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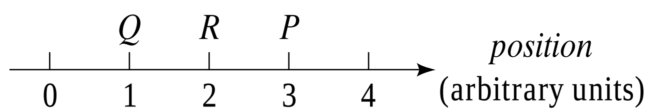
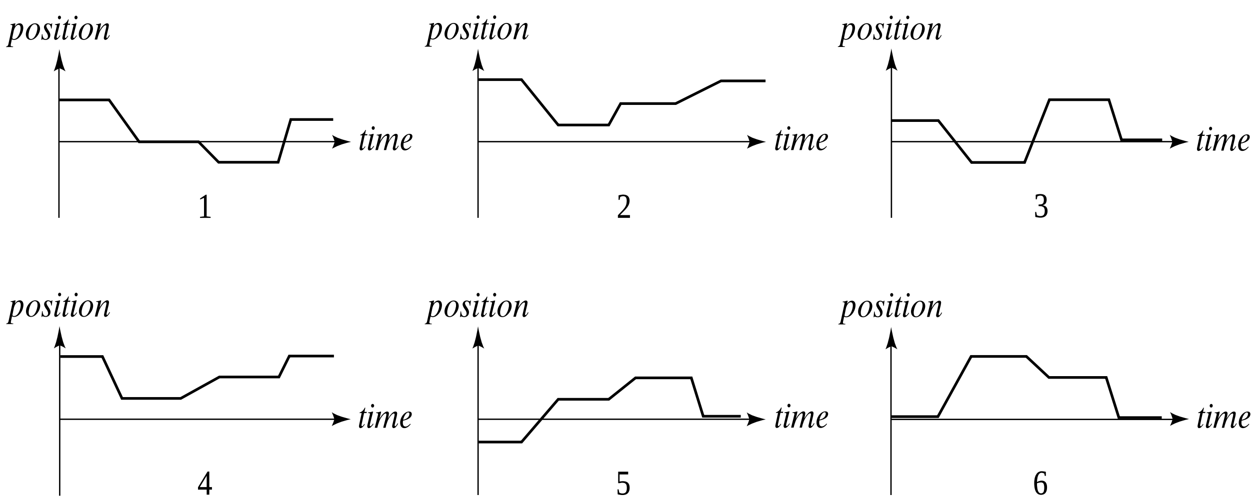
A person initially at point P in the illustration stays there a moment and then moves along the axis to Q and stays there a moment. She then runs quickly to R, stays there a moment, and then strolls slowly back to P. Which of the position vs. time graphs below correctly represents this motion?



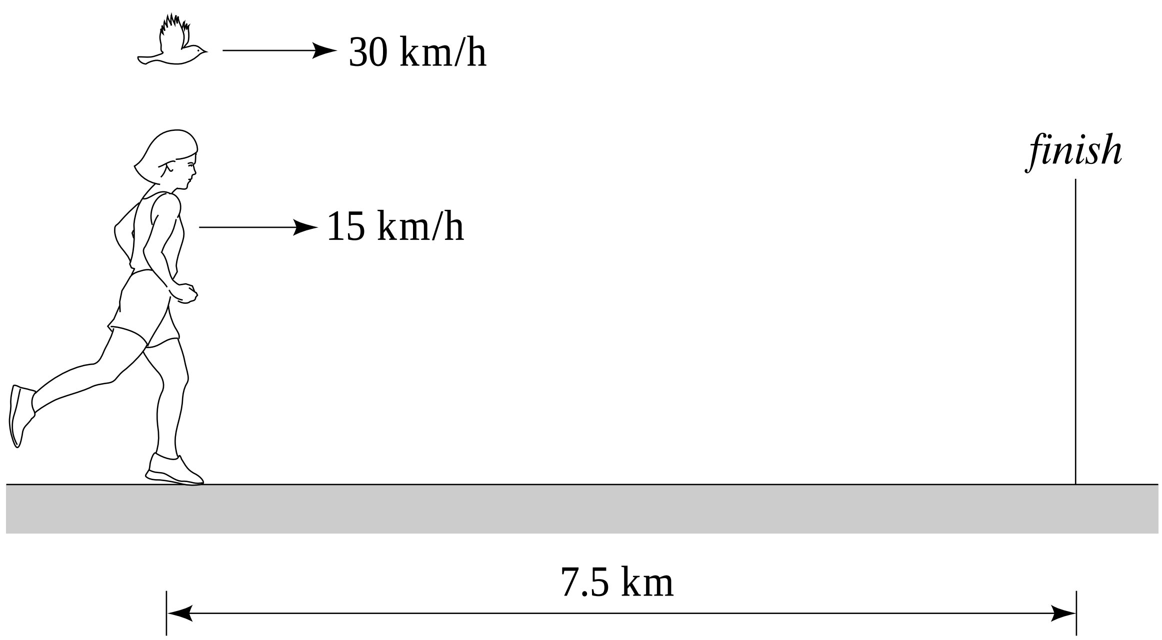


An object goes from one point in space to another. After it arrives at its destination, its displacement is:

1. either greater than or equal to
2. always greater than
3. always equal to
4. either smaller than or equal to
5. always smaller than
6. either smaller or larger

than the distance it traveled.

A marathon runner runs at a steady 15 km/hr. When the runner is 7.5 km from the finish, a bird begins flying from the runner to the finish at 30 km/hr. When the bird reaches the finish line, it turns around and flies back to the runner, and then turns around again, repeating the back-and-forth trips until the runner reaches the finish line. How many kilometers does the bird travel?



1. 10 km
2. 15 km
3. 20 km
4. 30 km

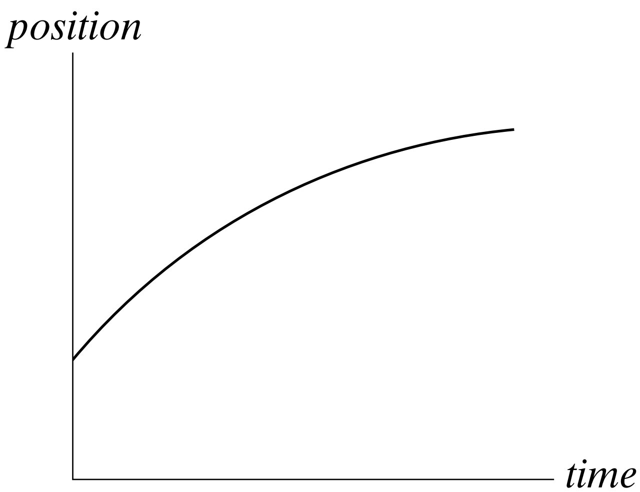
If you drop an object in the absence of air resistance, it accelerates downward at 9.8 m/s^2. If instead you throw it downward, its downward acceleration after release is

1. less than 9.8 m/s^2.
2. 9.8 m/s^2.
3. more than 9.8 m/s^2.

A person standing at the edge of a cliff throws one ball straight up and another ball straight down at the same initial speed. Neglecting air resistance, the ball to hit the ground below the cliff with the greater speed is the one initially thrown

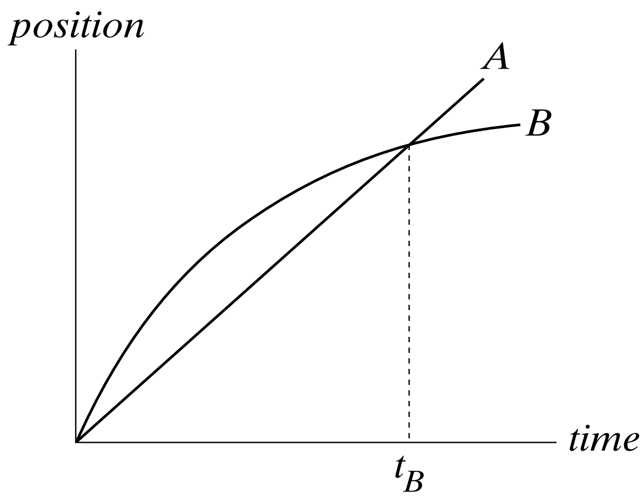
1. upward.
2. downward.
3. neither—they both hit at the same speed.

A train car moves along a long straight track. The graph shows the position as a function of time for this train. The graph shows that the train:



1. speeds up all the time.
2. slows down all the time.
3. speeds up part of the time and slows down part of the time.
4. moves at a constant velocity.

The graph shows position as a function of time for two trains running on parallel tracks. Which is true:

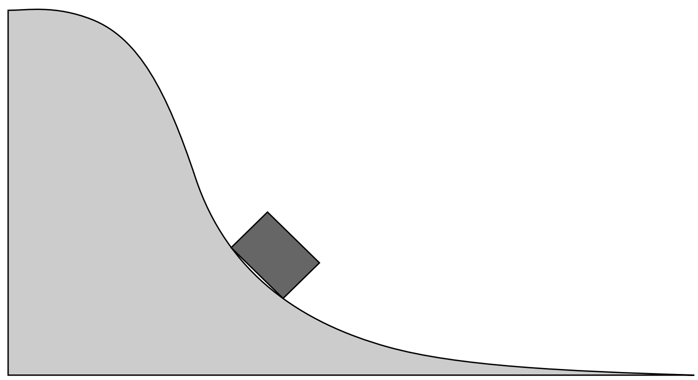


1. At time t_B, both trains have the same velocity.
2. Both trains speed up all the time.
3. Both trains have the same velocity at some time before t_B.
4. Somewhere on the graph, both trains have the same acceleration.

You are throwing a ball straight up in the air. At the highest point, the ball's

1. velocity and acceleration are zero.
2. velocity is nonzero but its acceleration is zero.
3. acceleration is nonzero, but its velocity is zero.
4. velocity and acceleration are both nonzero.

A cart on a roller-coaster rolls down the track shown below. As the cart rolls beyond the point shown, what happens to its speed and acceleration in the direction of motion?

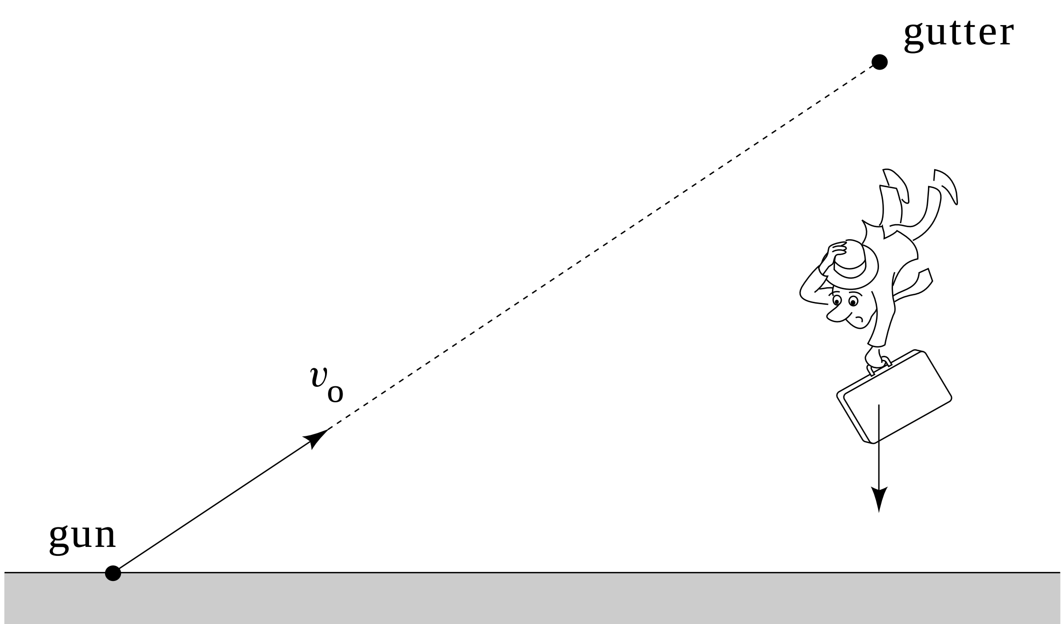


1. Both decrease.
2. The speed decreases, but the acceleration increases.
3. Both remain constant.
4. The speed increases, but acceleration decreases.
5. Both increase.
6. Other

A ball is thrown vertically up, its speed slowing under the influence of gravity. Suppose (*a*) we film this motion and play the tape backward (so the tape begins with the ball at its highest point and ends with it reaching the point from which it was released), and (*b*) we observe the motion of the ball from a frame of reference moving up at the initial speed of the ball. The ball has a downward acceleration g in

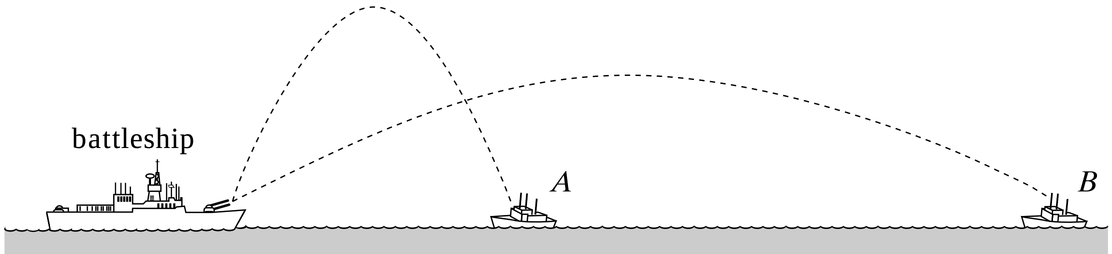
1. (*a*) and (*b*).
2. only (*a*).
3. only (*b*).
4. neither (*a*) nor (*b*).

Consider the situation depicted here. A gun is accurately aimed at a dangerous criminal hanging from the gutter of a building. The target is well within the gun's range, but the instant the gun is fired and the bullet moves with a speed v_o, the criminal lets go and drops to the ground. What happens? The bullet



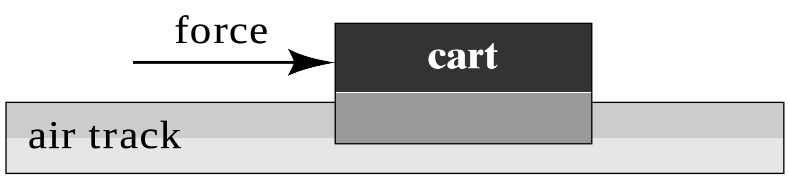
1. hits the criminal regardless of the value of v_o.
2. hits the criminal only if v_o is large enough.
3. misses the criminal.

A battleship simultaneously fires two shells at enemy ships. If the shells follow the parabolic trajectories shown, which ship gets hit first?



1. *A*
2. both at the same time
3. *B*
4. need more information

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.

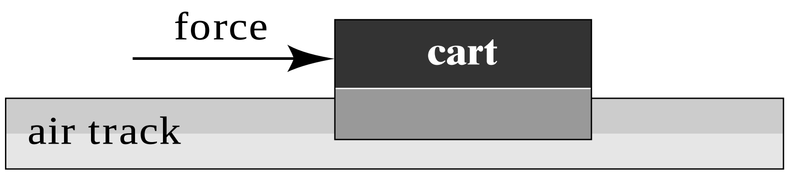


To reach the same final speed with a force that is only half as big, the force must be exerted on the cart for a time interval

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.

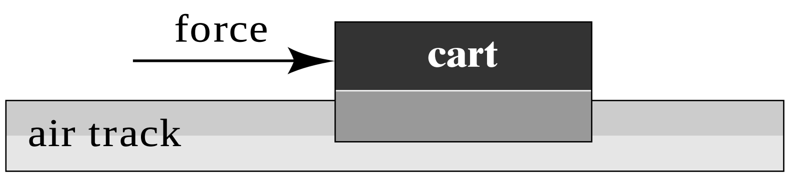
A constant force is exerted for a short time interval on a cart that is initially at rest on an air track. This force gives the cart a certain final speed. The same force is exerted for the same length of time on another cart, also initially at rest, that has twice the mass of the first one. The final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

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. Suppose we repeat the experiment but, instead of starting from rest, the cart is already moving with constant speed in the direction of the force at the moment we begin to apply the force. After we exert the same constant force for the same short time interval, the increase in the cart's speed



1. is equal to two times its initial speed.
2. is equal to the square of its initial speed.
3. is equal to four times its initial speed.
4. is the same as when it started from rest.
5. cannot be determined from the information provided.

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

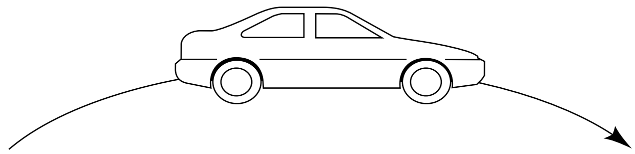
1. larger than
2. identical to
3. smaller than

the downward weight W of the person.

A locomotive pulls a series of wagons. Which is the correct analysis of the situation?

1. The train moves forward because the locomotive pulls forward slightly harder on the wagons than the wagons pull backward on the locomotive.
2. Because action always equals reaction, the locomotive cannot pull the wagon the wagons pull backward just as hard as the locomotive pulls forward, so there is no motion.
3. The locomotive gets the wagons to move by giving them a tug during which the force on the wagons is momentarily greater than the force exerted by the wagons on the locomotive.
4. The locomotive's force on the wagons is as strong as the force of the wagons on the locomotive, but the frictional force on the locomotive is forward and large while the backward frictional force on the wagons is small.
5. The locomotive can pull the wagons forward only if it weighs more than the wagons.

A car rounds a curve while maintaining a constant speed. Is there a net force on the car as it rounds the curve?



1. No—its speed is constant.
2. Yes.
3. It depends on the sharpness of the curve and the speed of the car.

In the 17th century, Otto von Güricke, a physicist in Magdeburg, fitted two hollow bronze hemispheres together and removed the air from the resulting sphere with a pump. Two eight-horse teams could not pull the halves apart even though the hemispheres fell apart when air was readmitted. Suppose von Güricke had tied both teams of horses to one side and bolted the other side to a heavy tree trunk. In this case, the tension on the hemispheres would be

1. twice
2. exactly the same as
3. half

what it was before.

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.

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

You are a passenger in a car and not wearing your seat belt. Without increasing or decreasing its speed, the car makes a sharp left turn, and you find yourself colliding with the right-hand door. Which is the correct analysis of the situation?

1. Before and after the collision, there is a rightward force pushing you into the door.
2. Starting at the time of collision, the door exerts a leftward force on you.
3. both of the above
4. neither of the above

Consider a horse pulling a buggy. Is the following statement true?

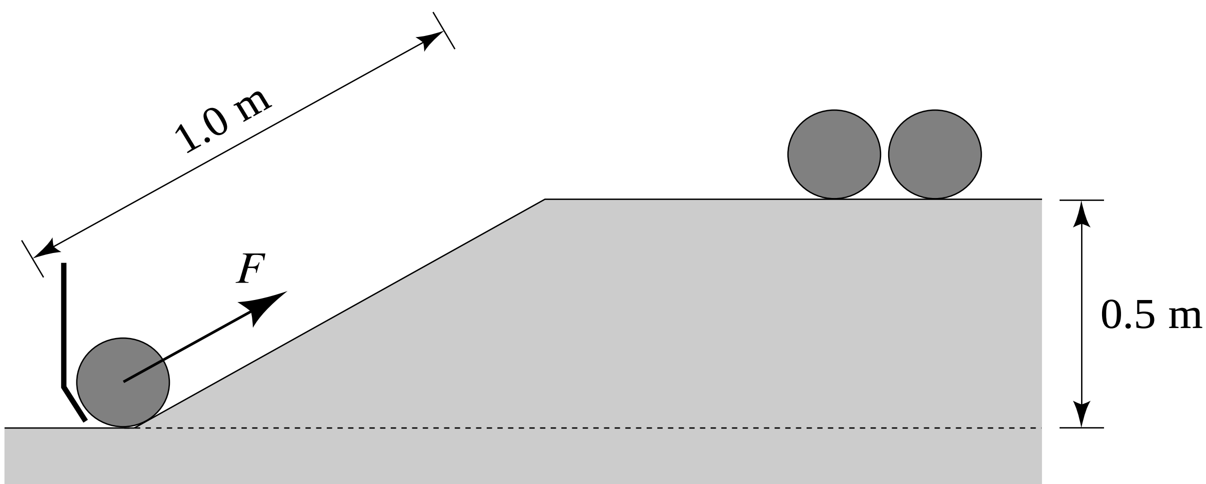
The weight of the horse and the normal force exerted by the ground on the horse constitute an interaction pair that are always equal and opposite according to Newton's third law.

1. yes
2. no

Consider a car at rest. 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

At the bowling alley, the ball-feeder mechanism must exert a force to push the bowling balls up a 1.0-m long ramp. The ramp leads the balls to a chute 0.5 m above the base of the ramp. Approximately how much force must be exerted on a 5.0-kg bowling ball?



1. 200 N
2. 50 N
3. 25 N
4. 5.0 N
5. impossible to determin

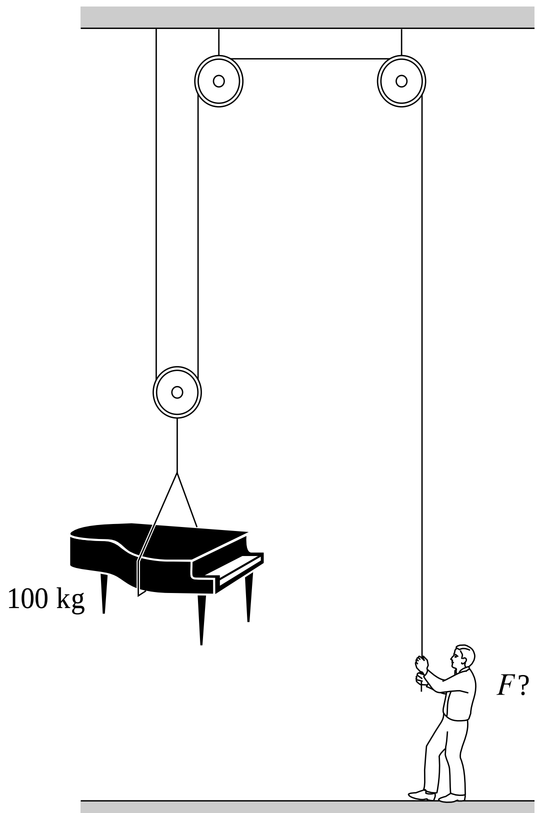
Two marbles, one twice as heavy as the other, are dropped to the ground from the roof of a building. Just before hitting the ground, the heavier marble has

1. as much kinetic energy as the lighter one.
2. twice as much kinetic energy as the lighter one.
3. half as much kinetic energy as the lighter one.
4. four times as much kinetic energy as the lighter one.
5. impossible to determine

Suppose you want to ride your mountain bike up a steep hill. Two paths lead from the base to the top, one twice as long as the other. Compared to the average force you would exert if you took the short path, the average force you exert along the longer path is

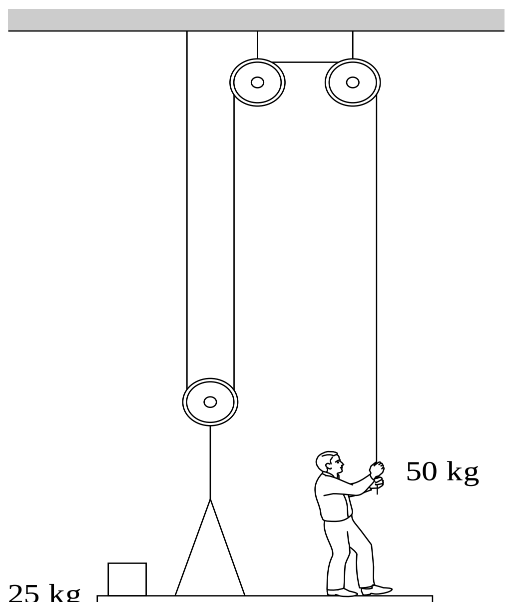
1. four times as small.
2. three times as small.
3. half as small.
4. the same.
5. undetermined—it depends on the time taken.

