Concept of Force
Concept Questions

Question 1: You are pushing a wooden crate across the floor at constant speed. You decide to turn the crate on end, reducing by half the surface area in contact with the floor. In the new orientation, to push the same crate across the same floor with the same speed, the force that you apply must be about

1. four times as great
2. twice as great
3. equally great
4. half as great
5. one-fourth as great

as the force required before you changed the crate's orientation.

Answer 3. The force is proportional to the coefficient of kinetic friction and the weight of the crate. Neither depends on the size of the surface in contact with the floor.

Question 2 A massive rope pulls a block at a constant speed. There is a non-zero contact force (friction) between the block and the table. Is the tension in the rope

1) greater than the pulling force?
2) equal to the pulling force?
3) less than the pulling force?

Answer 2. Suppose you are pulling the right end of the rope. If you make an imaginary slice anywhere in the rope, dividing the rope into a left and right halves, the forces acting on the right half of the rope are your pulling force $\vec{F}$ acting on one end, and the tension $\vec{T}$ exerted by the left side of the rope on the right side. Since the rope is not accelerating, the sum of the forces on the rope are zero. Therefore, $\vec{F} + \vec{T} = \vec{0}$. From this, we can conclude that the tension exerted by the left side of the rope on the right side is equal in magnitude but pointing in the opposite direction from your pulling force, $\vec{T} = -\vec{F}$.

Note that this is not a Third Law action reaction pair. Since the above argument is independent of the location of the imaginary slice, we can conclude that the magnitude of the tension in the rope is equal to the magnitude of the pulling force.

Question 3 Suppose you are sitting in a soundproof, windowless room aboard a hovercraft moving over flat terrain. The following motions occur on your trip.

A. rotation
B. deviation from the horizontal orientation
C. motion at a steady speed
D. acceleration
E. state of rest with respect to ground

Which of these can you detect from inside the room?

1.all of them
2.A, B, D
3.C, E
4.B, D
5. A, B, D, E
6. A, D
7. A
8. D

Answer 1: You cannot distinguish between relatively inertial reference frames. Motion at a steady speed and a state of rest with respect to the ground define two relatively inertial reference frames and so you cannot be distinguish one from the other. On the other hand, rotation (case A), deviation from the horizontal orientation (case B), and acceleration (case E) are all examples of accelerated motion and so you can detect those cases from inside the room.

Question 4 An object is held in place by friction on an inclined surface. The angle of inclination is increased until the object starts moving. If the surface is kept at this angle, the object

1. slows down.
2. moves at uniform speed.
3. speeds up.
4. none of the above

Answer 3. Once the object starts moving it is accelerating because the force on the object is non-zero pointing in the direction down the inclined plane. Therefore the object speeds up.

Question 5 Consider a person standing in an elevator that is accelerating upward. The upward normal force N exerted by the elevator floor on the person is

1. larger than

2. identical to

3. smaller than

the downward force of gravity on the person.

Answer 1. The normal force on the person is greater than the gravitational force on the person because the normal force must also accelerate the person, as well as oppose the gravitational force. Thus $N - mg = ma$ implies that $N = m(a + g)$. So the magnitude of upward normal force is larger than the magnitude of the downward gravitational force.

Question 6 Consider a car at rest on a level surface. We can conclude that the downward gravitational pull of Earth on the car and the upward contact force of Earth on it are equal and opposite because

1. the two forces form an interaction pair.

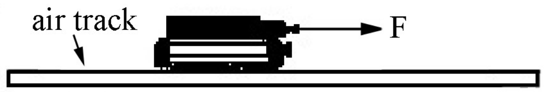
2. the net force on the car is zero.

3. neither of the above.

4. unsure

Answer 2. These two forces cannot be an interaction pair because they act on the same object. Because the car is at rest, however, its momentum is constant (and zero). Because net force equals the time rate of change in momentum, the net force on the car must be zero. This means that the two forces must be equal and opposite.

Question 7: A constant force is exerted on a cart that is initially at rest on an air track. Friction between the cart and the track is negligible. The force acts for a short time interval and gives the cart a certain final speed.



To reach the same final speed with a force that is only half as big, the force must be exerted on the cart for a time interval

1. four times as long as
2. twice as long as
3. equal to
4. half as long as
5. a quarter of

that for the stronger force.

Answer 2. The final speed is proportional to the acceleration of the cart and the time over which it acts.

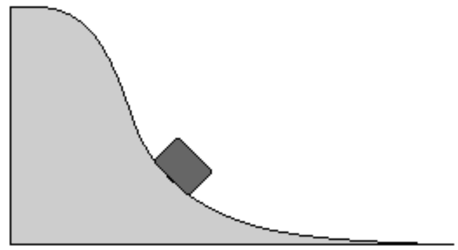
Question 8 A constant force is exerted for a short time interval on a cart that is initially at rest on an air track. This force gives the cart a certain final speed. The same force is exerted for the same length of time on another cart, also initially at rest, that has twice the mass of the first one. The final speed of the heavier cart is

1. one-fourth
2. four times
3. half
4. double
5. the same as

that of the lighter cart.

Answer 3. The final speed is proportional to both the force on the cart and the time over which it acts, and inversely proportional to the mass of the cart.

Question 9 A cart on a roller coaster rolls down the track shown below. As the cart rolls beyond the point shown, what happens to the components of the velocity and acceleration in the direction of motion? Briefly explain your answer.

