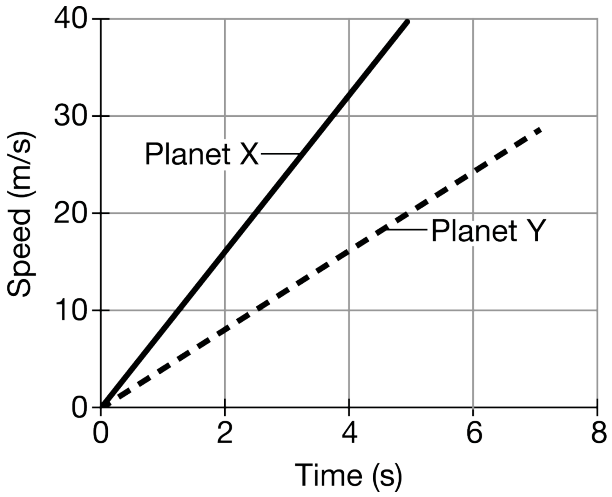
(C) The block continues to move upward but begins to accelerate downward.

(D) The block begins to move downward and to accelerate downward.

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chapter2

59.



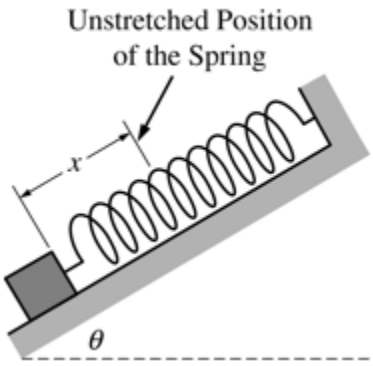
Identical spheres are dropped from a height of $100\ \mathrm{m}$ above the surfaces of Planet X and Planet Y. The speed of the spheres as a function of time is recorded for each planet in the graph above. Which planet exerts the greater force of gravity on the sphere, and what evidence supports this conclusion?

(A) Planet X, because its line has the greater area under it.

(B) Planet X, because its line has the greater slope.

(C) Planet Y, because it falls for the smaller amount of time.

(D) Planet Y, because the object's final speed is greater.



An object of mass m is attached to a spring on a frictionless inclined plane that makes an angle θ with the horizontal, as shown above. The object is released from rest with the spring in its unstretched position. As the object moves on the plane, its displacement from the unstretched position is x.

60. The object subsequently oscillates about an equilibrium position at a displacement x_0 from the unstretched position of the spring. What is the spring constant of the spring?

chapter2

(A) $\frac{mg}{x_0 \cos\theta}$

(B) $\frac{mg}{x_0 \sin\theta}$

(C) $\frac{mg \tan\theta}{x_0}$

(D) $\frac{mg \cos\theta}{x_0}$

(E) $\frac{mg \sin\theta}{x_0}$

61.

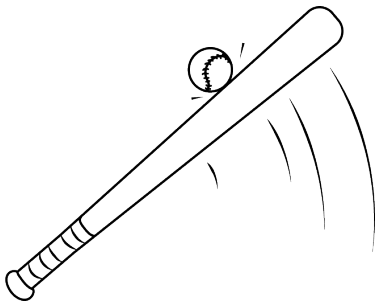


Figure 1

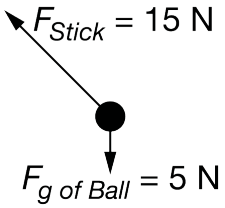


Figure 2

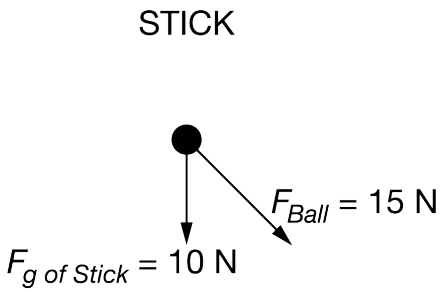


Figure 3

A stick is used to hit a ball at an angle above the horizontal, as shown in Figure 1. Figure 2 shows the free body diagram of the ball. Figure 3 shows the free body diagram of the stick. Which of the following pairs of forces represents an action-reaction pair and the object or objects involved in the action-reaction pair?