A piano mover raises a 100-kg piano at a constant rate using the frictionless pulley system shown here. With how much force is he pulling on the rope? Ignore friction and assume $g = 10$ m/s^2.



1. 2,000 N
2. 1,500 N
3. 1,000 N
4. 750 N
5. 500 N
6. 200 N
7. 50 N
8. impossible to determine

A 50-kg person stands on a 25-kg platform. He pulls on the rope that is attached to the platform via the frictionless pulley system shown here. If he pulls the platform up at a steady rate, with how much force is he pulling on the rope? Ignore friction and assume $g = 10\ \mathrm{m/s^2}$.



1. 750 N
2. 625 N
3. 500 N
4. 250 N
5. 75 N
6. 50 N
7. 25 N
8. impossible to determine

A block initially at rest is allowed to slide down a frictionless ramp and attains a speed v at the bottom. To achieve a speed $2v$ at the bottom, how many times as high must a new ramp be?

1. 1
2. 2
3. 3
4. 4
5. 5
6. 6

A spring-loaded toy dart gun is used to shoot a dart straight up in the air, and the dart reaches a maximum height of 24 m. The same dart is shot straight up a second time from the same gun, but this time the spring is compressed only half as far before firing. How far up does the dart go this time, neglecting friction and assuming an ideal spring?

1. 96 m
2. 48 m
3. 24 m
4. 12 m
5. 6 m
6. 3 m
7. impossible to determine

A sports car accelerates from zero to 30 mph in 1.5 s. How long does it take for it to accelerate from zero to 60 mph, assuming the power of the engine to be independent of velocity and neglecting friction?

1. 2 s
2. 3 s
3. 4.5 s
4. 6 s
5. 9 s
6. 12 s

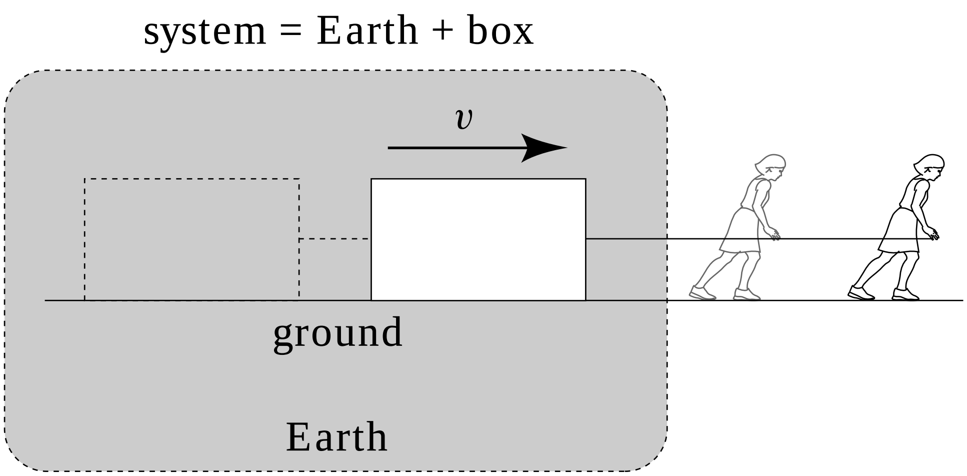
A cart on an air track is moving at 0.5 m/s when the air is suddenly turned off. The cart comes to rest after traveling 1 m. The experiment is repeated, but now the cart is moving at 1 m/s when the air is turned off. How far does the cart travel before coming to rest?

1. 1 m
2. 2 m
3. 3 m
4. 4 m
5. 5 m
6. impossible to determine

Suppose you drop a 1-kg rock from a height of 5 m above the ground. When it hits, how much force does the rock exert on the ground?

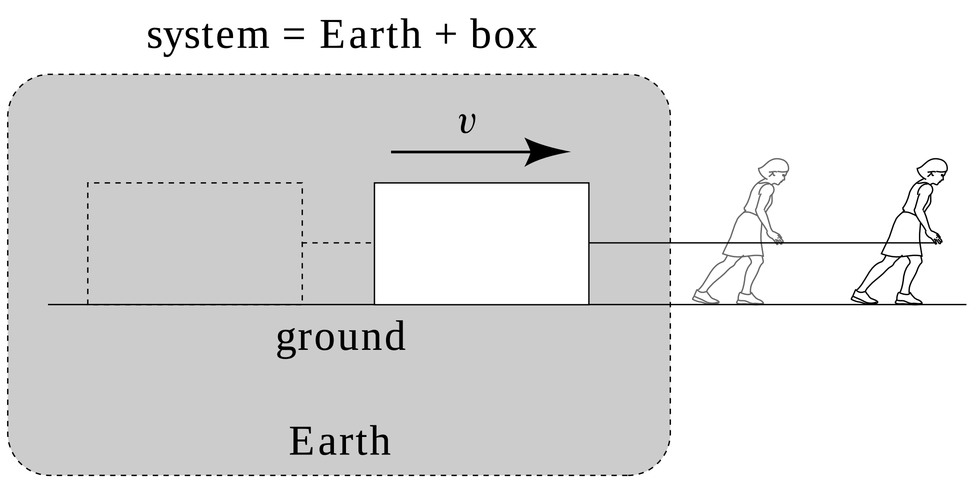
1. 0.2 N
2. 5 N
3. 50 N
4. 100 N
5. impossible to determine

A person pulls a box along the ground at a constant speed. If we consider Earth and the box as our system, what can we say about the net external force on the system?

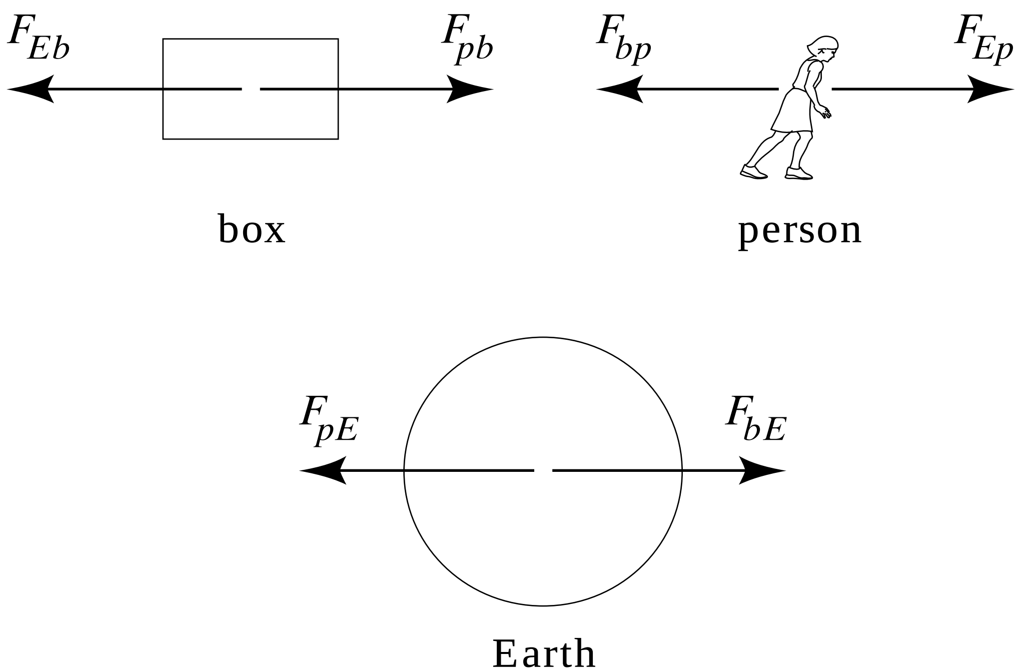


1. It is zero because the system is isolated.
2. It is nonzero because the system is not isolated.
3. It is zero even though the system is not isolated.
4. It is nonzero even though the system is isolated.
5. none of the above

A person pulls a box along the ground at a constant speed. If we consider Earth and the box as our system, the net force exerted by the person on the system is

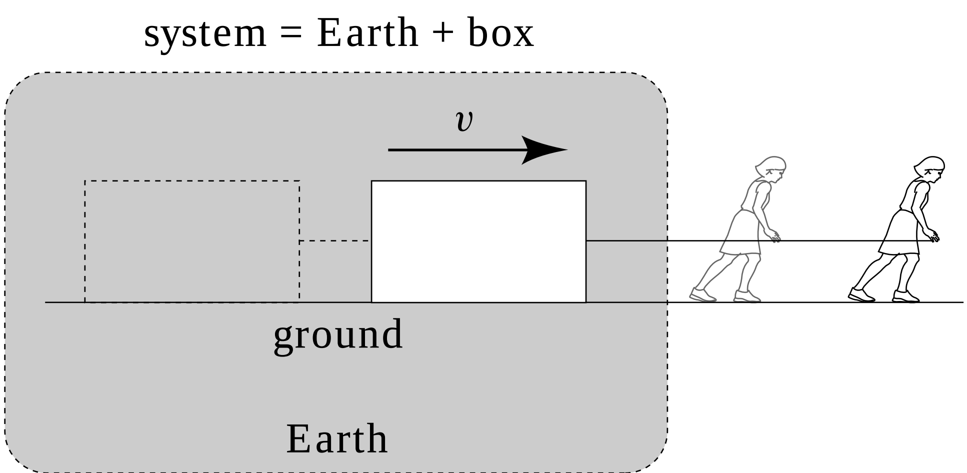


1. zero
2. nonzero



F_{Eb}
F_{pb}
F_{bp}
F_{Ep}
box
person
F_{pE}
F_{bE}
Earth

A person pulls a box along the ground at a constant speed. If we consider Earth and the box as our system, the work done by the person on the system is:



1. zero
2. nonzero

A stone is launched upward into the air. In addition to the force of gravity, the stone is subject to a frictional force due to air resistance. The time the stone takes to reach the top of its flight path is

1. larger than
2. equal to
3. smaller than

the time it takes to return from the top to its original position.

Which of the following depends on the inertial mass of an object (as opposed to its gravitational mass)?

1. the time the object takes to fall from a certain height
2. the weight of the object on a bathroom type spring scale
3. the acceleration given to the object by a compressed spring
4. the weight of the object on an ordinary balance

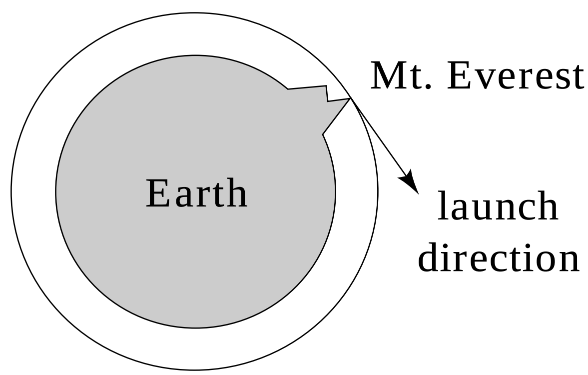
Two satellites A and B of the same mass are going around Earth in concentric orbits. The distance of satellite B from Earth's center is twice that of satellite A. What is the ratio of the centripetal force acting on B to that acting on A?

1. 1/8
2. 1/4
3. 1/2
4. $\sqrt{1/2}$
5. 1

Two satellites A and B of the same mass are going around Earth in concentric orbits. The distance of satellite B from Earth's center is twice that of satellite A. What is the ratio of the tangential speed of B to that of A?

1. $\frac{1}{2}$
2. $\sqrt{\frac{1}{2}}$
3. 1
4. $\sqrt{2}$
5. 2

Suppose Earth had no atmosphere and a ball were fired from the top of Mt. Everest in a direction tangent to the ground. If the initial speed were high enough to cause the ball to travel in a circular trajectory around Earth, the ball's acceleration would



1. be much less than g (because the ball doesn't fall to the ground).
2. be approximately g.
3. depend on the ball's speed.

A rock, initially at rest with respect to Earth and located an infinite distance away is released and accelerates toward Earth. An observation tower is built 3 Earth-radii high to observe the rock as it plummets to Earth. Neglecting friction, the rock's speed when it hits the ground is

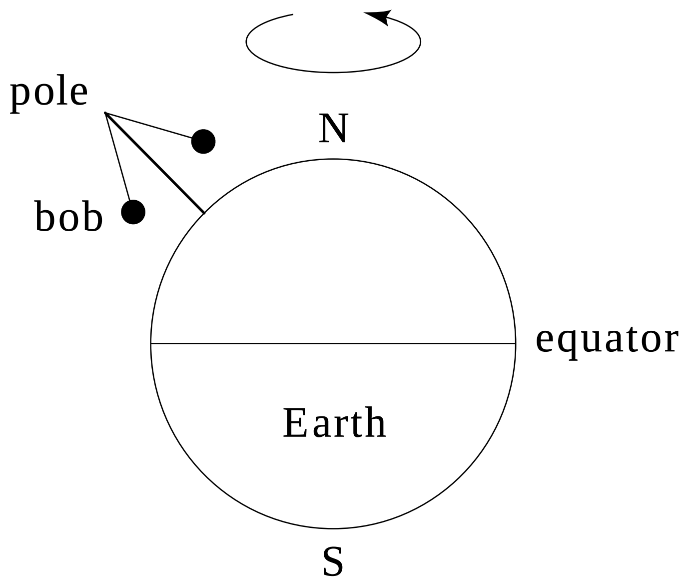
1. twice
2. three times
3. four times
4. six times
5. eight times
6. nine times
7. sixteen times

its speed at the top of the tower.

The Moon does not fall to Earth because

1. It is in Earth’s gravitational field.
2. The net force on it is zero.
3. It is beyond the main pull of Earth’s gravity.
4. It is being pulled by the Sun and planets as well as by Earth.
5. all of the above
6. none of the above

A pendulum bob is suspended from a long pole somewhere on the northern hemisphere. When the pendulum is at rest, the combined action of gravitation and Earth's rotation makes the bob



1. point straight down toward the center of Earth.
2. deviate toward the east.
3. deviate toward the west.
4. deviate toward the north.
5. deviate toward the south.
6. none of the above

An astronaut floating weightlessly in orbit shakes a large iron anvil rapidly back and forth. She reports back to Earth that

1. the shaking costs her no effort because the anvil has no inertial mass in space.
2. the shaking costs her some effort but considerably less than on Earth.
3. although weightless, the inertial mass of the anvil is the same as on Earth.

You are given two carts, A and B. They look identical, and you are told that they are made of the same material. You place A at rest on an air track and give B a constant velocity directed to the right so that it collides elastically with A. After the collision, both carts move to the right, the velocity of B being smaller than what it was before the collision. What do you conclude?

1. Cart A is hollow.
2. The two carts are identical.
3. Cart B is hollow.
4. need more information

Which of these systems are isolated?

A. While slipping on a patch of ice, a car collides totally inelastically with another car. *System:* both cars
B. Same situation as in A. *System:* slipping car
C. A single car slips on a patch of ice. *System:* car
D. A car makes an emergency stop on a road. *System:* car
E. A ball drops to Earth. *System:* ball
F. A billiard ball collides elastically with another billiard ball on a pool table. *System:* both balls

A car accelerates from rest. In doing so the absolute value of the car's momentum changes by a certain amount and that of the Earth changes by

1. a larger amount.
2. the same amount.
3. a smaller amount.
4. The answer depends on the interaction between the two.

A car accelerates from rest. It gains a certain amount of kinetic energy and Earth

1. gains more kinetic energy.
2. gains the same amount of kinetic energy.
3. gains less kinetic energy.
4. loses kinetic energy as the car gains it.

Suppose the entire population of the world gathers in one spot and, at the sounding of a prearranged signal, everyone jumps up. While all the people are in the air, does Earth gain momentum in the opposite direction?

1. No; the inertial mass of Earth is so large that the planet's change in motion is imperceptible.
2. Yes; because of its much larger inertial mass, however, the change in momentum of Earth is much less than that of all the jumping people.
3. Yes; Earth recoils, like a rifle firing a bullet, with a change in momentum equal to and opposite that of the people.
4. It depends.

Suppose the entire population of the world gathers in one spot and, at the sound of a prearranged signal, everyone jumps up. About a second later, 5 billion people land back on the ground. After the people have landed, Earth's momentum is

1. the same as what it was before the people jumped.
2. different from what it was before the people jumped.

Suppose rain falls vertically into an open cart rolling along a straight horizontal track with negligible friction. As a result of the accumulating water, the speed of the cart

1. increases.
2. does not change.
3. decreases.

Suppose rain falls vertically into an open cart rolling along a straight horizontal track with negligible friction. As a result of the accumulating water, the kinetic energy of the cart

1. increases.
2. does not change.
3. decreases.

Consider these situations:

(*i*) a ball moving at speed v is brought to rest;

(*ii*) the same ball is projected from rest so that it moves at speed v;

(*iii*) the same ball moving at speed v is brought to rest and then projected backward to its original speed.

In which case(s) does the ball undergo the largest change in momentum?

1. (*i*)
2. (*i*) and (*ii*)
3. (*i*), (*ii*), and (*iii*)
4. (*ii*)
5. (*ii*) and (*iii*)
6. (*iii*)

Consider two carts, of masses m and $2m$, at rest on an air track. If you push first one cart for 3 s and then the other for the same length of time, exerting equal force on each, the momentum of the light cart is

1. four times
2. twice
3. equal to
4. one-half
5. one-quarter

the momentum of the heavy cart.

Consider two carts, of masses m and $2m$, at rest on an air track. If you push first one cart for 3 s and then the other for the same length of time, exerting equal force on each, the kinetic energy of the light cart is

1. larger than
2. equal to
3. smaller than

the kinetic energy of the heavy car.

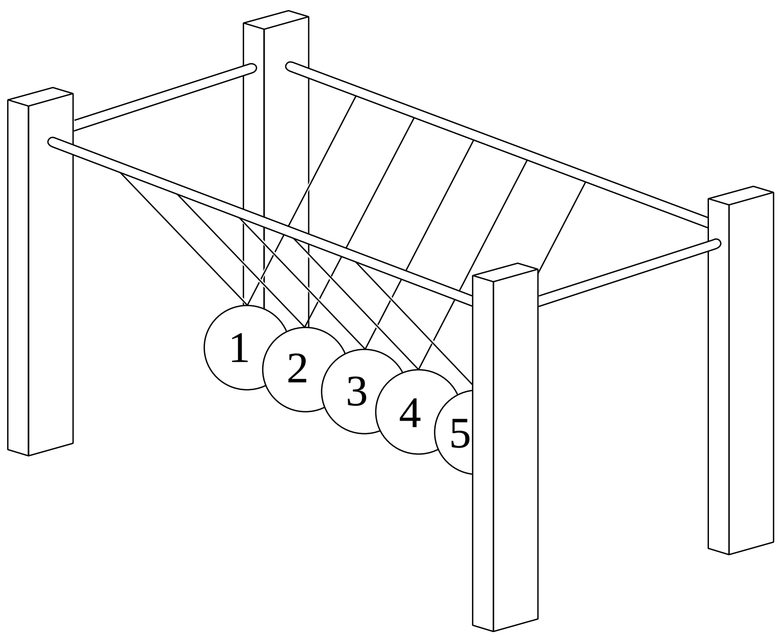
Suppose a ping-pong ball and a bowling ball are rolling toward you. Both have the same momentum, and you exert the same force to stop each. How do the time intervals to stop them compare?

1. It takes less time to stop the ping-pong ball.
2. Both take the same time.
3. It takes more time to stop the ping-pong ball.

Suppose a ping-pong ball and a bowling ball are rolling toward you. Both have the same momentum, and you exert the same force to stop each. How do the distances needed to stop them compare?

1. It takes a shorter distance to stop the ping-pong ball.
2. Both take the same distance.
3. It takes a longer distance to stop the ping-pong ball.

If ball 1 in the arrangement shown here is pulled back and then let go, ball 5 bounces forward. If balls 1 and 2 are pulled back and released, balls 4 and 5 bounce forward, and so on. The number of balls bouncing on each side is equal because



1. of conservation of momentum.
2. the collisions are all elastic.
3. neither of the above

A cart moving at speed v collides with an identical stationary cart on an airtrack, and the two stick together after the collision. What is their velocity after colliding?

1. v
2. $0.5\ v$
3. zero
4. $-0.5\ v$
5. $-v$
6. need more information

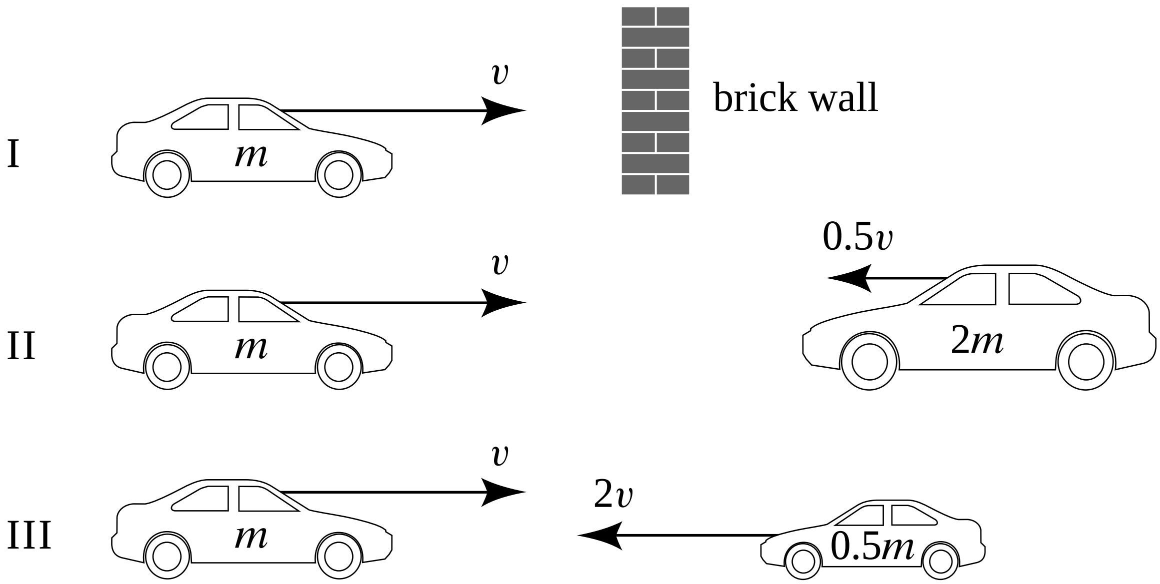
A person attempts to knock down a large wooden bowling pin by throwing a ball at it. The person has two balls of equal size and mass, one made of rubber and the other of putty. The rubber ball bounces back, while the ball of putty sticks to the pin. Which ball is most likely to topple the bowling pin?