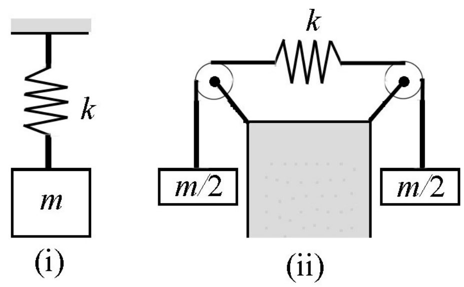


a) Both decrease;
b) The speed decreases, but the acceleration increases;
c) Both remain constant;
d) The speed increases, but acceleration decreases;
e) Both increase;
f) Some other combination.

Briefly explain your answer.

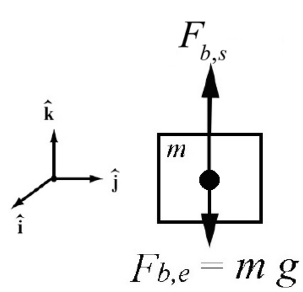
Answer: (d) As the cart moves down the track the component of the gravitational force in the direction of the motion (tangent to the track) decreases. Therefore the acceleration decreases. However, this component of the acceleration is still positive and therefore the component of the velocity in the direction of motion increases. The normal force is perpendicular to the surface so it does not contribute to the acceleration in the direction of motion. The kinetic friction opposes the motion for a roller coaster is much smaller than the component of the gravitational force in the direction of the motion so we can ignore its slowing effect on the roller coaster.

Question 10 A body of mass m is suspended from a spring with spring constant k in configuration (i) and the spring is stretched a distance x. If two identical bodies of mass $m/2$ are suspended from a spring with the same spring constant k in configuration (ii), how much will the spring stretch?



a) x
b) $2x$
c) $x/2$
d) $x/4$
e) not stretch at all.

Answer c. In part (a), assume that the spring is directly connected to the body. There are two forces acting on the body: the gravitational force between the body and the earth, $\vec{\mathbf{F}}_{\text{b.e}} = -mg\,\hat{\mathbf{k}}$, and the force between the body and the spring, $\vec{\mathbf{F}}_{\text{b.s}} = F_{\text{b.s}}\,\hat{\mathbf{k}}$. (The spring is actually connected to the rope, but since the rope is massless, the tension in the rope is uniform and the spring force transmits through the rope so the tension in the rope is equal to the magnitude of the spring force). The interaction between the body and the spring stretches the spring a distance x from its equilibrium length. By Hooke's Law the magnitude of this force is $F_{\text{b,s}} = k\,x$ and so the force acting on the spring is $\vec{\mathbf{F}}_{\text{b,s}} = k\,x\,\hat{\mathbf{k}}$. The force diagram on the body is shown below



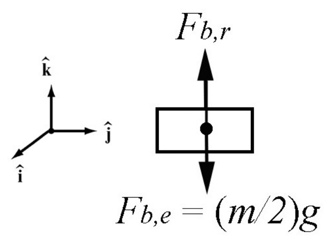
Theses two forces on the body balance since the body is in equilibrium, and so

$$\vec{\mathbf{F}}_{\text{b}}^{T} = \vec{\mathbf{F}}_{\text{b.e}} + \vec{\mathbf{F}}_{\text{b.s}} = -mg\,\hat{\mathbf{k}} + k\,x\,\hat{\mathbf{k}} = \vec{\mathbf{0}} \qquad (10.1)$$

Therefore the spring stretches a distance

$$x = mg / k \,. \tag{10.2}$$

In configuration (b), the forces acting on the body are the gravitational force between the body and the earth, and the force between the rope and the body. The force diagram is shown in the figure below.



Since the body is in static equilibrium,

$$\vec{\mathbf{F}}_{\mathrm{b}}^{T} = \vec{\mathbf{F}}_{\mathrm{b.e}} + \vec{\mathbf{F}}_{\mathrm{b.r}} = -\left(mg/2\right)\hat{\mathbf{k}} + F_{\mathrm{b,r}}\,\hat{\mathbf{k}} = \vec{\mathbf{0}}\,. \tag{10.3}$$

Therefore the magnitudes of the force of the rope (tension in the rope) and the gravitational force on the body are equal;

$$mg/2 = F_{\mathrm{b,r}}\,. \tag{10.4}$$

Suppose the spring stretches by an amount x_1. Just as in part (a), the tension in the rope is uniform, so the tension in the rope is equal to the magnitude of the spring force.

$$F_{\mathrm{b.r}} = k\,x_1\,. \tag{10.5}$$

Combining Equations (10.4) and (10.5) yields

$$k\,x_1 = (m/2)g\,. \tag{10.6}$$

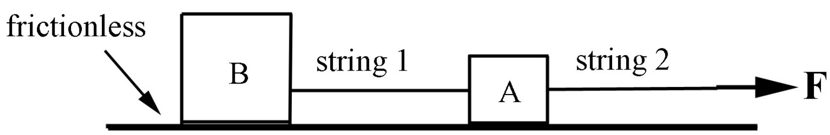
Thus the spring stretches by half the amount as in part (a), as given by Equation (10.2),

$$x_1 = (m/2)g/k = x/2\,. \tag{10.7}$$

Question 11

In the situation below, a person pulls a string attached to block A, which is in turn attached to another, heavier block B via a second string. Assume the strings are massless and inextensible; and ignore friction. Is the magnitude of the acceleration of block A

a) greater than the magnitude of the acceleration of block B?
b) equal to the magnitude of the acceleration of block B?
c) less than the magnitude of the acceleration of block B?
d) Do not have enough information to decide.



Answer b. Because the rope is does not stretch (inextensible) block A and block B move together, so they have the same acceleration.