(A) F_{Stick} and F_{Ball}

(B) $F_{g\ of\ Stick}$ and $F_{g\ of\ Ball}$

(C) F_{Stick} and $F_{g\ of\ Ball}$

(D) F_{Ball} and $F_{g\ of\ Stick}$

62. A student uses both hands to push a door such that it moves and swings open after the force has been applied. The student then makes the following claim: “I can use both of my hands to apply a constant force on my body so that my body falls backward.” Which of the following statements correctly justifies the student's claim?

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chapter2

(A) The claim is correct because the situation is the same as if another person's hands applied a force on the student.

(B) The claim is correct because the student's hands will exert a net force on the student's body.

(C) The claim is not correct because the student's hands cannot exert a force on the student's body.

(D) The claim is not correct because the student's body will exert a force of equal magnitude back on the student's hands as a result of Newton's third law of motion.

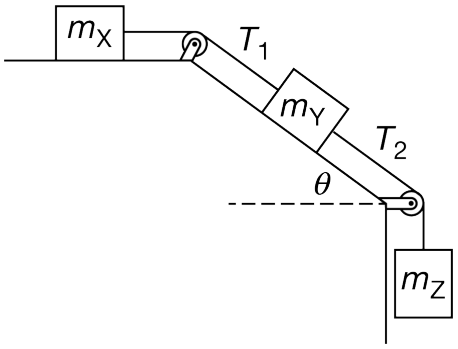
63.

Block X	$T_1 - m_{\mathrm{X}} g \sin\theta - \mu m_{\mathrm{X}} g \cos\theta = m_{\mathrm{X}} a$
Block Y	$T_2 - T_1 - \mu m_{\mathrm{Y}} g = m_{\mathrm{Y}} a$
Block Z	$m_{\mathrm{Z}} g - T_2 = m_{\mathrm{Z}} a$

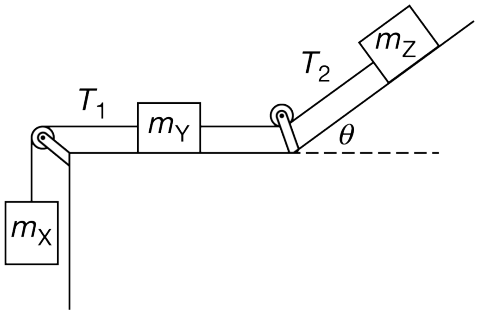
The table above shows equations describing the forces and acceleration a of three blocks that are connected by light strings, some of which run over pulleys. The pulleys are all massless and frictionless, and the coefficient of kinetic friction between each block and surface is μ. In the diagrams below, the mass of each block and the tension in each of the two strings are labeled. Which of the following arrangements could be described by the equations in the table above?

chapter2

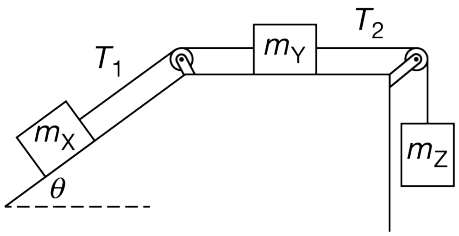
(A)



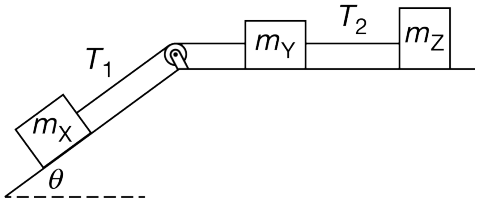
(B)



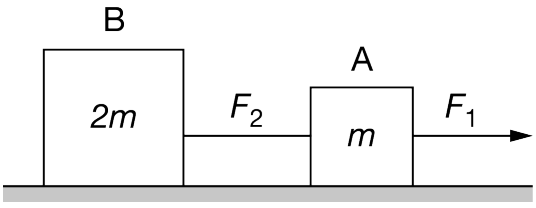
(C)



(D)



64.



Blocks A and B, of masses m and $2m$, respectively, are connected by a light string and pulled across a surface of negligible friction with a constant force F_1, as shown above. The acceleration of the blocks is a. The force of the string pulling block B forward has magnitude F_2. Which of the following claims correctly describes the relationship between the magnitude of the forces acting on the blocks?

(A) F_1 is equal to F_2.