1. the rubber ball
2. the ball of putty
3. makes no difference
4. need more information

Think fast! You've just driven around a curve in a narrow, one-way street at 25 mph when you notice a car identical to yours coming straight toward you at 25 mph. You have only two options: hitting the other car head on or swerving into a massive concrete wall, also head on. In the split second before the impact, you decide to

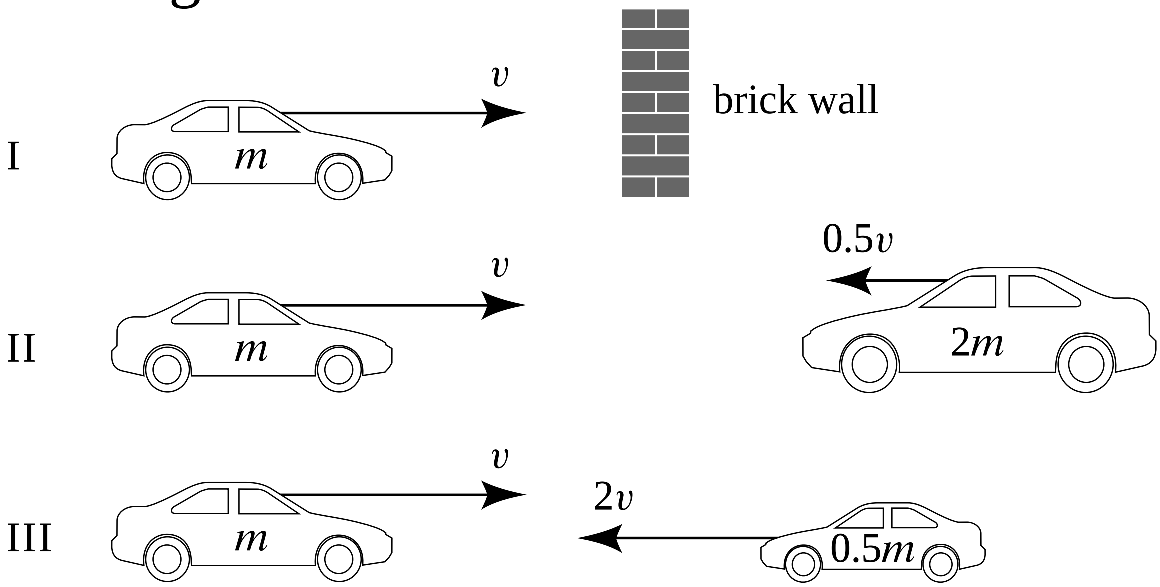
1. hit the other car.
2. hit the wall.
3. hit either one—it makes no difference.
4. consult your lecture notes.

If all three collisions in the figure shown here are totally inelastic, which bring(s) the car on the left to a halt?



1. I
2. II
3. III
4. I, II
5. I, III
6. II, III
7. all three

If all three collisions in the figure shown are totally inelastic, which cause(s) the most damage?



1. I
2. II
3. III
4. I, II
5. I, III
6. II, III
7. all three

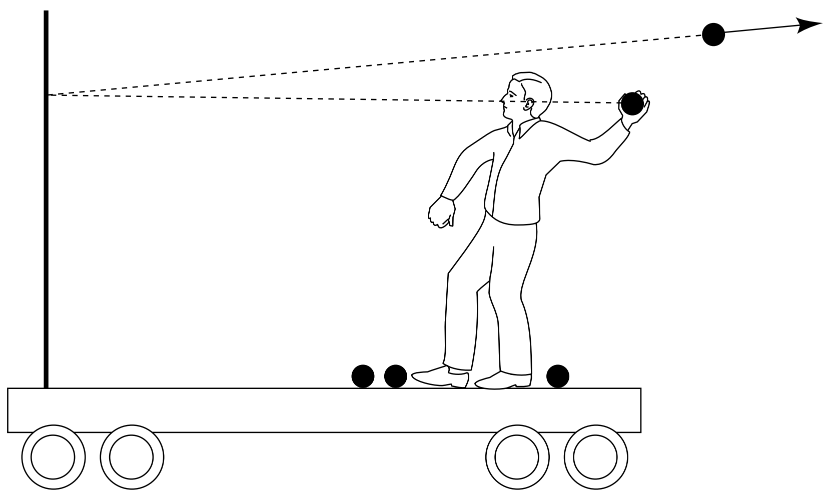
A golf ball is fired at a bowling ball initially at rest and bounces back elastically. Compared to the bowling ball, the golf ball after the collision has

1. more momentum but less kinetic energy.
2. more momentum and more kinetic energy.
3. less momentum and less kinetic energy.
4. less momentum but more kinetic energy.
5. none of the above

A golf ball is fired at a bowling ball initially at rest and sticks to it. Compared to the bowling ball, the golf ball after the collision has

1. more momentum but less kinetic energy.
2. more momentum and more kinetic energy.
3. less momentum and less kinetic energy.
4. less momentum but more kinetic energy.
5. none of the above

Suppose you are on a cart, initially at rest on a track with very little friction. You throw balls at a partition that is rigidly mounted on the cart. If the balls bounce straight back as shown in the figure, is the cart put in motion?



1. Yes, it moves to the right.
2. Yes, it moves to the left.
3. No, it remains in place.

A compact car and a large truck collide head on and stick together. Which undergoes the larger momentum change?

1. car
2. truck
3. The momentum change is the same for both vehicles.
4. Can't tell without knowing the final velocity of combined mass.

A compact car and a large truck collide head on and stick together. Which vehicle undergoes the larger acceleration during the collision?

1. car
2. truck
3. Both experience the same acceleration.
4. Can’t tell without knowing the final velocity of combined mass.

Is it possible for a stationary object that is struck by a moving object to have a larger final momentum than the initial momentum of the incoming object?

1. Yes.
2. No because such an occurrence would violate the law of conservation of momentum.

Two carts of identical inertial mass are put back-to-back on a track. Cart A has a spring-loaded piston; cart B is entirely passive. When the piston is released, it pushes against cart B, and

1. A is put in motion but B remains at rest.
2. both carts are set into motion, with A gaining more speed than B.
3. both carts gain equal speed but in opposite directions.
4. both carts are set into motion, with B gaining more speed than A.
5. B is put in motion but A remains at rest.

Two carts are put back-to-back on a track. Cart A has a spring-loaded piston; cart B, which has twice the inertial mass of cart A, is entirely passive. When the piston is released, it pushes against cart B, and the carts move apart. How do the magnitudes of the final momenta and kinetic energies compare?

1. $p_A > p_B, k_A > k_B$
2. $p_A > p_B, k_A = k_B$
3. $p_A > p_B, k_A < k_B$
4. $p_A = p_B, k_A > k_B$
5. $p_A = p_B, k_A = k_B$
6. $p_A = p_B, k_A < k_B$
7. $p_A < p_B, k_A > k_B$
8. $p_A < p_B, k_A = k_B$
9. $p_A < p_B, k_A < k_B$

Two carts are put back-to-back on a track. Cart A has a spring-loaded piston; cart B, which has twice the inertial mass of cart A, is entirely passive. When the piston is released, it pushes against cart B, and the carts move apart. Ignoring signs, while the piston is pushing,

1. A has a larger acceleration than B.
2. the two have the same acceleration.
3. B has a larger acceleration than A.

Two people on roller blades throw a ball back and forth. After a couple of throws, they are (ignore friction)

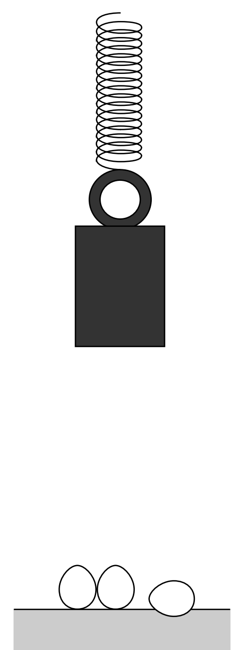
1. standing where they were initially.
2. standing farther away from each other.
3. standing closer together.
4. moving away from each other.
5. moving toward each other.

Two people on roller blades throw a ball back and forth. Which statement(s) is/are true?

A. The interaction mediated by the ball is repulsive.
B. If we film the action and play the movie backward, the interaction appears attractive.
C. The total momentum of the two people is conserved.
D. The total energy of the two people is conserved.

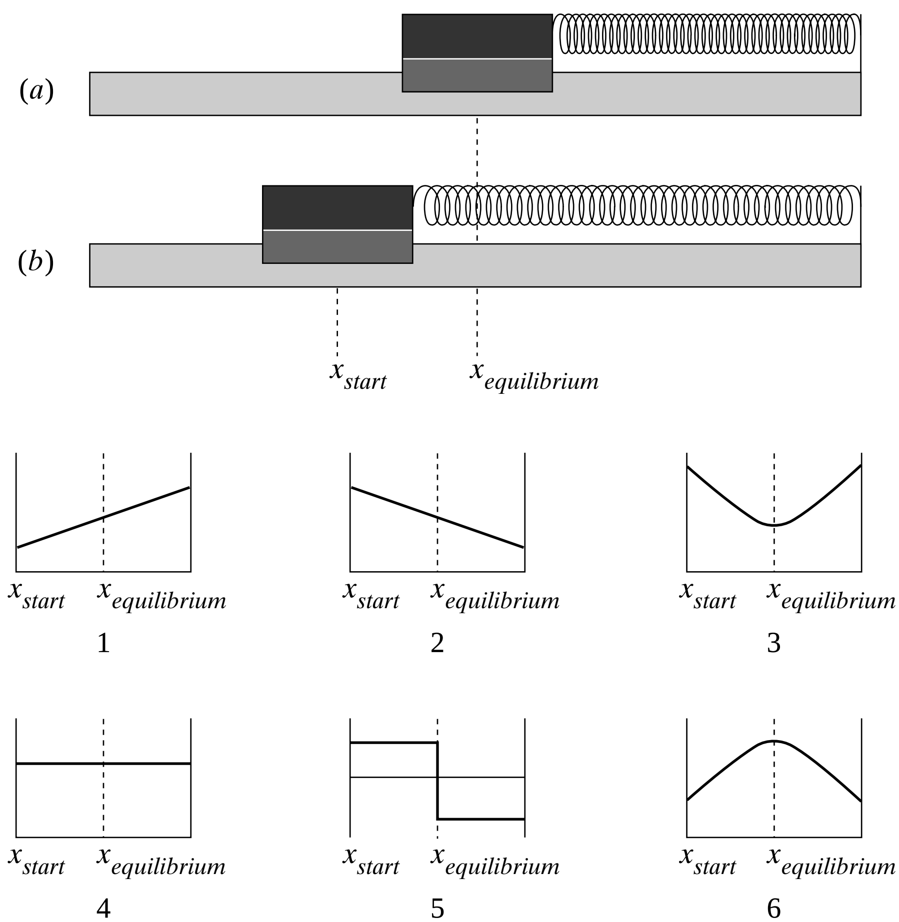
What about the conservation laws? The ball carries both momentum and energy back and forth between the two roller-bladers. Their momentum and energy therefore cannot be conserved.

In the following figure, a 10-kg weight is suspended from the ceiling by a spring. The weight-spring system is at equilibrium with the bottom of the weight about 1 m above the floor. The spring is then stretched until the weight is just above the eggs. When the spring is released, the weight is pulled up by the contracting spring and then falls back down under the influence of gravity. On the way down, it



1. reverses its direction of travel well above the eggs.
2. reverses its direction of travel precisely as it reaches the eggs.
3. makes a mess as it crashes into the eggs.

In part (*a*) of the figure, an air track cart attached to a spring rests on the track at the position $x_{equilibrium}$ and the spring is relaxed. In (*b*), the cart is pulled to the position x_{start} and released. It then oscillates about $x_{equilibrium}$. Which graph correctly represents the potential energy of the spring as a function of the position of the cart?



Two cars, one twice as heavy as the other, are at rest on a horizontal track. A person pushes each car for 5 s. Ignoring friction and assuming equal force exerted on both cars, the momentum of the light car after the push is

1. smaller than
2. equal to
3. larger than

the momentum of the heavy car.

Two cars, one twice as heavy as the other, are at rest on a horizontal track. A person pushes each car for 5 s. Ignoring friction and assuming equal force exerted on both cars, the kinetic energy of the light car after the push is

1. smaller than
2. equal to
3. larger than

the kinetic energy of the heavy car.

When a small ball collides elastically with a more massive ball initially at rest, the massive ball tends to remain at rest, whereas the small ball bounces back at almost its original speed. Now consider a massive ball of inertial mass M moving at speed v and striking a small ball of inertial mass m initially at rest. The change in the small ball's momentum is

1. Mv
2. $2Mv$
3. mv
4. $2mv$
5. none of the above

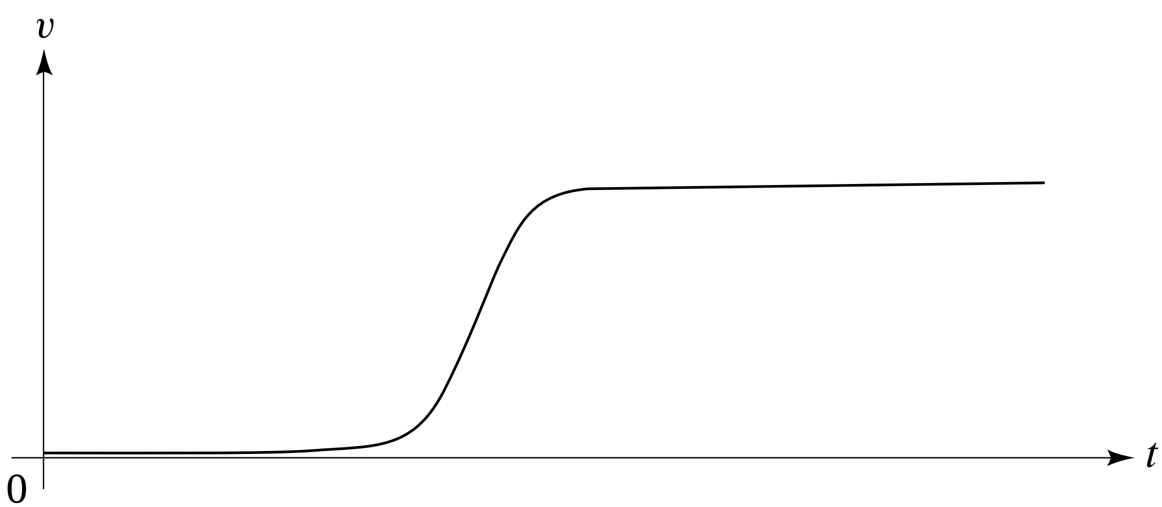
A small rubber ball is put on top of a volleyball, and the combination is dropped from a certain height. Compared to the speed it has just before the volleyball hits the ground, the speed with which the rubber ball rebounds is

1. the same.
2. twice as large.
3. three times as large.
4. four times as large.
5. none of the above

Suppose you are sitting in a soundproof, windowless room aboard a hovercraft moving over flat terrain. Which of the following can you detect from inside the room?

1. rotation
2. deviation from the horizontal orientation
3. motion at a steady speed
4. acceleration
5. state of rest with respect to ground

An air track cart initially at rest is put in motion when a compressed spring is released and pushes the cart. In the frame of reference of Earth, the velocity-versus-time graph of the cart is shown here. In a frame moving at constant speed relative to Earth, the cart's change in the following quantities can have any value:



1. velocity
2. momentum
3. kinetic energy
4. none of the above

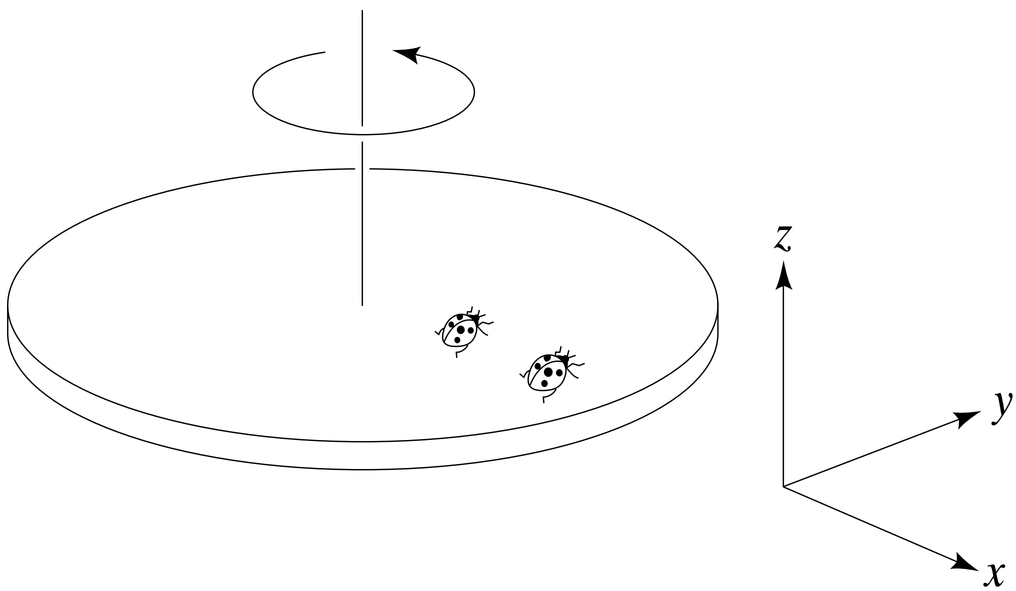
An air track cart initially at rest is put in motion when a compressed spring is released and pushes the cart. Earth and the cart constitute an isolated system. The change in the cart's kinetic energy is different in the frame of reference of Earth and in a frame moving at constant speed relative to Earth because in the moving frame:

1. conservation of energy does not apply.
2. the amount of energy released by the spring is different.
3. the change in the kinetic energy of Earth is different.
4. a combination of 2 and 3.
5. none of the above

Two objects collide inelastically. Can all the initial kinetic energy in the collision be converted to other forms of energy?

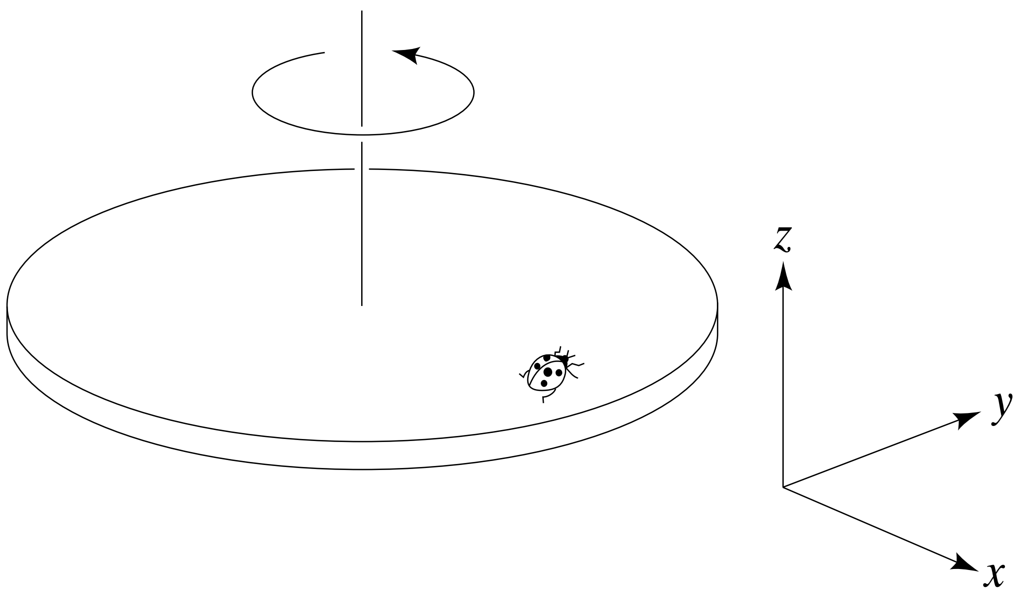
1. Yes, but only for certain special initial speeds.
2. Yes, provided the objects are soft enough.
3. No, this violates a fundamental law of physics.
4. none of the above

A ladybug sits at the outer edge of a merry-go-round, and a gentleman bug sits halfway between her and the axis of rotation. The merry-go-round makes a complete revolution once each second. The gentleman bug's angular speed is



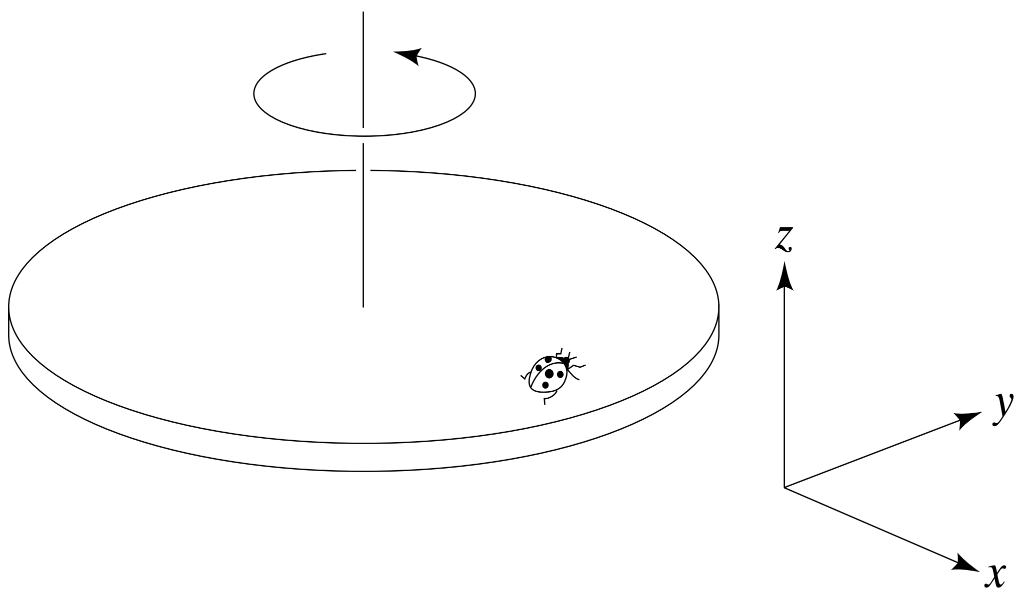
1. half the ladybug's.
2. the same as the ladybug's.
3. twice the ladybug's.
4. impossible to determine

A ladybug sits at the outer edge of a merry-go-round, that is turning and slowing down. At the instant shown in the figure, the radial component of the ladybug's (Cartesian) acceleration is



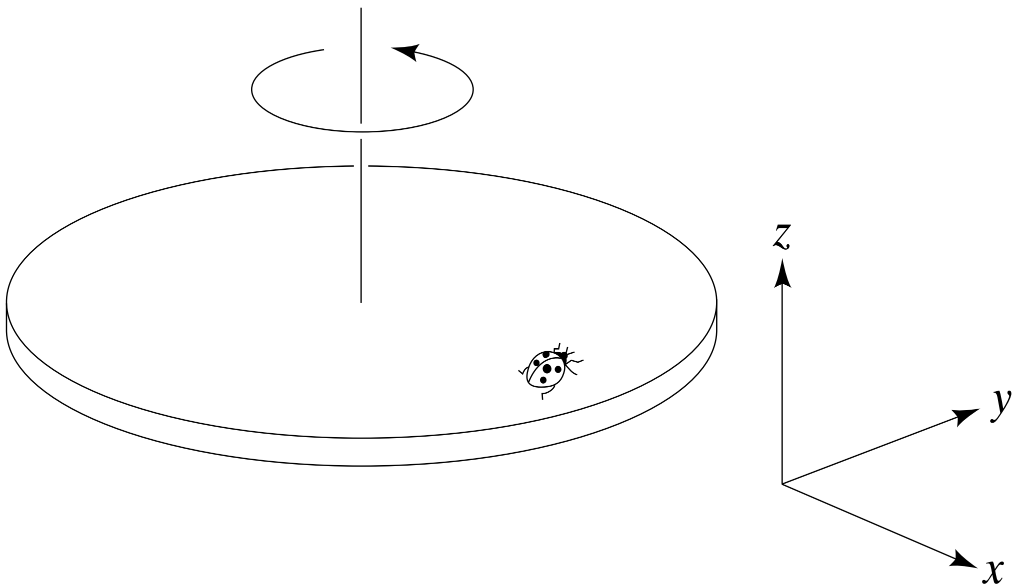
1. in the $+x$ direction.
2. in the $-x$ direction.
3. in the $+y$ direction.
4. in the $-y$ direction.
5. in the $+z$ direction.
6. in the $-z$ direction.
7. zero.

A ladybug sits at the outer edge of a merry-go-round that is turning and slowing down. The tangential component of the ladybug's (Cartesian) acceleration is



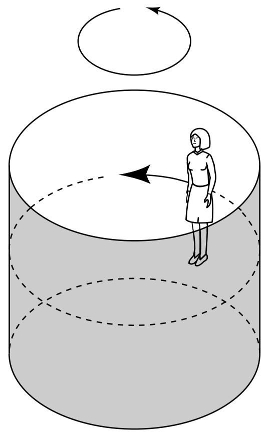
1. in the $+x$ direction.
2. in the $-x$ direction.
3. in the $+y$ direction.
4. in the $-y$ direction.
5. in the $+z$ direction.
6. in the $-z$ direction.
7. zero.

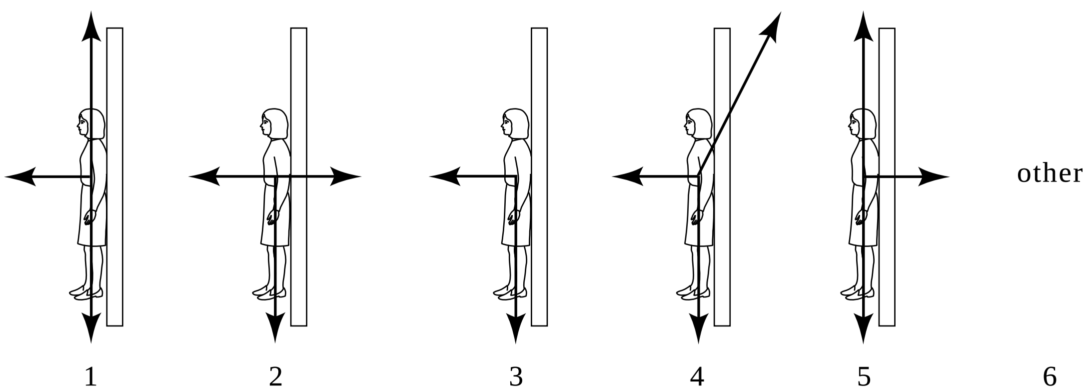
A ladybug sits at the outer edge of a merry-go-round that is turning and is slowing down. The vector expressing her angular velocity is



1. in the $+x$ direction.
2. in the $-x$ direction.
3. in the $+y$ direction.
4. in the $-y$ direction.
5. in the $+z$ direction.
6. in the $-z$ direction.
7. zero.

A rider in a "barrel of fun" finds herself stuck with her back to the wall. Which diagram correctly shows the forces acting on her?





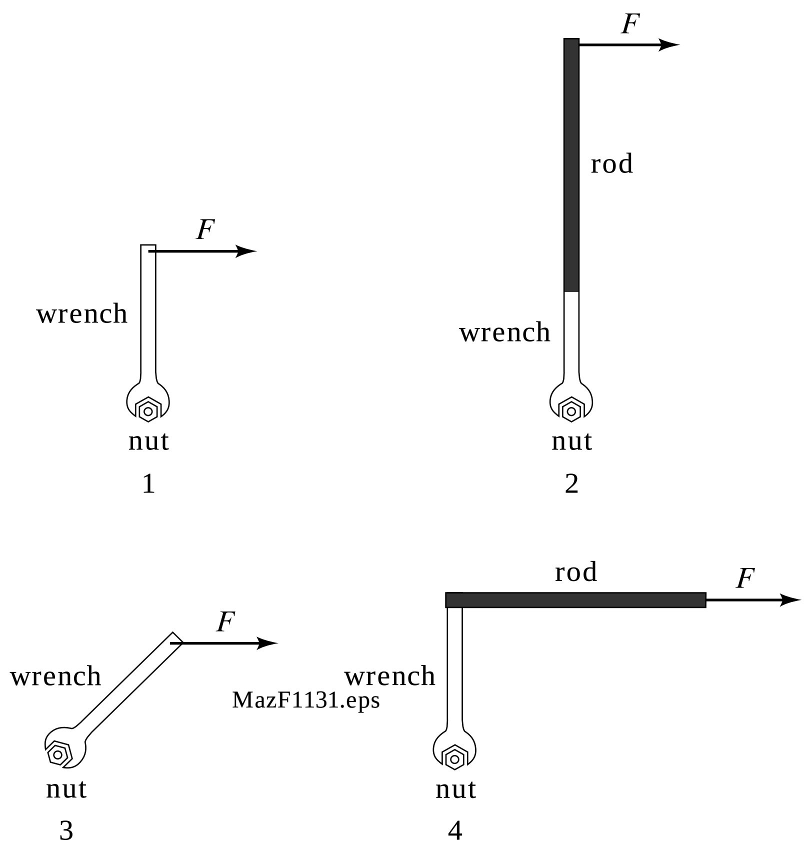
Consider two people on opposite sides of a rotating merry-go-round. One of them throws a ball toward the other. In which frame of reference is the path of the ball straight when viewed from above: (*a*) the frame of the merry-go-round or (*b*) that of Earth?

1. (*a*) only
2. (*a*) and (*b*)—although the paths appear to curve
3. (*b*) only
4. neither; because it's thrown while in circular motion, the ball travels along a curved path.

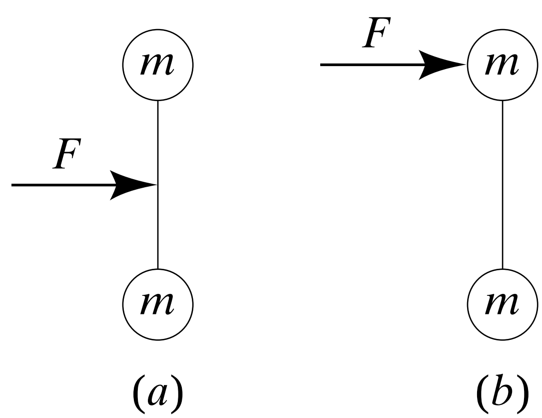
You are trying to open a door that is stuck by pulling on the doorknob in a direction perpendicular to the door. If you instead tie a rope to the doorknob and then pull with the same force, is the torque you exert increased?

1. yes
2. no

You are using a wrench and trying to loosen a rusty nut. Which of the arrangements shown is most effective in loosening the nut? List in order of descending efficiency the following arrangements:

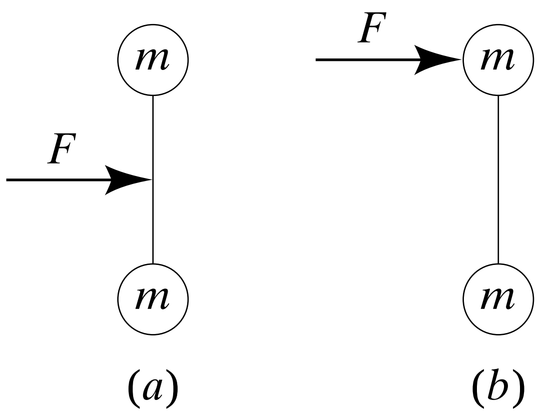


A force F is applied to a dumbbell for a time interval Δt, first as in (a) and then as in (b). In which case does the dumbbell acquire the greater center-of-mass speed?



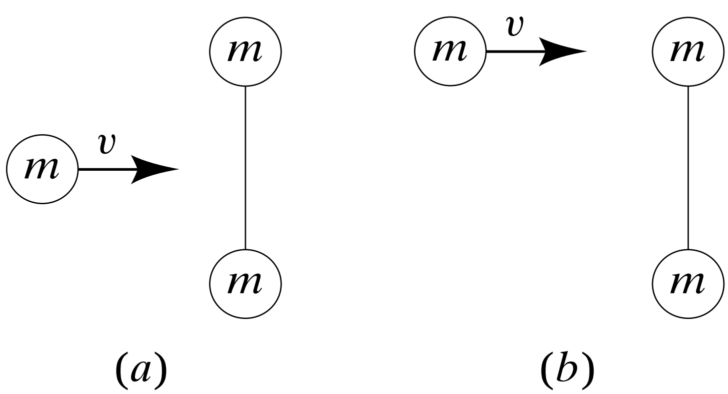
1. (a)
2. (b)
3. no difference
4. The answer depends on the rotational inertia of the dumbbell.

A force F is applied to a dumbbell for a time interval Δt, first as in (a) and then as in (b). In which case does the dumbbell acquire the greater energy?



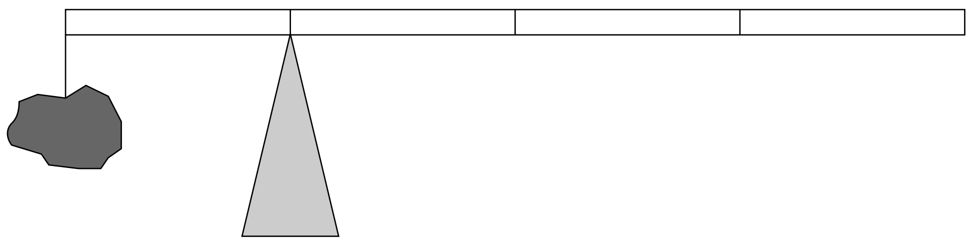
1. (a)
2. (b)
3. no difference
4. The answer depends on the rotational inertia of the dumbbell.

Imagine hitting a dumbbell with an object coming in at speed v, first at the center, then at one end. Is the center-of-mass speed of the dumbbell the same in both cases?



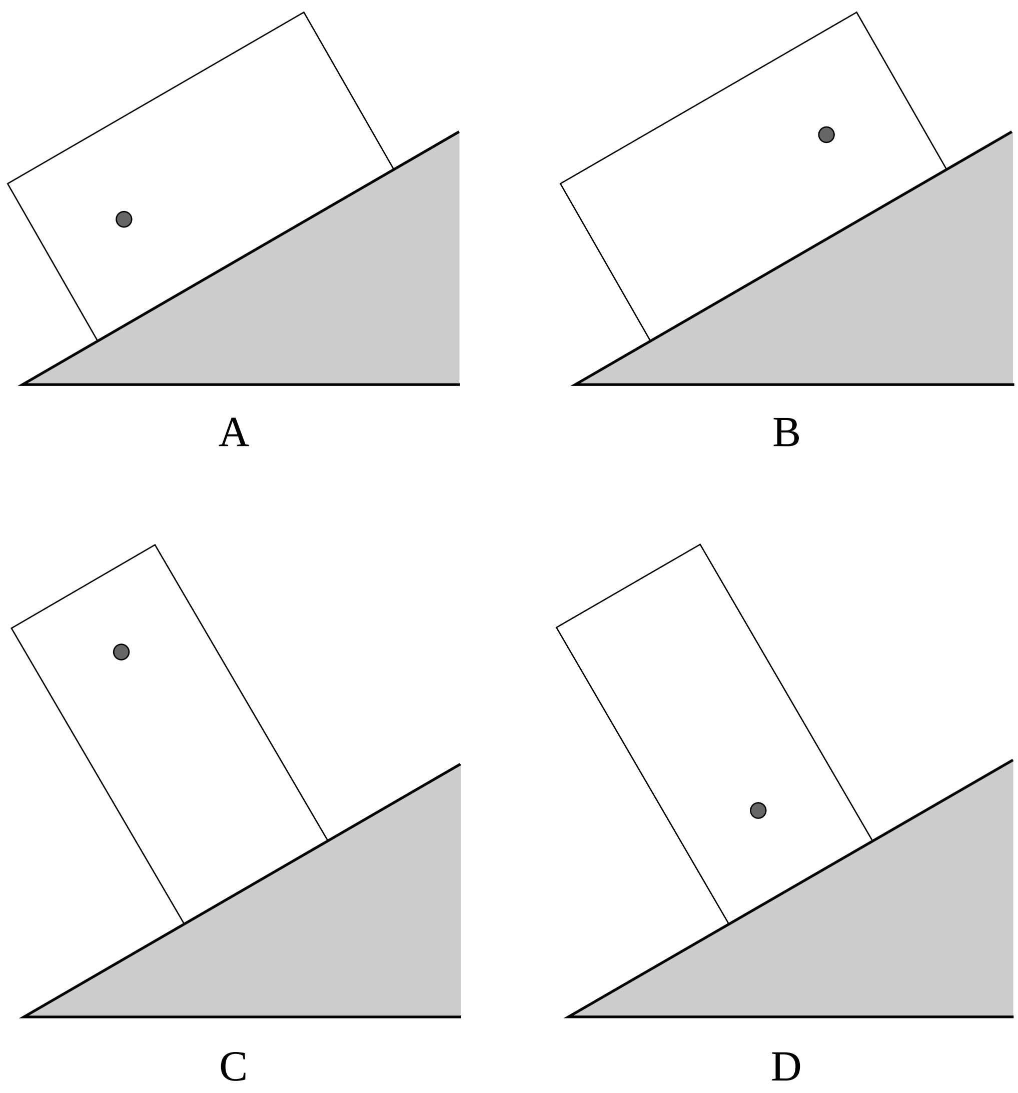
1. yes
2. no

A 1-kg rock is suspended by a massless string from one end of a 1-m measuring stick. What is the weight of the measuring stick if it is balanced by a support force at the 0.25-m mark?

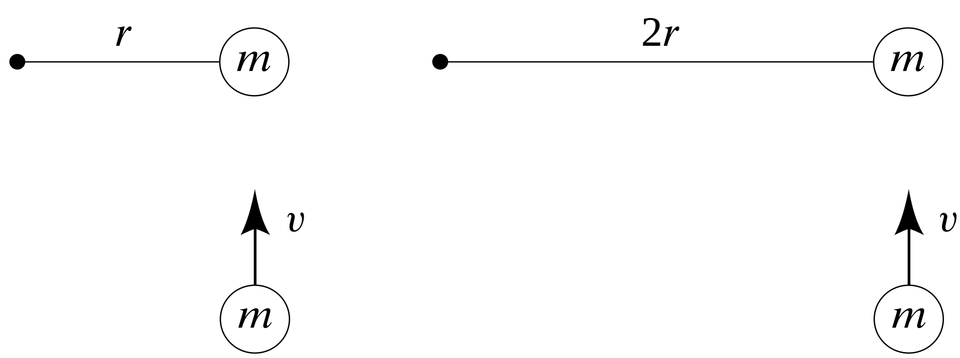


1. 0.25 kg
2. 0.5 kg
3. 1 kg
4. 2 kg
5. 4 kg
6. impossible to determine

A box, with its center-of-mass off-center as indicated by the dot, is placed on an inclined plane. In which of the four orientations shown, if any, does the box tip over?



Consider the situation shown at left below. A puck of mass m, moving at speed v hits an identical puck which is fastened to a pole using a string of length r. After the collision, the puck attached to the string revolves around the pole. Suppose we now lengthen the string by a factor 2, as shown on the right, and repeat the experiment. Compared to the angular speed in the first situation, the new angular speed is



1. twice as high
2. the same
3. half as much
4. none of the above

A figure skater stands on one spot on the ice (assumed frictionless) and spins around with her arms extended. When she pulls in her arms, she reduces her rotational inertia and her angular speed increases so that her angular momentum is conserved. Compared to her initial rotational kinetic energy, her rotational kinetic energy after she has pulled in her arms must be

1. the same.
2. larger because she's rotating faster.
3. smaller because her rotational inertia is smaller.

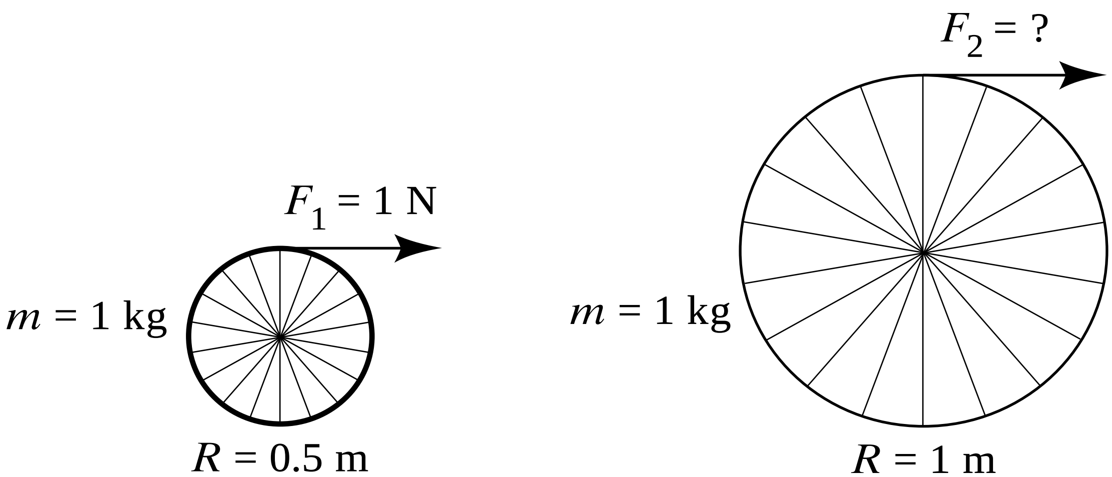
Two cylinders of the same size and mass roll down an incline. Cylinder A has most of its weight concentrated at the rim, while cylinder B has most of its weight concentrated at the center. Which reaches the bottom of the incline first?

1. A
2. B
3. Both reach the bottom at the same time.

A solid disk and a ring roll down an incline. The ring is slower than the disk if

1. $m_{ring} = m_{disk}$, where m is the inertial mass.
2. $r_{ring} = r_{disk}$, where r is the radius.
3. $m_{ring} = m_{disk}$ and $r_{ring} = r_{disk}$.
4. The ring is always slower regardless of the relative values of m and r.

Two wheels with fixed hubs, each having a mass of 1 kg, start from rest, and forces are applied as shown. Assume the hubs and spokes are massless, so that the rotational inertia is $I = mR^2$. In order to impart identical angular accelerations, how large must F_2 be?

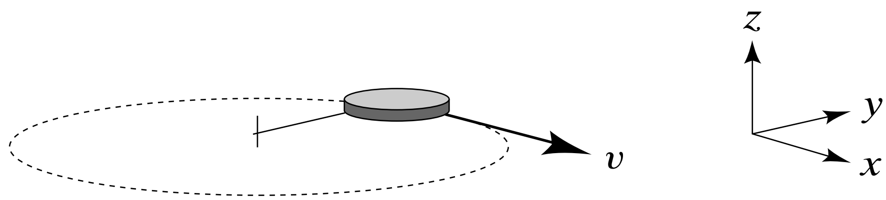


1. 0.25 N
2. 0.5 N
3. 1 N
4. 2 N
5. 4 N

Two wheels initially at rest roll the same distance without slipping down identical inclined planes starting from rest. Wheel B has twice the radius but the same mass as wheel A. All the mass is concentrated in their rims, so that the rotational inertias are $I = mR^2$. Which has more translational kinetic energy when it gets to the bottom?

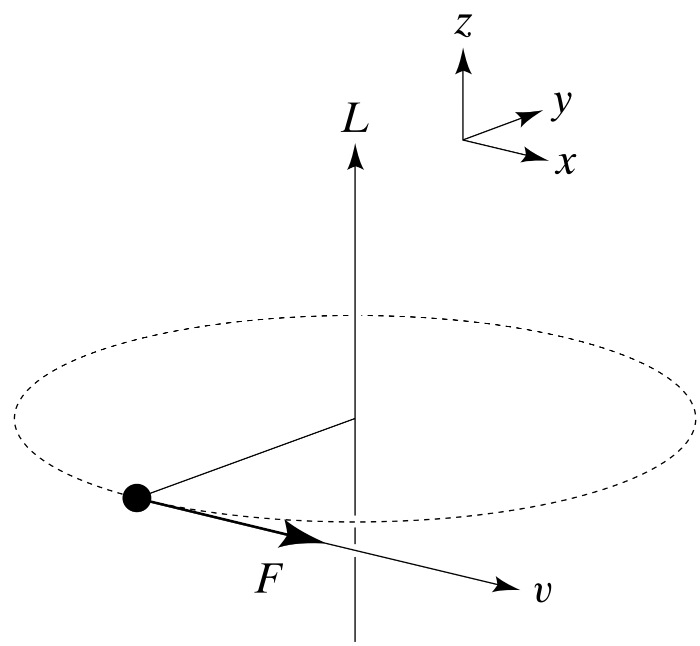
1. Wheel A
2. Wheel B
3. The kinetic energies are the same.
4. need more information

Consider the uniformly rotating object shown below. If the object's angular velocity is a vector (in other words, it points in a certain direction in space) is there a particular direction we should associate with the angular velocity?



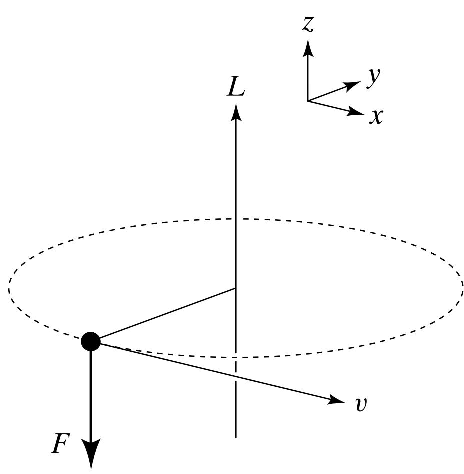
1. yes, $\pm x$
2. yes, $\pm y$
3. yes, $\pm z$
4. yes, some other direction
5. no, the choice is really arbitrary

A person spins a tennis ball on a string in a horizontal circle (so that the axis of rotation is vertical). At the point indicated below, the ball is given a sharp blow in the forward direction. This causes a change in angular momentum ΔL in the

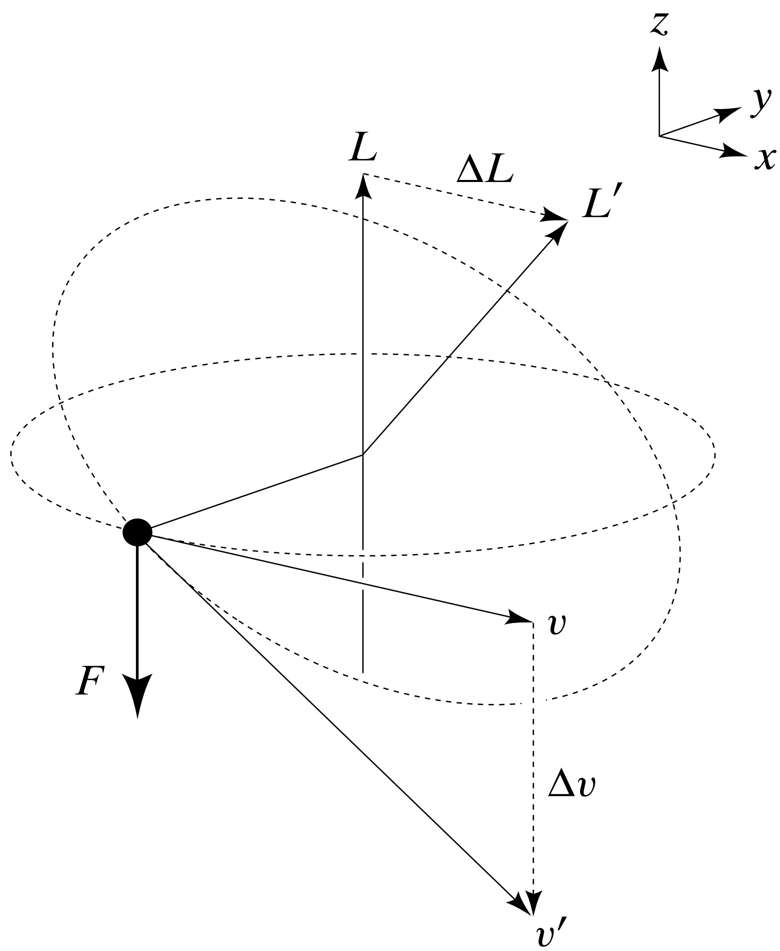


1. x direction
2. y direction
3. z direction

A person spins a tennis ball on a string in a horizontal circle (so that the axis of rotation is vertical). At the point indicated below, the ball is given a sharp blow vertically downward. In which direction does the axis of rotation tilt after the blow?