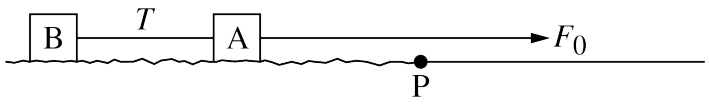
(B) F_1 is greater than F_2.

(C) F_2 is equal to $3ma$.

(D) F_2 is greater than $3ma$.

chapter2

65.



Two identical blocks A and B are connected by a lightweight rope. Block A is pulled to the right by a constant force F_0. The blocks are moving to the right across a rough surface and approach point P, where the rough surface transitions to a surface with negligible friction. How does the tension, T, in the rope connecting the blocks change, if at all, as block A passes point P?

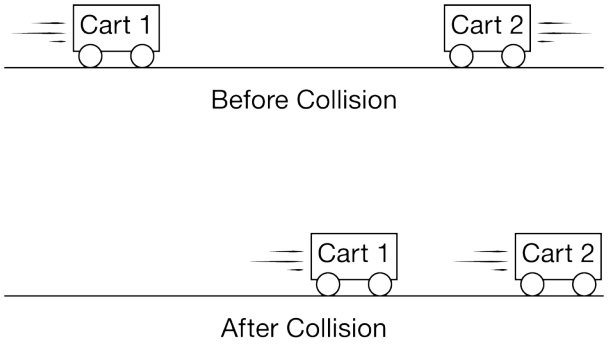
(A) T decreases.

(B) T increases.

(C) T remains constant.

(D) The change in T cannot be determined without knowing the coefficient of friction and the mass of the blocks.

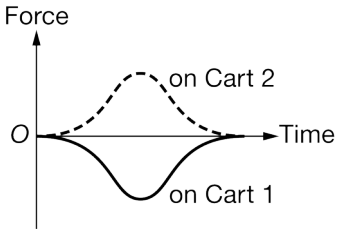
66.



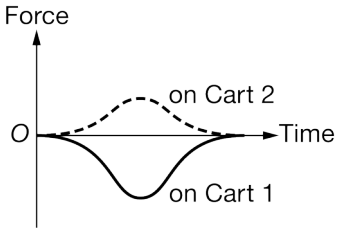
Carts 1 and 2 are initially moving toward each other, as shown in the top figure. The carts collide and afterward are both moving to the right, as shown in the bottom figure. If the positive direction is to the right, which of the following best represents the force exerted on each cart by the other during the collision as a function of time?

chapter2

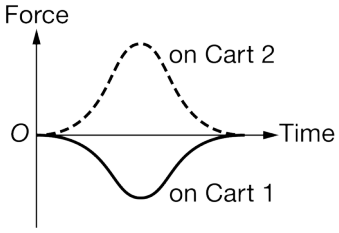
(A)



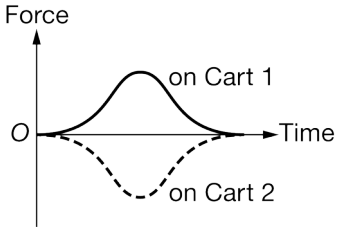
(B)



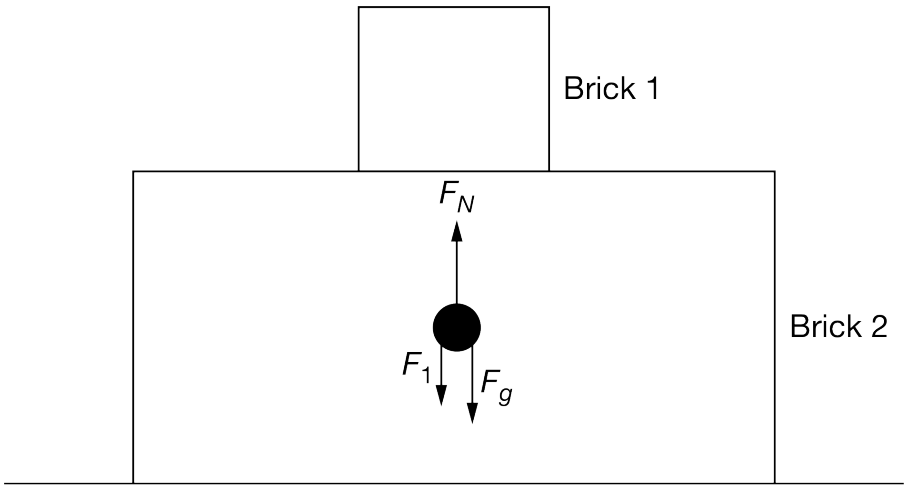
(C)



(D)



67.