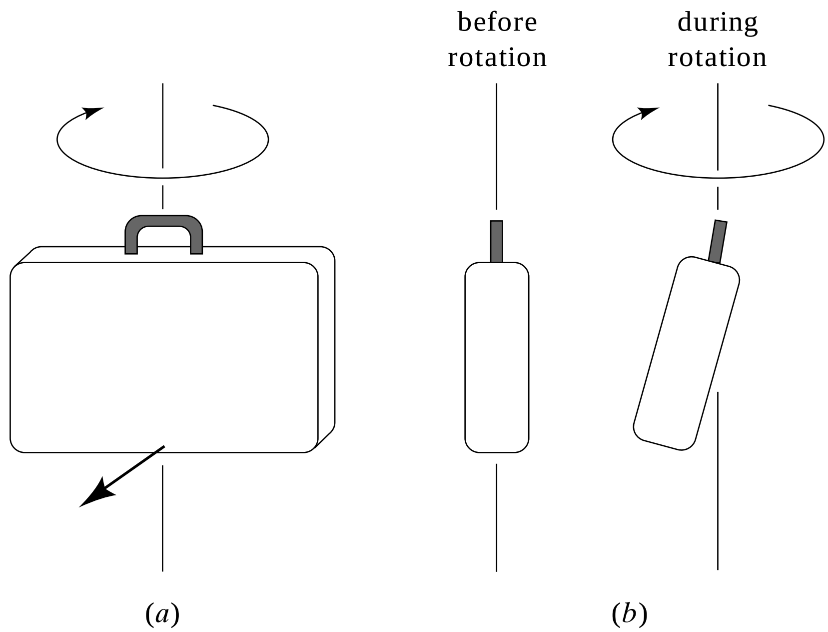


1. $+x$ direction
2. $-x$ direction
3. $+y$ direction
4. $-y$ direction
5. It stays the same (but the magnitude of the angular momentum changes).
6. The ball starts wobbling in all directions.



z
y
x
L
ΔL
L′
v
F
Δv
v′

A suitcase containing a spinning flywheel is rotated about the vertical axis as shown in (*a*). As it rotates, the bottom of the suitcase moves out and up, as in (*b*). From this, we can conclude that the flywheel, as seen from the side of the suitcase as in (*a*), rotates



1. clockwise.
2. counterclockwise.

An object is in equilibrium when the net force and the net torque on it is zero. Which of the following statements is/are correct for an object in an inertial frame of reference?

A. Any object in equilibrium is at rest.
B. An object in equilibrium need not be at rest.
C. An object at rest must be in equilibrium.

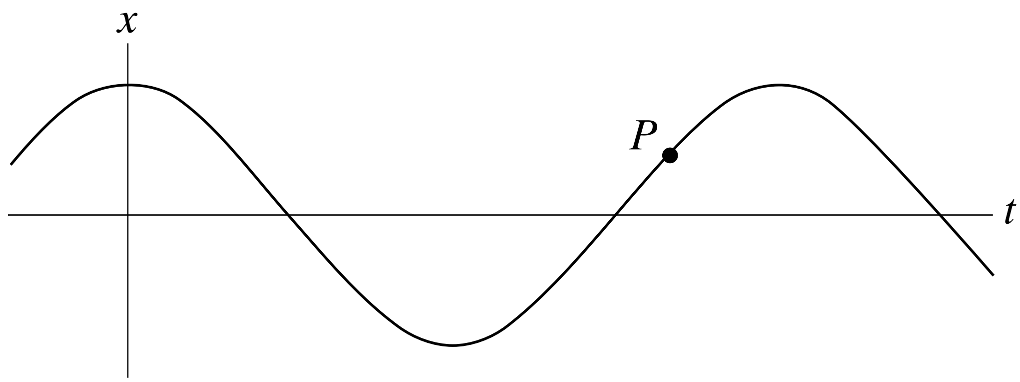
An object can oscillate around

1. any equilibrium point.
2. any stable equilibrium point.
3. certain stable equilibrium points.
4. any point, provided the forces exerted on it obey Hooke's law.
5. any point.

Which of the following is necessary to make an object oscillate?

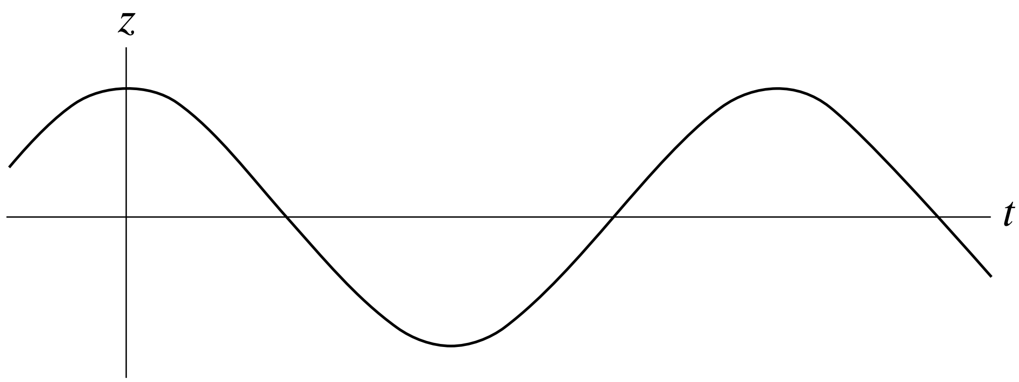
A. a stable equilibrium
B. little or no friction
C. a disturbance

A mass attached to a spring oscillates back and forth as indicated in the position vs. time plot below. At point *P*, the mass has



1. positive velocity and positive acceleration.
2. positive velocity and negative acceleration.
3. positive velocity and zero acceleration.
4. negative velocity and positive acceleration.
5. negative velocity and negative acceleration.
6. negative velocity and zero acceleration.
7. zero velocity but is accelerating (positively or negatively).
8. zero velocity and zero acceleration.

A mass suspended from a spring is oscillating up and down as indicated. Consider two possibilities: (*i*) at some point during the oscillation the mass has zero velocity but is accelerating (positively or negatively); (*ii*) at some point during the oscillation the mass has zero velocity and zero acceleration.



1. Both occur sometime during the oscillation.
2. Neither occurs during the oscillation.
3. Only (*i*) occurs.
4. Only (*ii*) occurs.

An object hangs motionless from a spring. When the object is pulled down, the sum of the elastic potential energy of the spring and the gravitational potential energy of the object and Earth.

1. increases.
2. stays the same.
3. decreases.

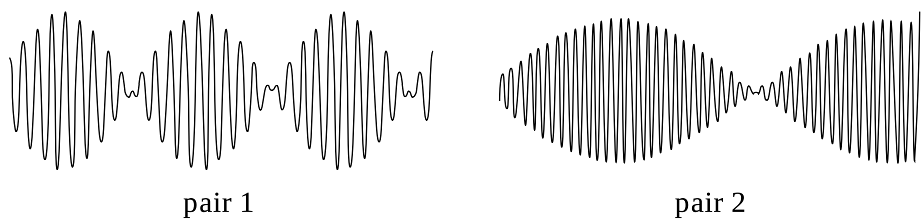
A person swings on a swing. When the person sits still, the swing oscillates back and forth at its natural frequency. If, instead, two people sit on the swing, the new natural frequency of the swing is

1. greater.
2. the same.
3. smaller.

A person swings on a swing. When the person sits still, the swing oscillates back and forth at its natural frequency. If, instead, the person stands on the swing, the new natural frequency of the swing is

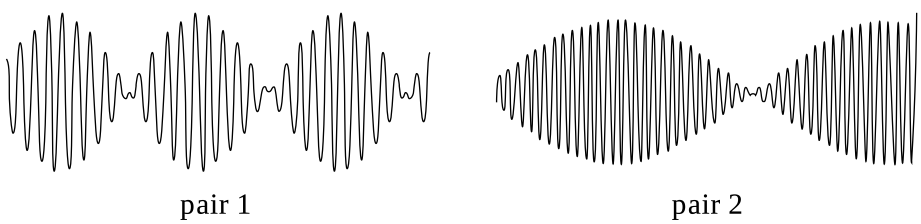
1. greater.
2. the same.
3. smaller.

The traces below show beats that occur when two different pairs of waves are added. For which of the two is the difference in frequency of the original waves greater?



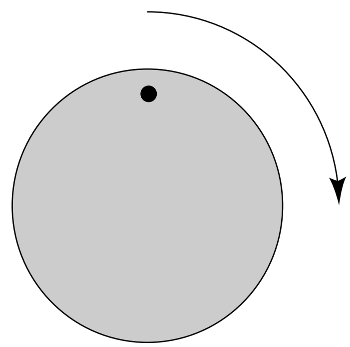
1. Pair 1
2. Pair 2
3. The frequency difference was the same for both pairs of waves.
4. Need more information.

The traces below show beats that occur when two different pairs of waves are added. Which of the two pairs of original waves contains the wave with the highest frequency?

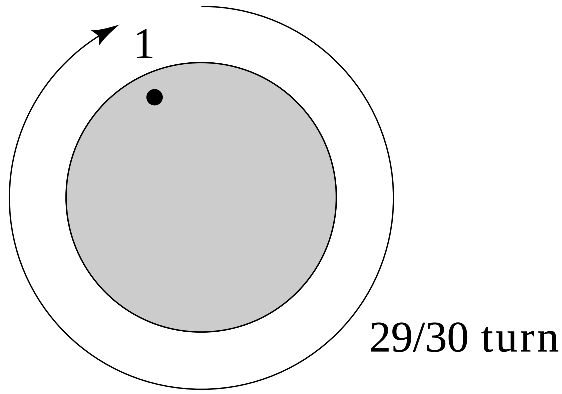


1. Pair 1
2. Pair 2
3. The frequency difference was the same for both pairs of waves.
4. Need more information.

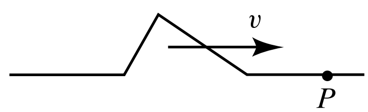
The circular object pictured here is made to rotate clockwise at 29 revolutions per second. It is filmed with a camera that takes 30 frames per second. Compared to its actual motion, the dot on the film appears to move

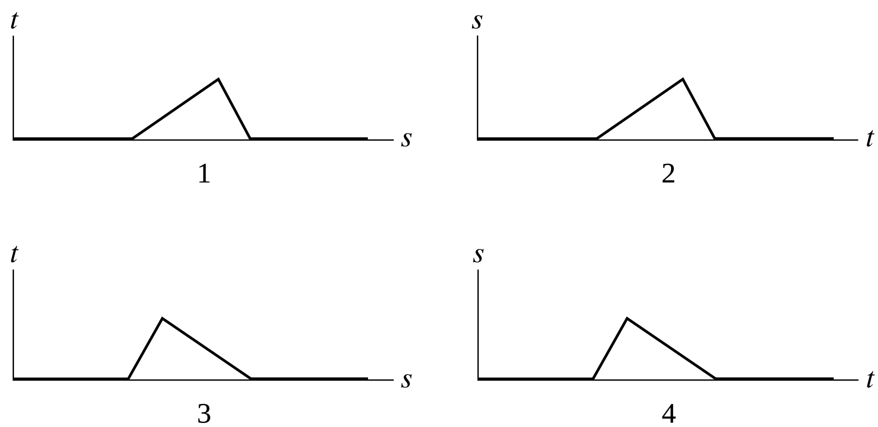


1. clockwise at a very slow rate.
2. counterclockwise at a very slow rate.
3. clockwise at a very fast rate.
4. counterclockwise at a very fast rate.
5. in a random fashion.

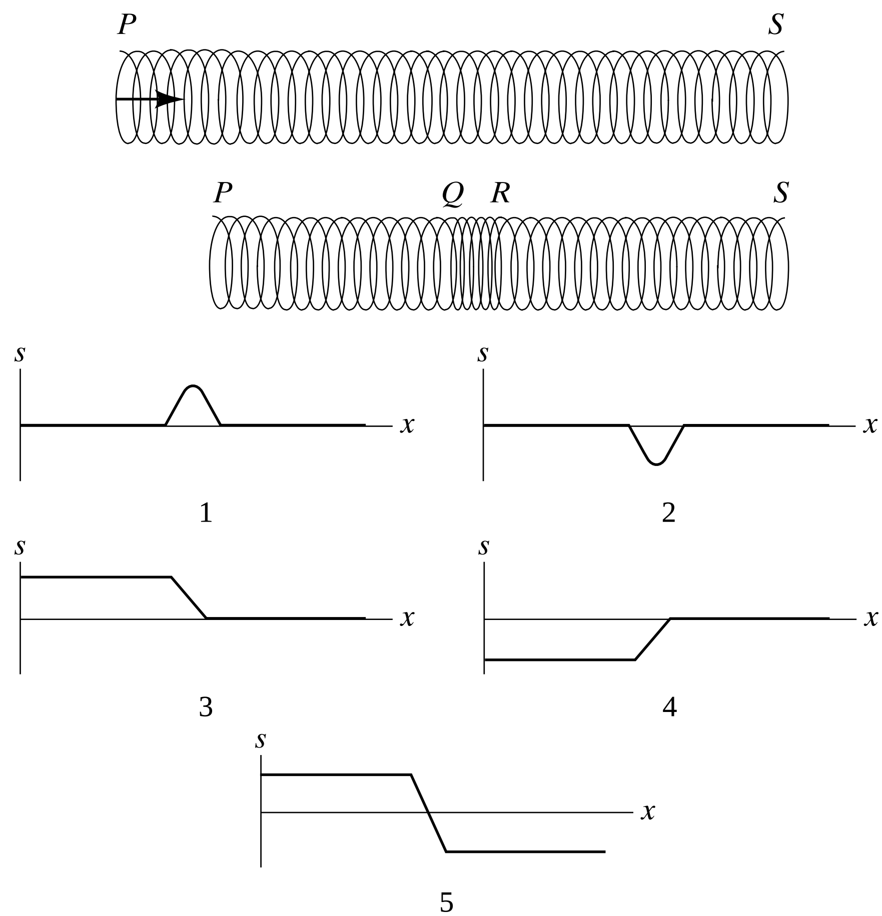

1
29/30 turn

A wave pulse is moving, as illustrated, with uniform speed v along a rope. Which of the graphs 1–4 below correctly shows the relation between the displacement s of point P and time t?





A wave is sent along a long spring by moving the left end rapidly to the right and keeping it there. The figure shows the wave pulse at *QR*—part *RS* of the long spring is as yet undisturbed. Which of the graphs 1–5 correctly shows the relation between displacement *s* and position *x*? (Displacements to the right are positive.)



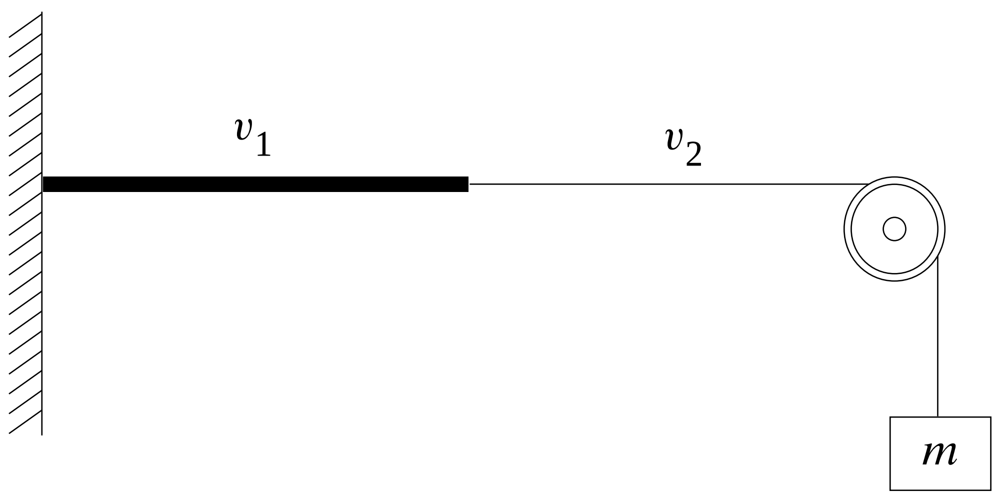
Two strings, one thick and the other thin, are connected to form one long string. A wave travels along the string and passes the point where the two strings are connected. Which of the following change(s) at that point:

A. frequency
B. period
C. propagation speed
D. wavelength

By shaking one end of a stretched string, a single pulse is generated. The traveling pulse carries

1. energy.
2. momentum.
3. energy and momentum.
4. neither of the two.

A weight is hung over a pulley and attached to a string composed of two parts, each made of the same material but one having four times the diameter of the other. The string is plucked so that a pulse moves along it, moving at speed v_1 in the thick part and at speed v_2 in the thin part. What is v_1/v_2?

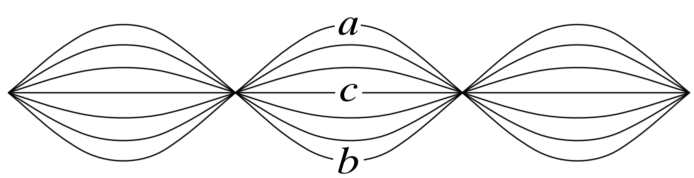


1. 1
2. 2
3. 1/2
4. 1/4

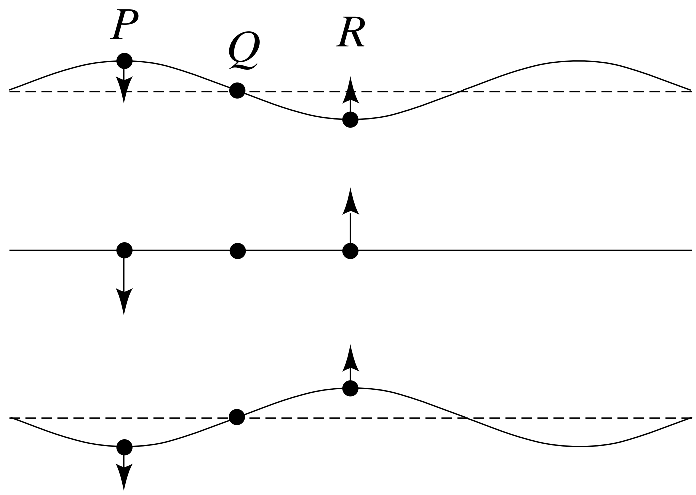
Two identical pulses of opposite amplitude travel along a stretched string and interfere destructively. Which of the following is/are true?

A. There is an instant at which the string is completely straight.
B. When the two pulses interfere, the energy of the pulses is momentarily zero.
C. There is a point on the string that does not move up or down.
D. There are several points on the string that do not move up or down.

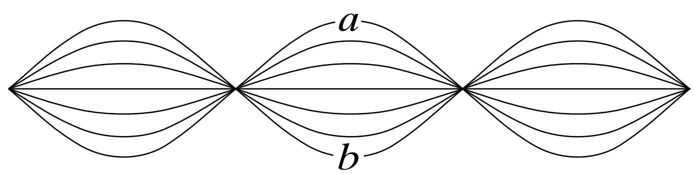
A string is clamped at both ends and plucked so it vibrates in a standing mode between two extreme positions a and b. Let upward motion correspond to positive velocities. When the string is in position c, the instantaneous velocity of points along the string:



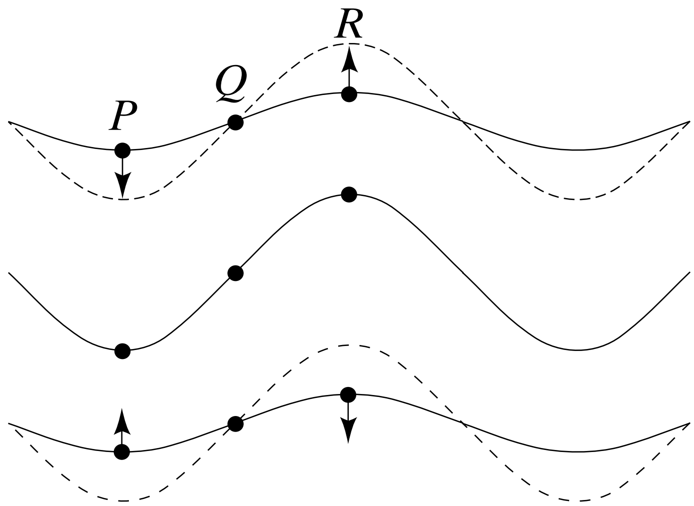
1. is zero everywhere.
2. is positive everywhere.
3. is negative everywhere.
4. depends on location.


P
Q
R

A string is clamped at both ends and plucked so it vibrates in a standing mode between two extreme positions a and b. Let upward motion correspond to positive velocities. When the string is in position b, the instantaneous velocity of points along the string

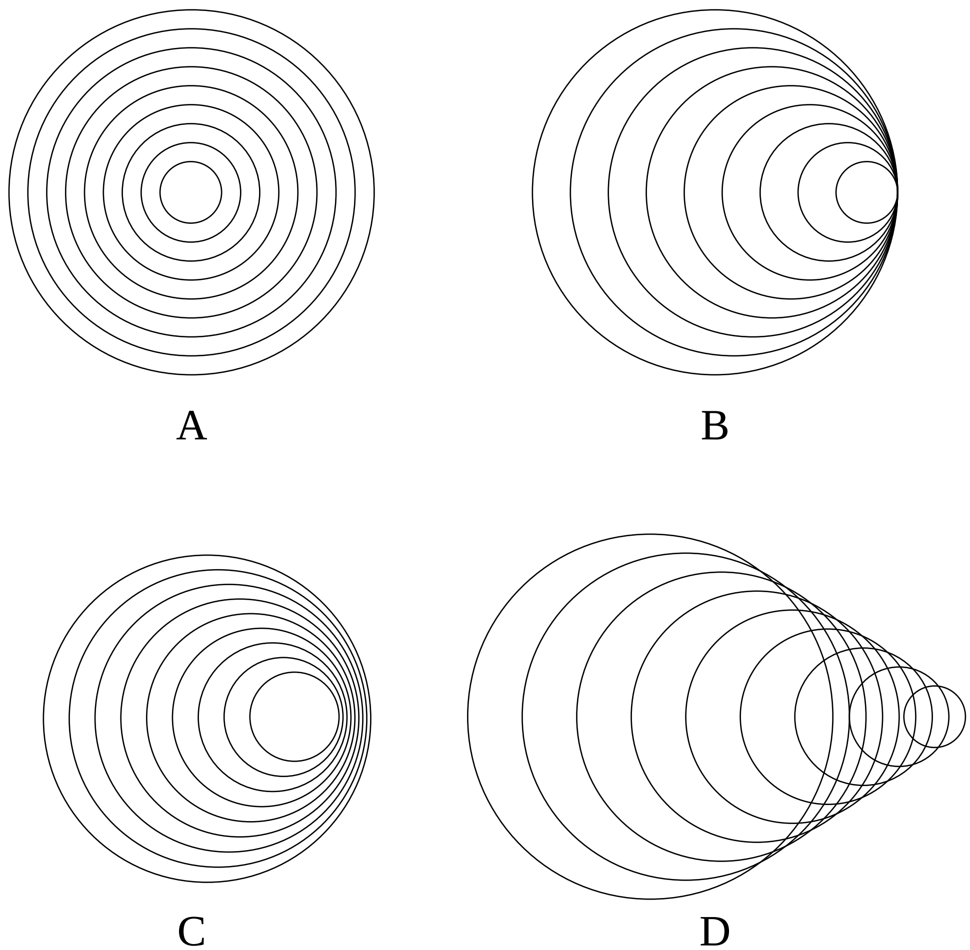


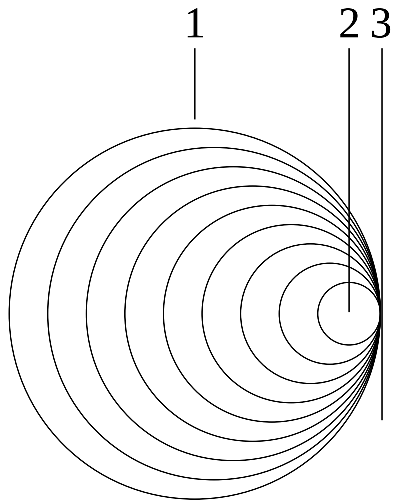
1. is zero everywhere.
2. is positive everywhere.
3. is negative everywhere.
4. depends on location.



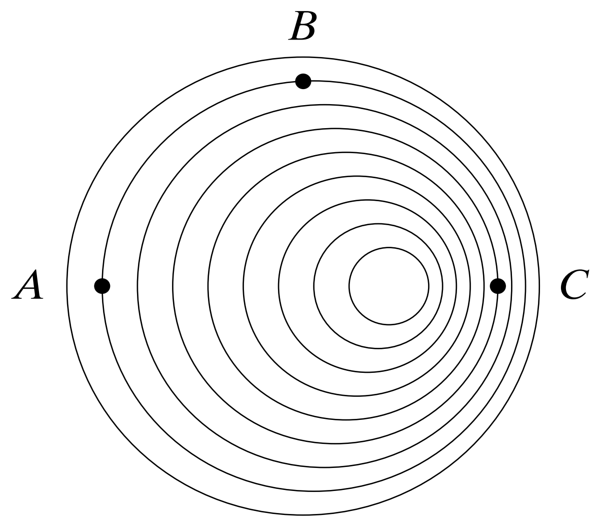
R
Q
P

The four figures below represent sound waves emitted by a moving source. Which picture(s) represent(s) a source moving at less than the speed of sound?



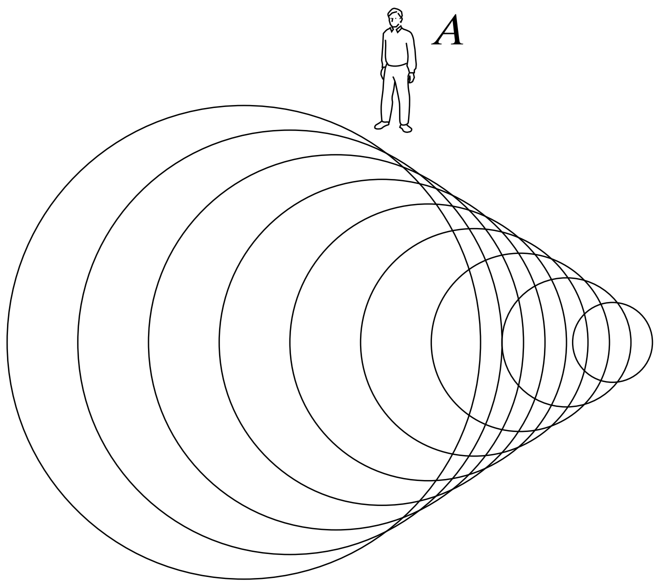

1
2
3

Three observers, A, B, and C are listening to a moving source of sound. The diagram below shows the location of the wavecrests of the moving source with respect to the three observers. Which of the following is true?



1. The wavefronts move faster at A than at B and C.
2. The wavefronts move faster at C than at A and B.
3. The frequency of the sound is highest at A.
4. The frequency of the sound is highest at B.
5. The frequency of the sound is highest at C.

The following figure shows the wavefronts generated by an airplane flying past an observer A at a speed greater than that of sound. After the airplane has passed, the observer reports hearing



1. a sonic boom only when the airplane breaks the sound barrier, then nothing.
2. a succession of sonic booms.
3. a sonic boom, then silence.
4. first nothing, then a sonic boom, then the sound of engines.
5. no sonic boom because the airplane flew faster than sound all along.

Imagine holding two identical bricks under water. Brick A is just beneath the surface of the water, while brick B is at a greater depth. The force needed to hold brick B in place is

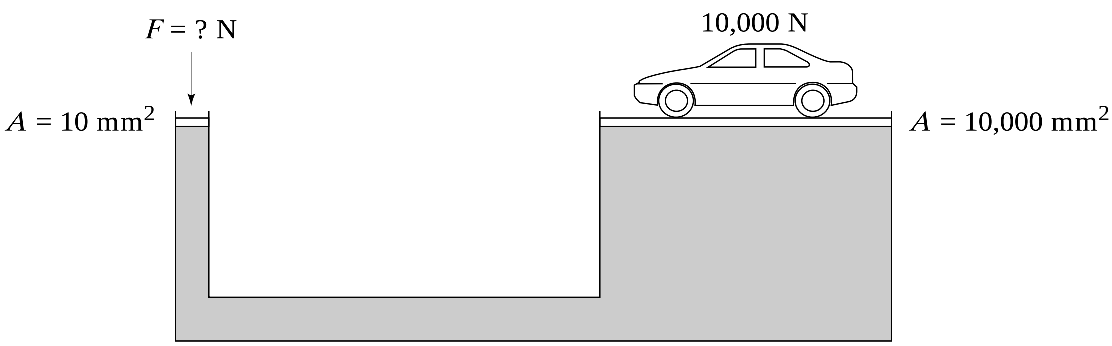
1. larger
2. the same as
3. smaller

than the force required to hold brick A in place.

. When a hole is made in the side of a container holding water, water flows out and follows a parabolic trajectory. If the container is dropped in free fall, the water flow

1. diminishes.
2. stops altogether.
3. goes out in a straight line.
4. curves upward.

A container is filled with oil and fitted on both ends with pistons. The area of the left piston is 10 mm^2; that of the right piston 10,000 mm^2. What force must be exerted on the left piston to keep the 10,000-N car on the right at the same height?



1. 10 N
2. 100 N
3. 10,000 N
4. 10^6 N
5. 10^8 N
6. insufficient information

A 200-ton ship enters the lock of a canal. The fit between the sides of the lock and the ship is tight so that the weight of the water left in the lock after it closes is much less than 200 tons. Can the ship still float if the quantity of water left in the lock is much less than the ship's weight?

1. Yes, as long as the water gets up to the ship's waterline.
2. No, the ship touches bottom because it weighs more than the water in the lock.

Two identical glasses are filled to the same level with water. One of the two glasses has ice cubes floating in it. Which weighs more?

1. The glass without ice cubes.
2. The glass with ice cubes.
3. The two weigh the same.

Two identical glasses are filled to the same level with water. One of the two glasses has ice cubes floating in it. When the ice cubes melt, in which glass is the level of the water higher?

1. The glass without ice cubes.
2. The glass with ice cubes.
3. It is the same in both.

Two cups are filled to the same level with water. One of the two cups has plastic balls floating in it. If the density of the plastic balls is less than that of ice, which of the two cups weighs more?

1. The cup without plastic balls.
2. The cup with plastic balls.
3. The two weigh the same.

A lead weight is fastened on top of a large solid piece of Styrofoam that floats in a container of water. Because of the weight of the lead, the water line is flush with the top surface of the Styrofoam. If the piece of Styrofoam is turned upside down so that the weight is now suspended underneath it,

1. the arrangement sinks.
2. the water line is below the top surface of the Styrofoam.
3. the water line is still flush with the top surface of the Styrofoam.

A lead weight is fastened to a large solid piece of Styrofoam that floats in a container of water. Because of the weight of the lead, the water line is flush with the top surface of the Styrofoam. If the piece of Styrofoam is turned upside down, so that the weight is now suspended underneath it, the water level in the container

1. rises.
2. drops.
3. remains the same.

A boat carrying a large boulder is floating on a lake. The boulder is thrown overboard and sinks. The water level in the lake (with respect to the shore)

1. rises.
2. drops.
3. remains the same.

Consider an object that floats in water but sinks in oil. When the object floats in water, half of it is submerged. If we slowly pour oil on top of the water so it completely covers the object, the object

1. moves up.
2. stays in the same place.
3. moves down.

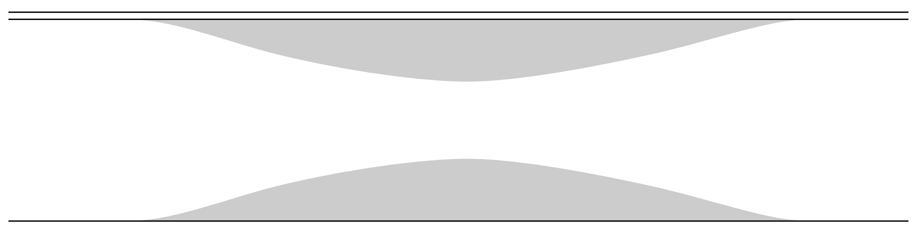
Consider an object floating in a container of water. If the container is placed in an elevator that accelerates upward,

1. more of the object is below water.
2. less of the object is below water.
3. there is no difference.

A circular hoop sits in a stream of water, oriented perpendicular to the current. If the area of the hoop is doubled, the flux (volume of water per unit time) through it

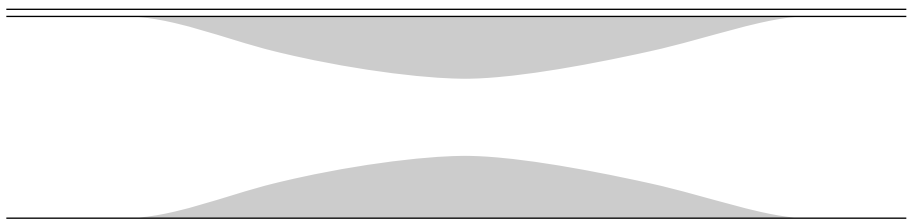
1. decreases by a factor of 4.
2. decreases by a factor of 2.
3. remains the same.
4. increases by a factor of 2.
5. increases by a factor of 4.

Blood flows through a coronary artery that is partially blocked by deposits along the artery wall. Through which part of the artery is the flux (volume of blood per unit time) largest?



1. The narrow part.
2. The wide part.
3. The flux is the same in both parts.

. Blood flows through a coronary artery that is partially blocked by deposits along the artery wall. Through which part of the artery is the flow speed largest?

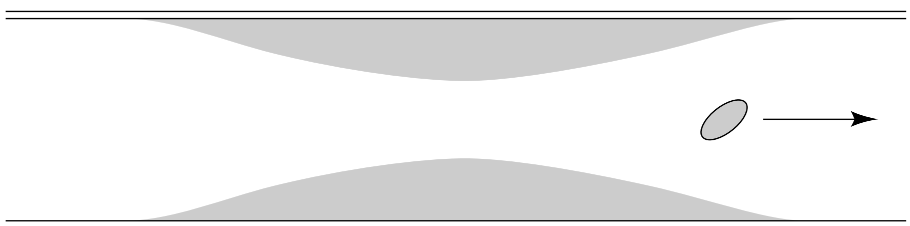


1. The narrow part.
2. The wide part.
3. The flow speed is the same in both parts.

Two hoses, one of 20-mm diameter, the other of 15-mm diameter are connected one behind the other to a faucet. At the open end of the hose, the flow of water measures 10 liters per minute. Through which pipe does the water flow faster?

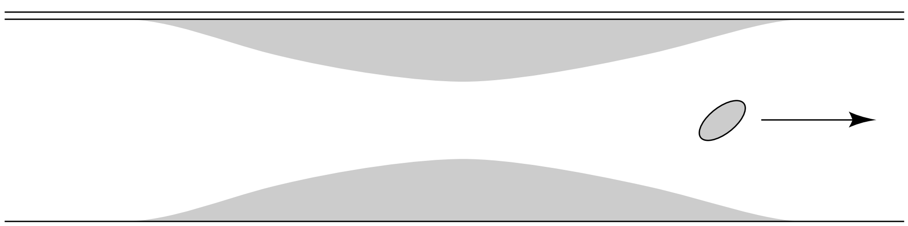
1. the 20-mm hose
2. the 15-mm hose
3. The flow rate is the same in both cases.
4. The answer depends on which of the two hoses comes first in the flow.

A blood platelet drifts along with the flow of blood through an artery that is partially blocked by deposits. As the platelet moves from the narrow region to the wider region, its speed



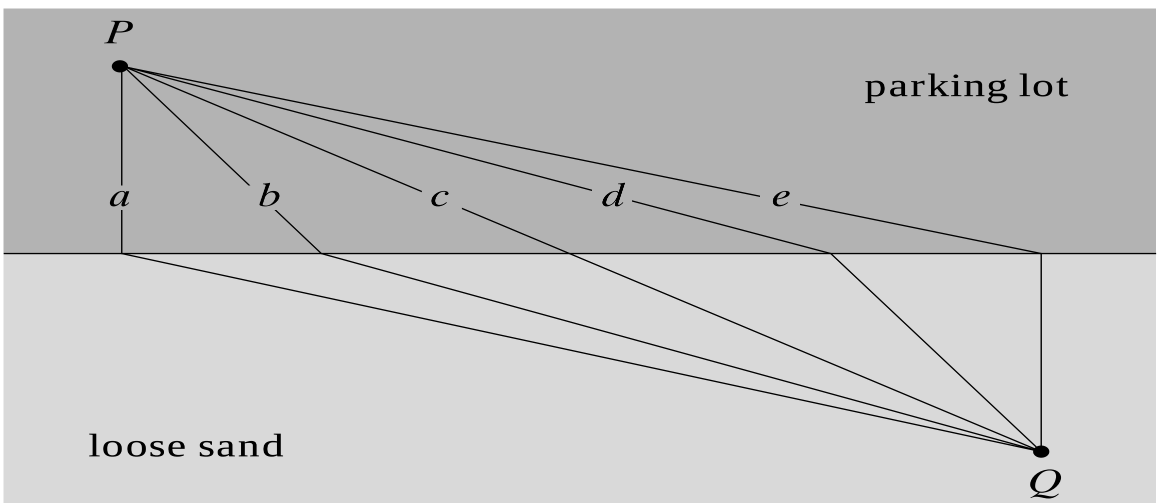
1. increases.
2. remains the same.
3. decreases.

A blood platelet drifts along with the flow of blood through an artery that is partially blocked by deposits. As the platelet moves from the narrow region to the wider region, it experiences



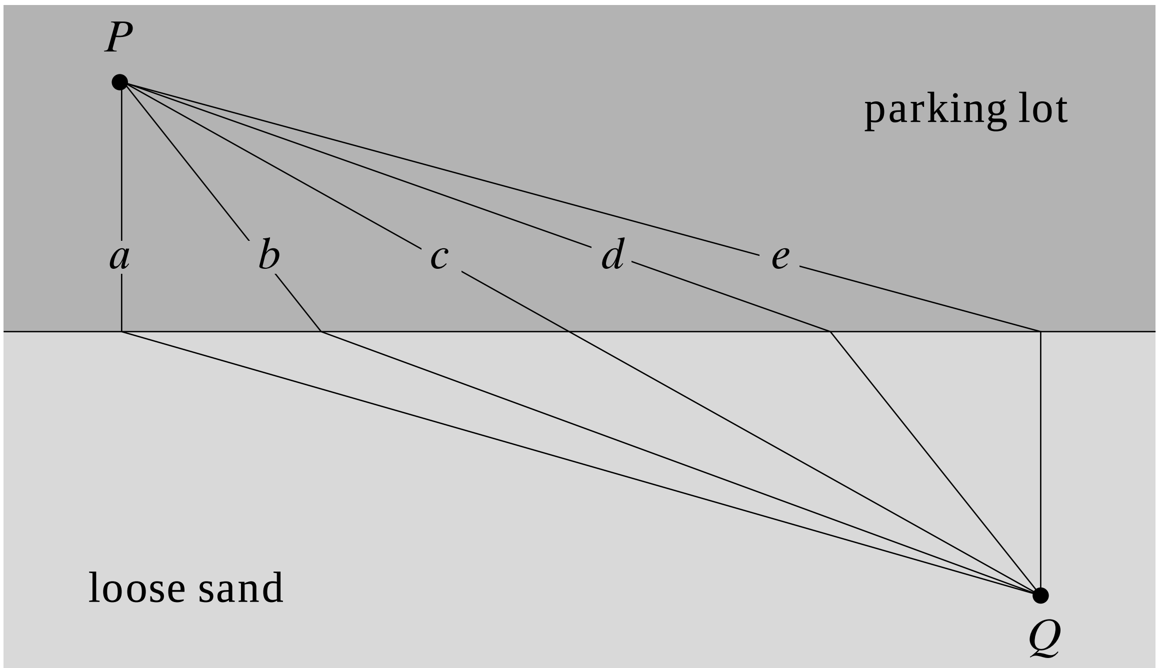
1. an increase in pressure.
2. no change in pressure.
3. a decrease in pressure.

A group of sprinters gather at point P on a parking lot bordering a beach. They must run across the parking lot to a point Q on the beach as quickly as possible. Which path from P to Q takes the least time? You should consider the relative speeds of the sprinters on the hard surface of the parking lot and on loose sand.



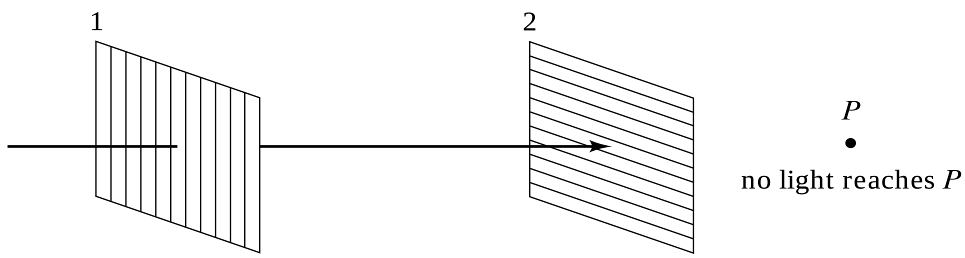
1. a
2. b
3. c
4. d
5. e
6. All paths take the same amount of time.

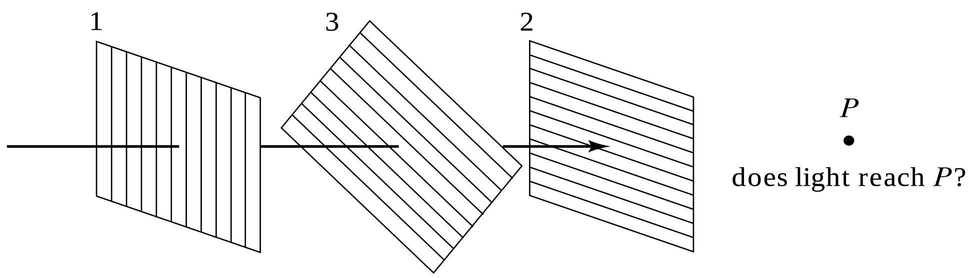
Suppose the sprinters wish to get from point Q on the beach to point P on the parking lot as quickly as possible. Which path takes the least time?



1. a
2. b
3. c
4. d
5. e
6. All paths take the same amount of time.

When a ray of light is incident on two polarizers with their polarization axes perpendicular, no light is transmitted. If a third polarizer is inserted between these two with its polarization axis at 45° to that of the other two, does any light get through to point P?



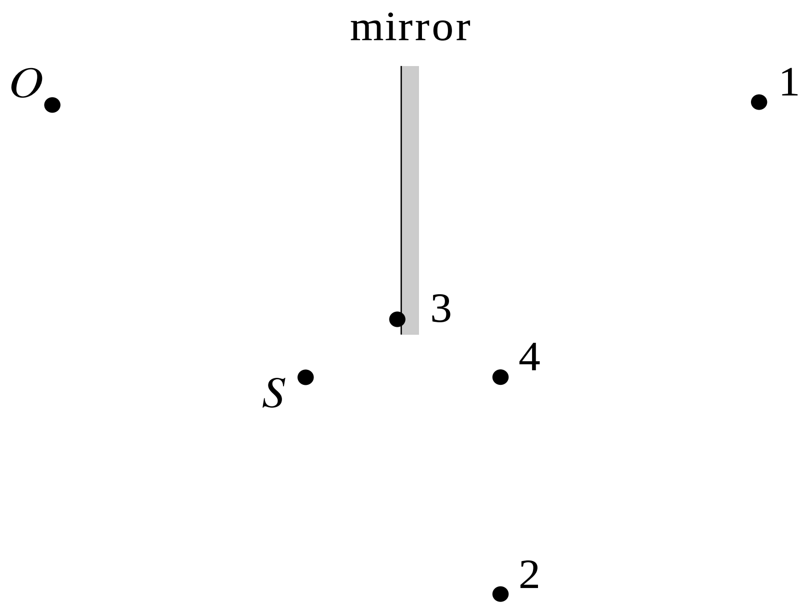


1. yes
2. no

When a third polarizer is inserted at 45° between two orthogonal polarizers, some light is transmitted. If, instead of a single polarizer at 45°, we insert a large number N of polarizers, each time rotating the axis of polarization over an angle $90°/N$,

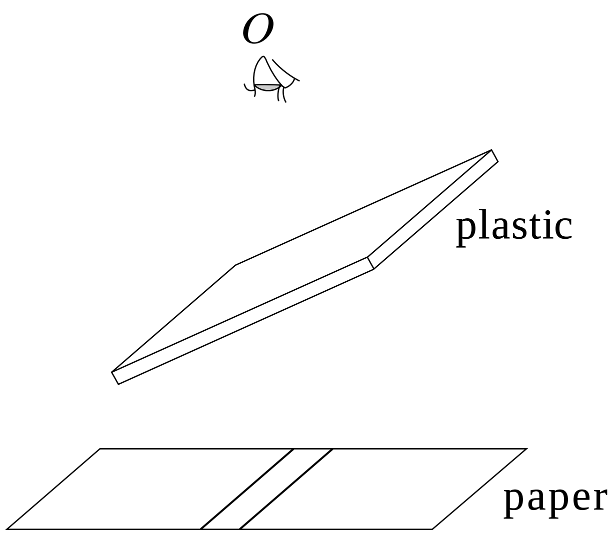
1. no light
2. less light
3. the same amount of light
4. more light gets through.

An observer O, facing a mirror, observes a light source S. Where does O perceive the mirror image of S to be located?



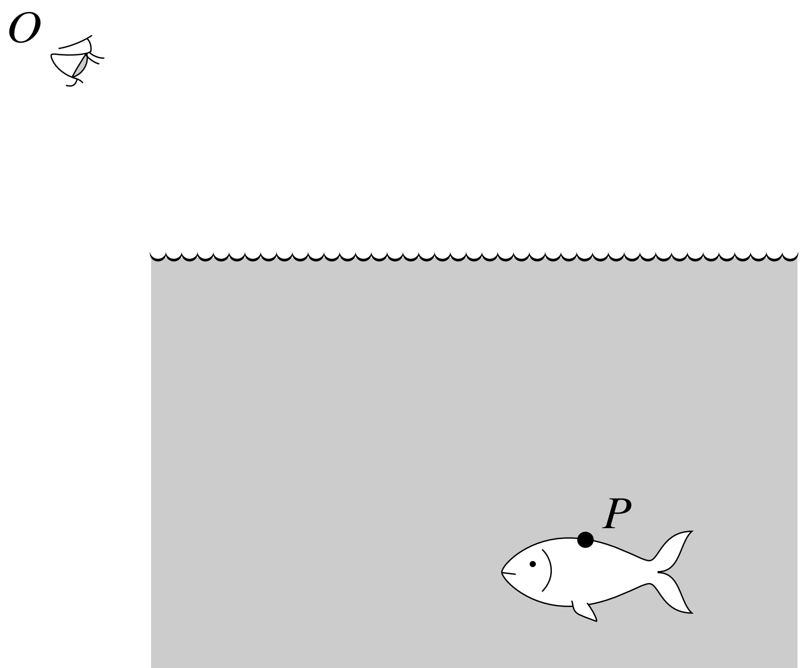
1. 1
2. 2
3. 3
4. 4
5. Some other location.
6. The image of S cannot be seen by O when O and S are located as shown.