Two bricks are stacked on a floor. A student draws the force diagram for brick 2, as shown above. The forces are an upward normal force, a downward force exerted by brick 1, and a downward gravitational force. How many of the forces, if any, in the force diagram are contact forces caused by microscopic interactions?

(A) Zero

(B) Only one

(C) Only two

(D) All three

68. A group of students attaches an object of unknown mass to a spring with unknown spring constant. The students displace the object from equilibrium and measure the period of oscillation of the object. The students' procedure could be used to determine which of the following? Select two answers.

A If the mass of the object were known, the students could use the procedure to determine the spring constant of the spring.

B If the mass of the object were known, the students could use the procedure to determine the acceleration due to gravity.

C If the spring constant were known, the students could use the procedure to determine the gravitational mass of the object.

D If the spring constant were known, the students could use the procedure to determine the inertial mass of the object.

69. A $2\ \text{kg}$ object is released from rest near the surface of a planet such that its gravitational field is considered to be constant. The mass of the planet is unknown. The object's speed after falling for $3\ \text{s}$ is $75\ \text{m/s}$. Air resistance is considered to be negligible. Calculate the weight of the $2\ \text{kg}$ object on the planet of unknown mass.

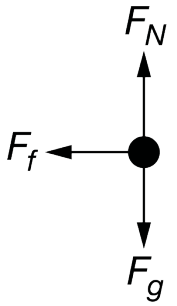
(A) $2\ \text{N}$

(B) $25\ \text{N}$

(C) $50\ \text{N}$

(D) $75\ \text{N}$

70.



A block slides to the right on a rough horizontal surface. The forces exerted on the block are shown above. Which of the following statements about the frictional force F_f exerted on the block is true?

(A) It is the only force acting on the block that is caused by microscopic interactions.

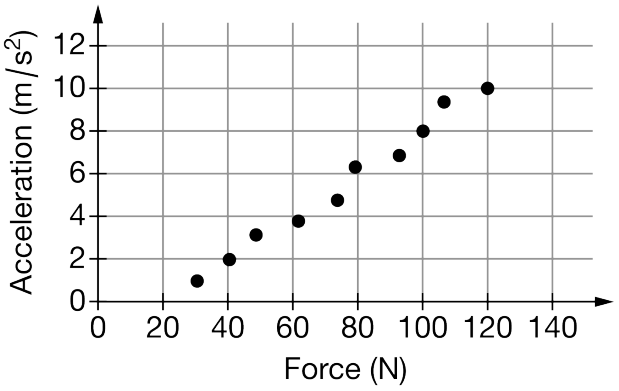
(B) It does not depend on the materials that the block and the surface are made of.

(C) It is caused by gravitational interactions between the atoms in the block and the atoms in the surface.

(D) It is the sum of all the microscopic contact forces between the bottom of the block and the surface.

chapter2

71.



A person exerts a continually increasing force on an object in a constant direction. A graph of the acceleration of the object as a function of the applied force is shown above. Which of the following best explains why a best-fit line would not pass through the origin?

(A) An additional force is exerted on the object in the same direction as the applied force.

(B) An additional force is exerted on the object in the direction opposite the applied force.

(C) The object was moving at constant speed before the force was applied.

(D) Data was not collected for applied forces less than $20\ \text{N}$.

72. When a box is at rest on a level floor, forces are exerted between the atoms in the bottom surface of the box and atoms in the top surface of the floor. Why does the floor not exert a frictional force on the box?

(A) The force exerted between any atom in the floor and any atom in the box is always vertical, leading to a normal force but not a frictional force.

(B) The forces exerted between atoms are equal in magnitude and opposite in direction, so the net force between the box and floor is zero.

(C) The horizontal component of the force exerted between any atom in the floor and any atom in the box is always negligible compared to the vertical component of the force.

(D) The horizontal components of the forces exerted between atoms in the floor and atoms in the box are not negligible but sum to zero.