The observer at *O* views two closely spaced lines through an angled piece of plastic. To the observer, the lines appear (choose all that apply)

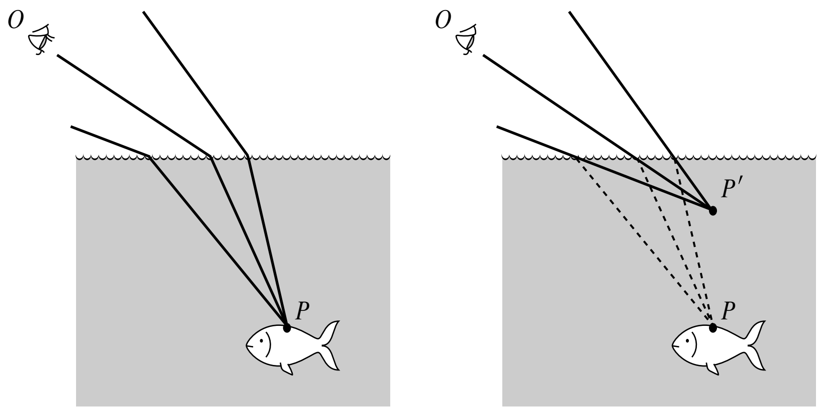


A. shifted to the right.
B. shifted to the left.
C. spaced farther apart.
D. spaced closer together.
E. exactly as they do without the piece of plastic.

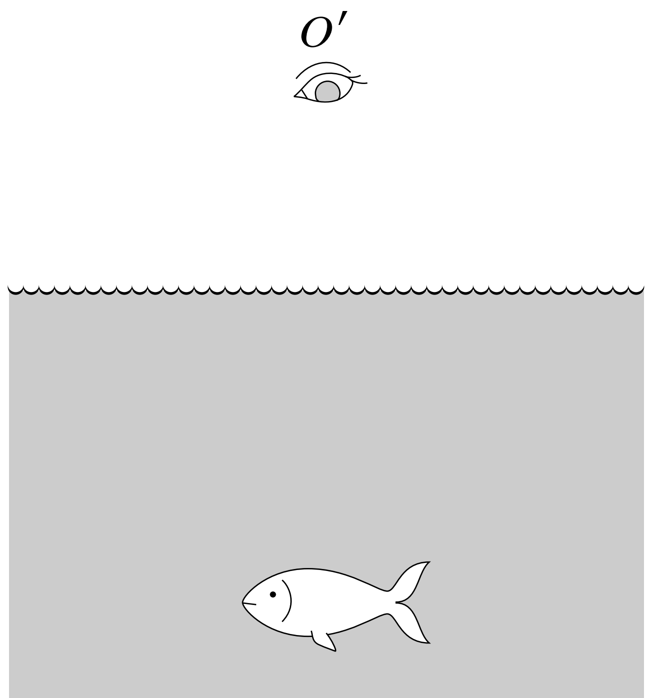
A fish swims below the surface of the water at P. An observer at O sees the fish at



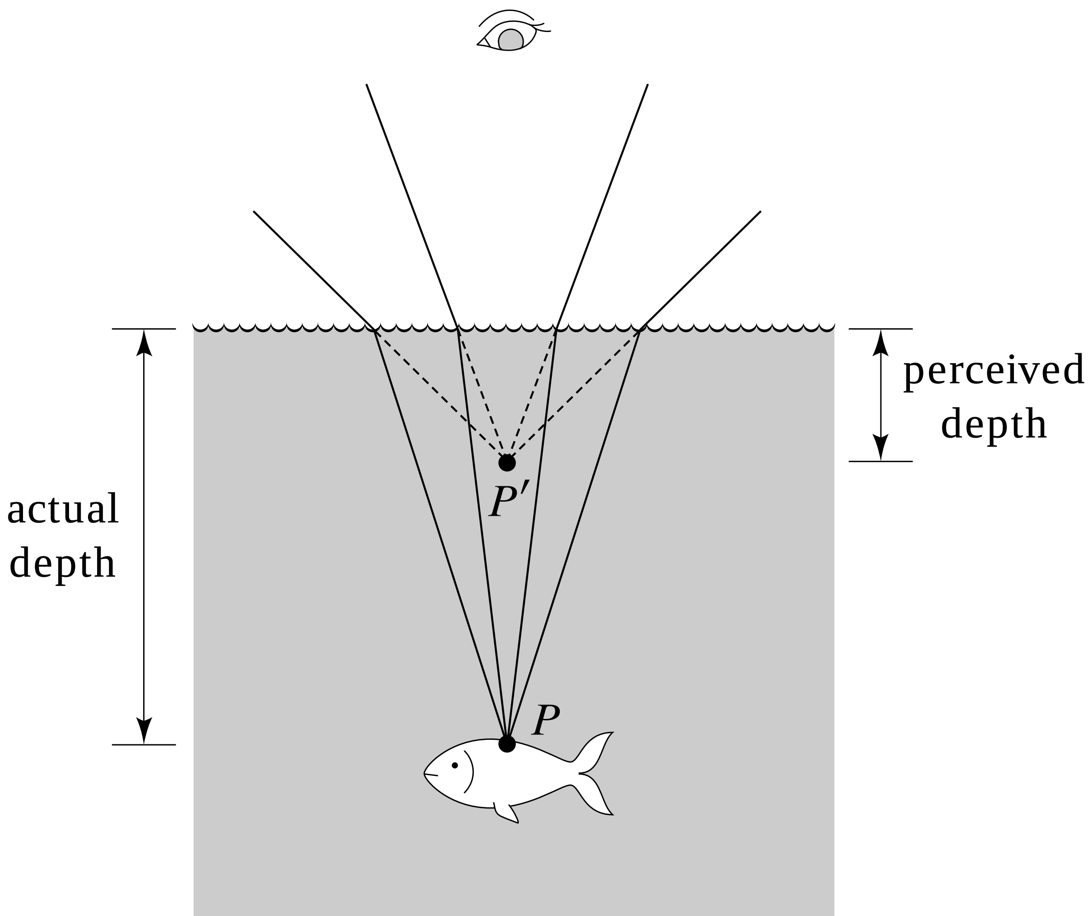
1. a greater depth than it really is.
2. the same depth.
3. a smaller depth than it really is.


O
P
O
P′
P

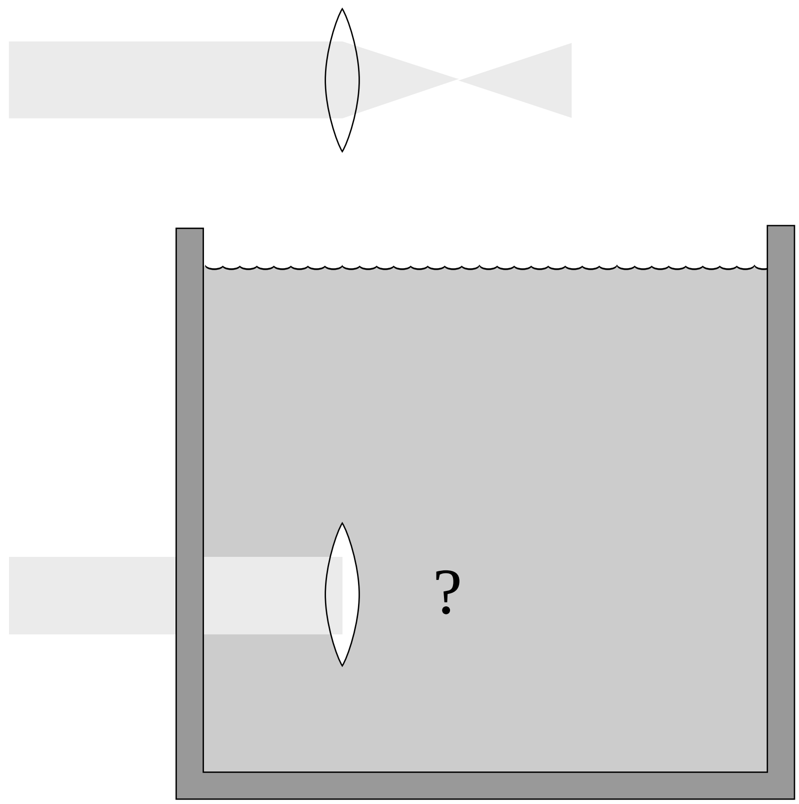
A fish swims below the surface of the water. Suppose an observer is looking at the fish from point O'—straight above the fish. The observer sees the fish at



1. a greater depth than it really is.
2. the same depth.
3. a smaller depth than it really is.


perceived
depth
actual
depth
P′
P

A parallel beam of light is sent through an aquarium. If a convex glass lens is held in the water, it focuses the beam



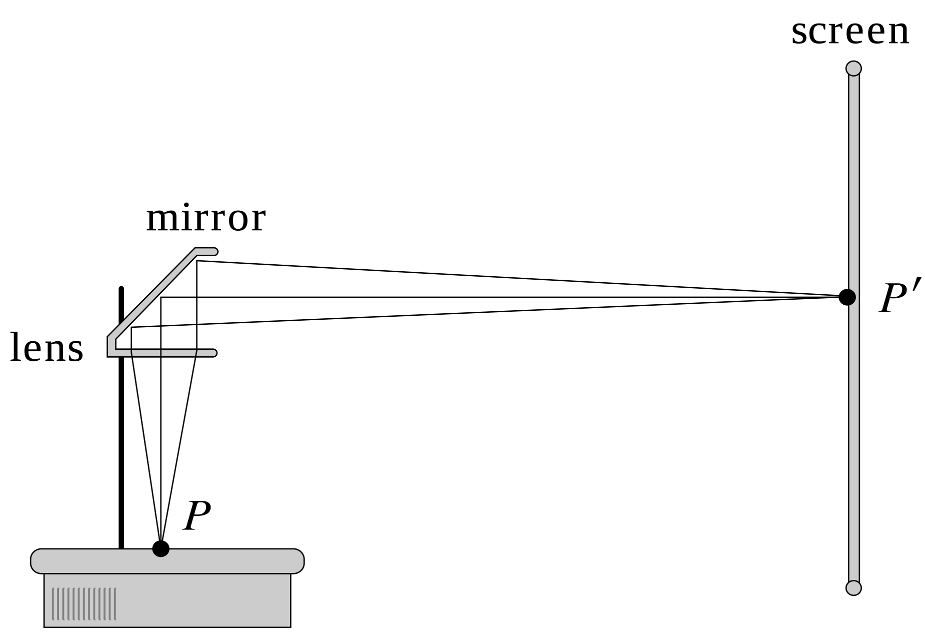
1. closer to the lens than
2. at the same position as
3. farther from the lens than

outside the water.

A lens is used to image an object onto a screen. If the right half of the lens is covered,

1. the left half of the image disappears.
2. the right half of the image disappears.
3. the entire image disappears.
4. the image becomes blurred.
5. the image becomes fainter.

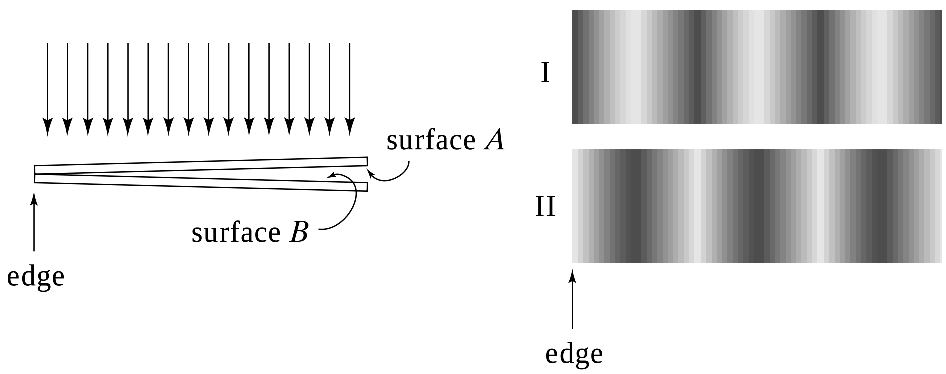
The lens in an overhead projector forms an image P' of a point P on an overhead transparency. If the screen is moved closer to the projector, the lens must be:



1. moved up
2. left in place
3. moved down

to keep the image on the screen in focus.

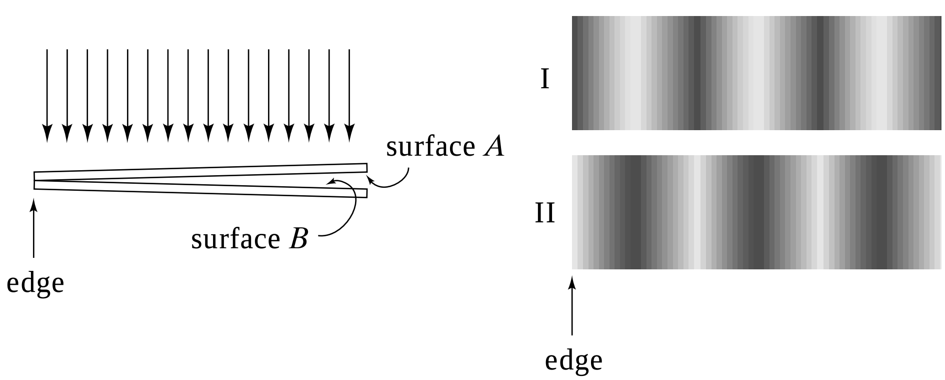
Monochromatic light shines on a pair of identical glass microscope slides that form a very narrow wedge. The top surface of the upper slide and the bottom surface of the lower slide have special coatings on them so that they reflect no light. The inner two surfaces (*A* and *B*) have nonzero reflectivities.



A top view of the slides looks like

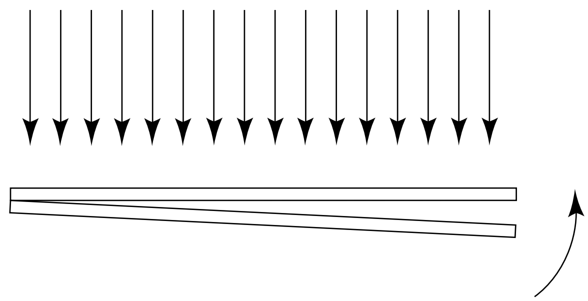
1. I.
2. II.

Monochromatic light shines on a pair of microscope slides that form a very narrow wedge. The top slide is made of crown glass ($n = 1.5$) and the bottom slide of flint glass ($n = 1.7$). Both slides are immersed in sassafras oil, which has an index intermediate between those of the two slides. The top surface of the upper slide and the bottom surface of the lower slide have special coatings on them so that they reflect no light. The inner two surfaces (*A* and *B*) have nonzero reflectivities. A top view of the slides looks like



1. I.
2. II.

Consider two identical microscope slides in air illuminated with monochromatic light. The bottom slide is rotated (counterclockwise about the point of contact in the side view) so that the wedge angle gets a bit smaller. What happens to the fringes?



1. They are spaced farther apart.
2. They are spaced closer together.
3. They don't change.

Two identical slides in air are illuminated with monochromatic light. The slides are exactly parallel, and the top slide is moving slowly upward. What do you see in top view?

1. all black
2. all bright
3. fringes moving apart
4. sequentially all black, then all bright
5. none of the above

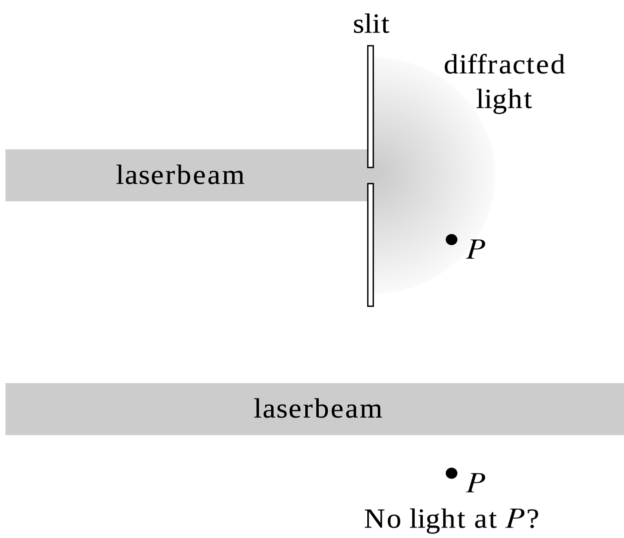
Diffraction occurs when light passes a:

A. pinhole.
B. narrow slit.
C. wide slit.
D. sharp edge.
E. all of the above

The Huygens-Fresnel principle tells us to pretend that each point of a wavefront in a slit or aperture is a point source of light emitting a spherical wave. Is this true only for points inside the slit? What if there is no slit? The Huygens-Fresnel principle really applies

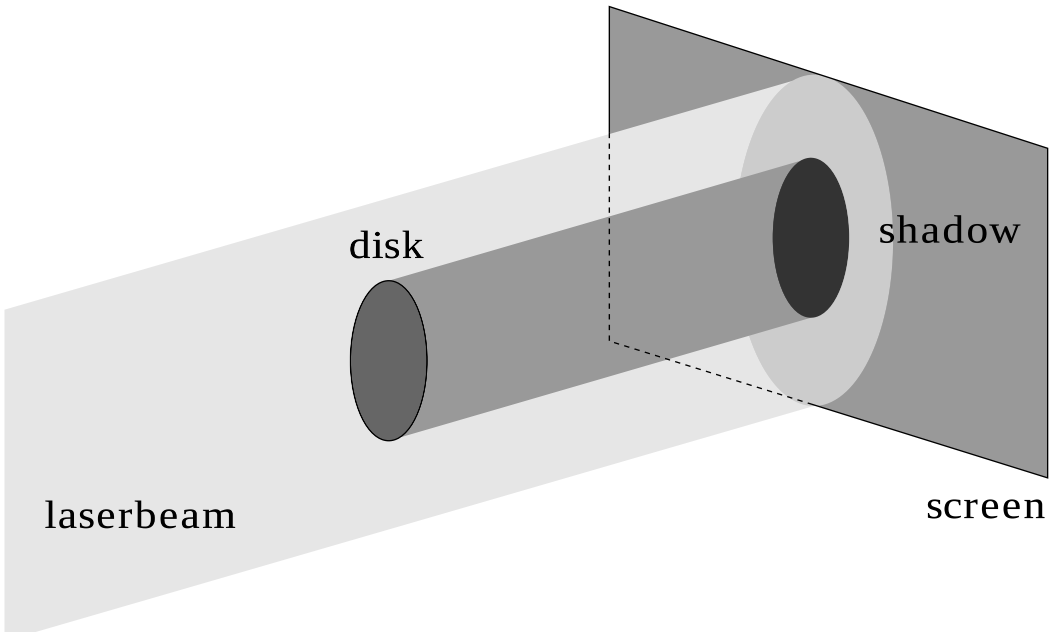
1. to any point anywhere in a beam path.
2. to any point in a beam path where matter is present.
3. only in slits or apertures.

If the Huygens-Fresnel principle applies to any point anywhere in a beam path, why doesn't a laser beam without any slit spread out in all directions?



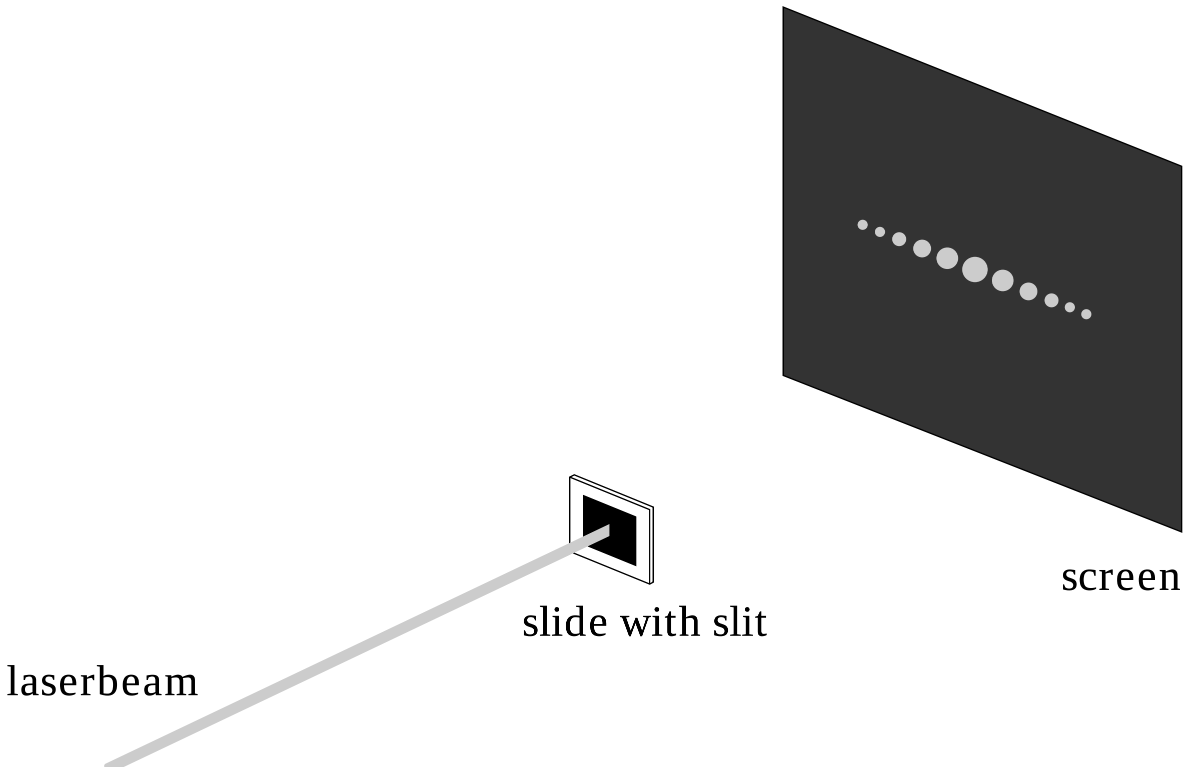
1. Because all waves that spread interfere destructively.
2. It does spread, but the spread is so small that we normally don't notice it.
3. We can't apply the Huygens-Fresnel principle anywhere but in slits and apertures.

Imagine holding a circular disk in a beam of monochromatic light. If diffraction occurs at the edge of the disk, the center of the shadow of the disk is



1. a bright spot.
2. darker than the rest of the shadow.
3. bright or dark, depending on the distance between the disk and the screen.
4. as dark as the rest of the shadow, but less dark than if there is no diffraction.

The pattern on the screen is due to a narrow slit that is



1. horizontal.
2. vertical.

Suppose we cover each slit in Young's experiment with a polarizer such that the polarization transmitted by each slit is orthogonal to that transmitted through the other. On a screen behind the slits, we see:

1. the usual fringe pattern.
2. the usual fringes shifted over such that the maxima occur where the minima used to be.
3. nothing at all.
4. a fairly uniformly illuminated elongated spot.

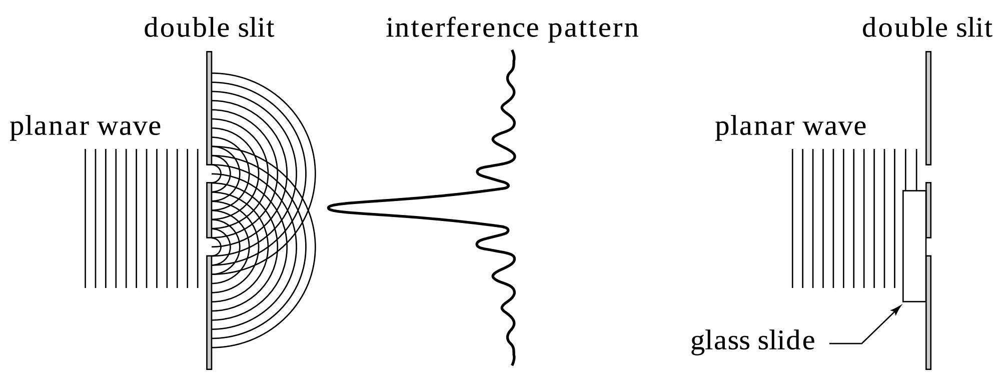
A diffraction grating is illuminated with yellow light at normal incidence. The pattern seen on a screen behind the grating consists of three yellow spots, one at zero degrees (straight through) and one each at ±45°. You now add red light of equal intensity, coming in the same direction as the yellow light. The new pattern consists of

1. red spots at 0° and ±45°.
2. yellow spots at 0° and ±45°.
3. orange spots at 0° and ±45°.
4. an orange spot at 0°, yellow spots at ±45°, and red spots slightly farther out.
5. an orange spot at 0°, yellow spots at ±45°, and red spots slightly closer in.

A planar wave is incident on a pair of slits as shown. Seen on a screen behind the slits is/are

1. two spots, one behind each slit.
2. only one spot, behind the center of the pair of slits.
3. many spots distributed randomly.
4. many spots distributed evenly.

An interference pattern is formed on a screen by shining a planar wave on a double-slit arrangement (left). If we cover one slit with a glass plate (right), the phases of the two emerging waves will be different because the wavelength is shorter in glass than in air. If the phase difference is 180°, how is the interference pattern, shown left, altered?



1. The pattern vanishes.
2. The bright spots lie closer together.
3. The bright spots are farther apart.
4. There are no changes.
5. Bright and dark spots are interchanged.

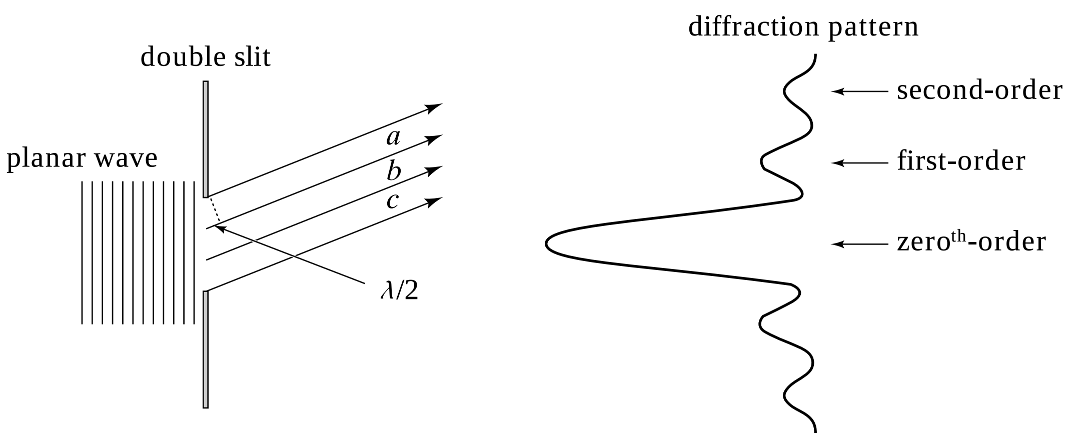
For a given lens diameter, which light gives the best resolution in a microscope?

1. red
2. yellow
3. green
4. blue
5. All give the same resolution.

Blue light of wavelength λ passes through a single slit of width a and forms a diffraction pattern on a screen. If the blue light is replaced by red light of wavelength 2λ, the original diffraction pattern is reproduced if the slit width is changed to

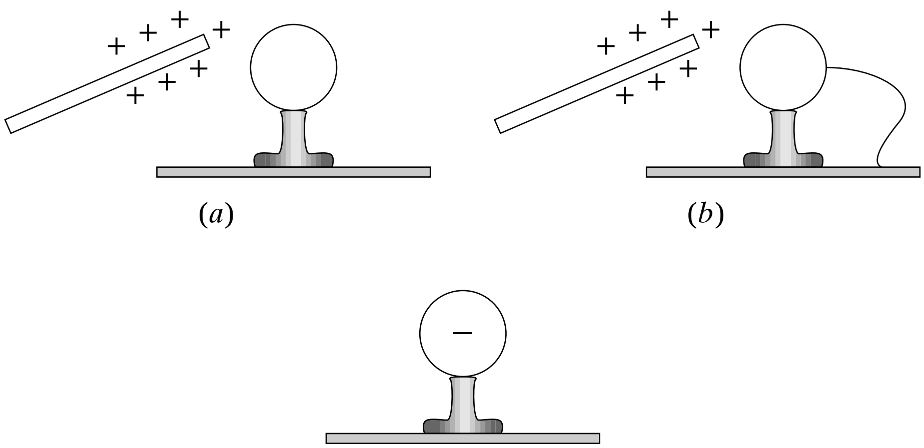
1. $a/4$.
2. $a/2$.
3. No change is necessary.
4. $2a$.
5. $4a$.
6. There is no width that can be used to reproduce the original pattern.

A planar wave is incident on a single slit and forms a diffraction pattern on a screen. The pattern has a central, zeroth-order maximum and a number of secondary maxima. The first-order maximum is formed in a direction where light from the top third (a) of the slit cancels light from the middle third (b). The intensity of the first-order maximum is thus due only to the bottom third of the light through the slit (c) and is therefore roughly 1/9 of the intensity I of the central maximum. What is the intensity of the second-order maximum?



1. $I/4$
2. $I/9$
3. $I/16$
4. $I/25$

A positively charged object is placed close to a conducting object attached to an insulating glass pedestal (*a*). After the opposite side of the conductor is grounded for a short time interval (*b*), the conductor becomes negatively charged (*c*). Based on this information, we can conclude that within the conductor



(*a*) (*b*) (*c*)

1. both positive and negative charges move freely.
2. only negative charges move freely.
3. only positive charges move freely.
4. We can’t really conclude anything.

Three pithballs are suspended from thin threads. Various objects are then rubbed against other objects (nylon against silk, glass against polyester, etc.) and each of the pithballs is charged by touching them with one of these objects. It is found that pithballs 1 and 2 repel each other and that pithballs 2 and 3 repel each other. From this we can conclude that

1. 1 and 3 carry charges of opposite sign.
2. 1 and 3 carry charges of equal sign.
3. all three carry the charges of the same sign.
4. one of the objects carries no charge.
5. we need to do more experiments to determine the sign of the charges.

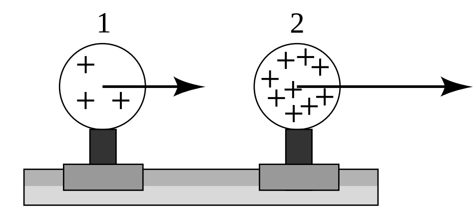
Three pithballs are suspended from thin threads. Various objects are then rubbed against other objects (nylon against silk, glass against polyester, etc.) and each of the pithballs is charged by touching them with one of these objects. It is found that pithballs 1 and 2 attract each other and that pithballs 2 and 3 repel each other. From this we can conclude that

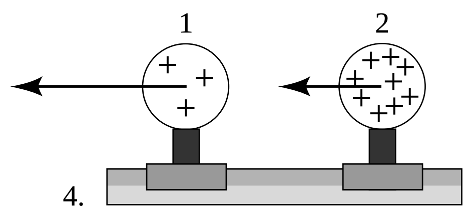
1. 1 and 3 carry charges of opposite sign.
2. 1 and 3 carry charges of equal sign.
3. all three carry the charges of the same sign.
4. one of the objects carries no charge.
5. we need to do more experiments to determine the sign of the charges.

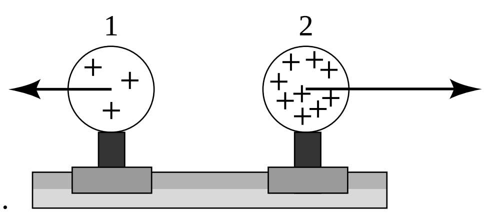
A hydrogen atom is composed of a nucleus containing a single proton, about which a single electron orbits. The electric force between the two particles is 2.3×10^{39} greater than the gravitational force! If we can adjust the distance between the two particles, can we find a separation at which the electric and gravitational forces are equal?

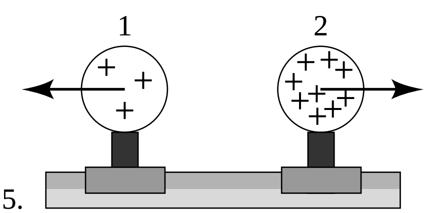
1. Yes, we must move the particles farther apart.
2. Yes, we must move the particles closer together.
3. no, at any distance

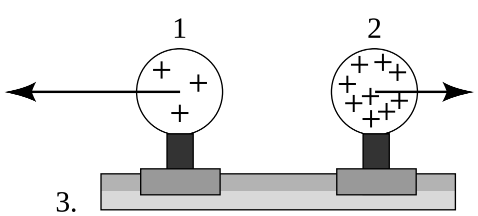
Two uniformly charged spheres are firmly fastened to and electrically insulated from frictionless pucks on an air table. The charge on sphere 2 is three times the charge on sphere 1. Which force diagram correctly shows the magnitude and direction of the electrostatic forces:

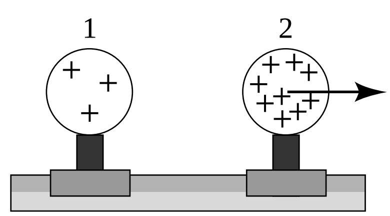
1. 

4. 

2. 

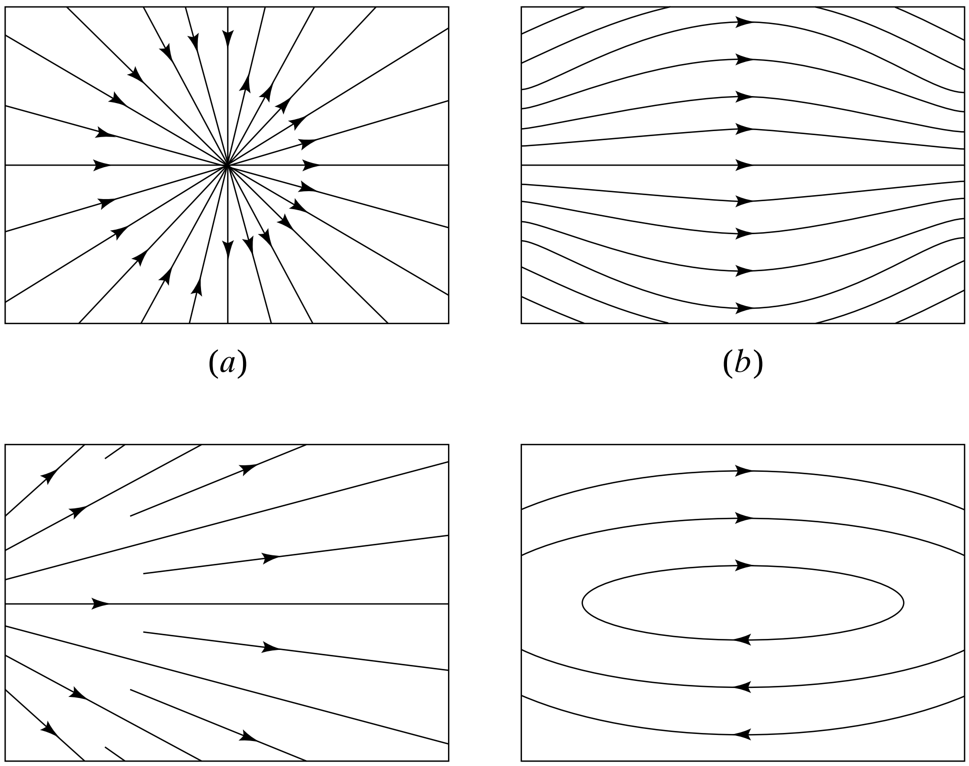
5. 

3. 

6. 

7. none of the above

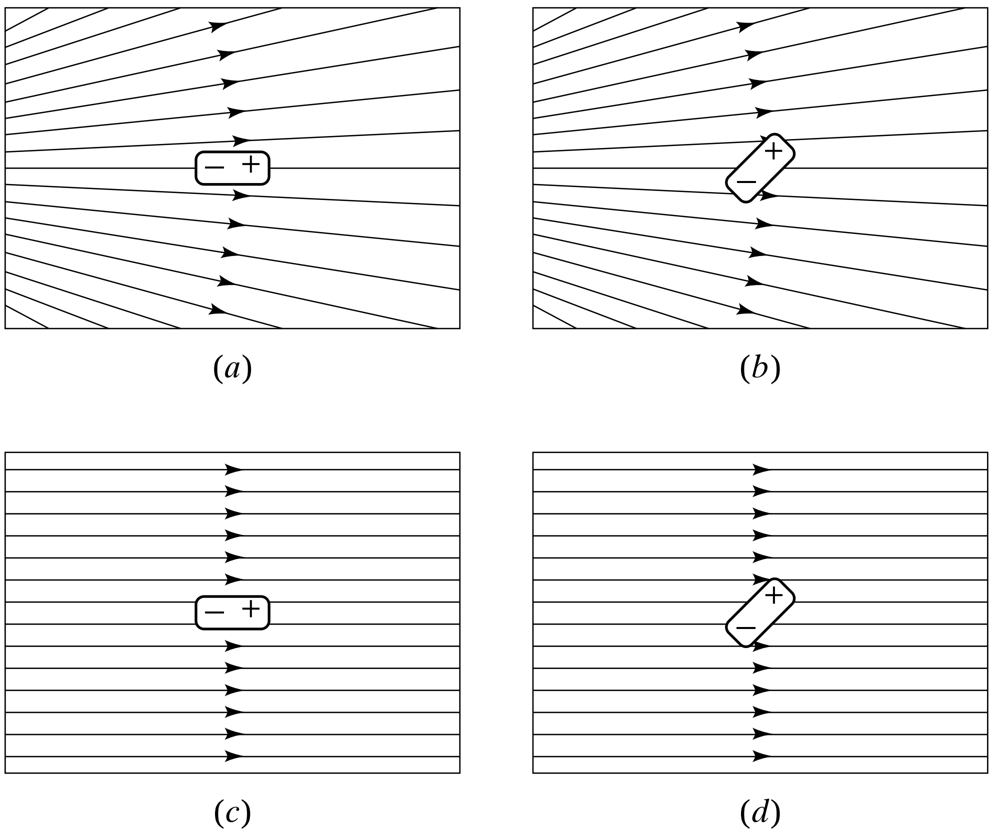
Consider the four field patterns shown. Assuming there are no charges in the regions shown, which of the patterns represent(s) a possible electrostatic field:



(*a*) (*b*) (*c*) (*d*)

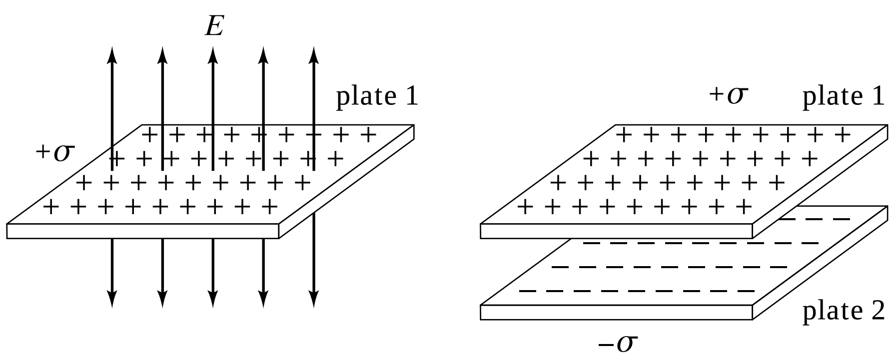
1. (*a*)
2. (*b*)
3. (*b*) and (*d*)
4. (*a*) and (*c*)
5. (*b*) and (*c*)
6. some other combination
7. None of the above.

An electrically neutral dipole is placed in an external field. In which situation(s) is the net force on the dipole zero?



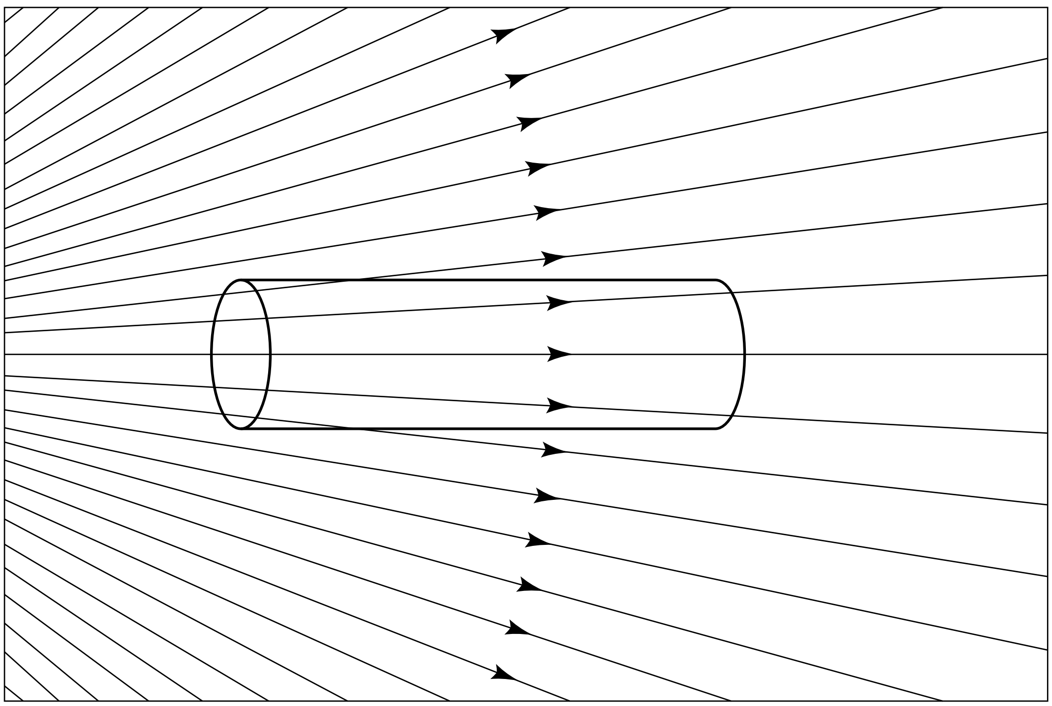
1. (*a*)
2. (*c*)
3. (*b*) and (*d*)
4. (*a*) and (*c*)
5. (*c*) and (*d*)
6. some other combination
7. none of the above

The electric charge per unit area is $+\sigma$ for plate 1 and $-\sigma$ for plate 2. The magnitude of the electric field associated with plate 1 is σ/ε_o, and the electric field lines for this plate are as shown. When the two are placed parallel to one another, the magnitude of the electric field is



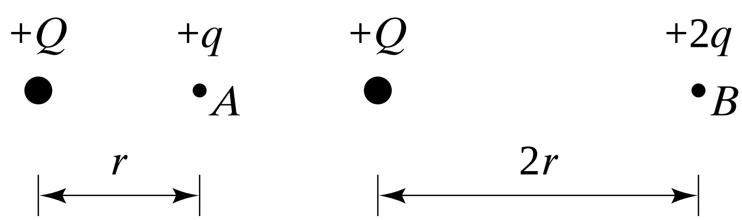
1. $2\sigma/\varepsilon_o$ between, 0 outside.
2. $2\sigma/\varepsilon_o$ between, $\pm\sigma/\varepsilon_o$ outside.
3. zero both between and outside.
4. $\pm\sigma/\varepsilon_o$ both between and outside.
5. none of the above.

A cylindrical piece of insulating material is placed in an external electric field, as shown. The net electric flux passing through the surface of the cylinder is



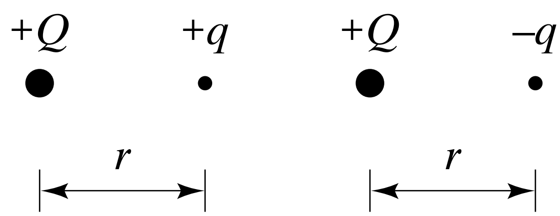
1. positive.
2. negative.
3. zero.

Two test charges are brought separately into the vicinity of a charge $+Q$. First, test charge $+q$ is brought to point A a distance r from $+Q$. Next, $+q$ is removed and a test charge $+2q$ is brought to point B a distance $2r$ from $+Q$. Compared with the electrostatic potential of the charge at A, that of the charge at B is



1. greater.
2. smaller.
3. the same.

Two test charges are brought separately into the vicinity of a charge $+Q$. First, test charge $+q$ is brought to a point a distance r from $+Q$. Then this charge is removed and test charge $-q$ is brought to the same point. The electrostatic potential energy of which test charge is greater:



1. $+q$
2. $-q$
3. It is the same for both.

An electron is pushed into an electric field where it acquires a 1-V electrical potential. Suppose instead that two electrons are pushed the same distance into the same electric field. The electrical potential of the two electrons is

1. 0.25 V.
2. 0.5 V.
3. 1 V.
4. 2 V.
5. 4 V.

A solid spherical conductor is given a net nonzero charge. The electrostatic potential of the conductor is

1. largest at the center.
2. largest on the surface.
3. largest somewhere between center and surface.
4. constant throughout the volume.

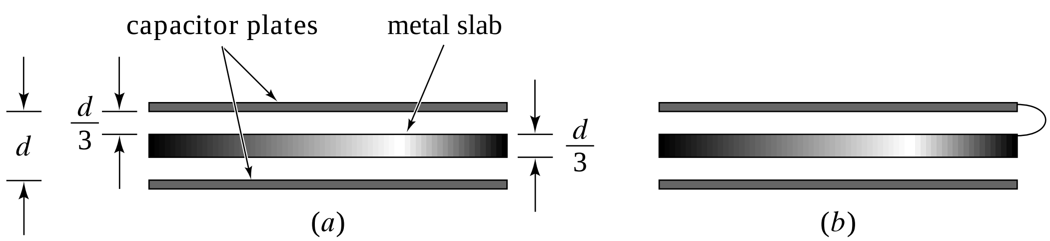
Consider two isolated spherical conductors each having net charge Q. The spheres have radii a and b, where $b > a$. Which sphere has the higher potential?

1. the sphere of radius a
2. the sphere of radius b
3. They have the same potential.

Consider a capacitor made of two parallel metallic plates separated by a distance d. The top plate has a surface charge density $+\sigma$, the bottom plate $-\sigma$. A slab of metal of thickness $l < d$ is inserted between the plates, not connected to either one. Upon insertion of the metal slab, the potential difference between the plates

1. increases.
2. decreases.
3. remains the same.

Consider two capacitors, each having plate separation d. In each case, a slab of metal of thickness $d/3$ is inserted between the plates. In case (a), the slab is not connected to either plate. In case (b), it is connected to the upper plate. The capacitance is higher for



1. case (a).
2. case (b).
3. The two capacitances are equal.

Consider a simple parallel-plate capacitor whose plates are given equal and opposite charges and are separated by a distance d. Suppose the plates are pulled apart until they are separated by a distance $D > d$. The electrostatic energy stored in the capacitor is

1. greater than
2. the same as
3. smaller than

before the plates were pulled apart.

A dielectric is inserted between the plates of a capacitor. The system is then charged and the dielectric is removed. The electrostatic energy stored in the capacitor is

1. greater than
2. the same as
3. smaller than

it would have been if the dielectric were left in place.

A parallel-plate capacitor is attached to a battery that maintains a constant potential difference V between the plates. While the battery is still connected, a glass slab is inserted so as to just fill the space between the plates. The stored energy

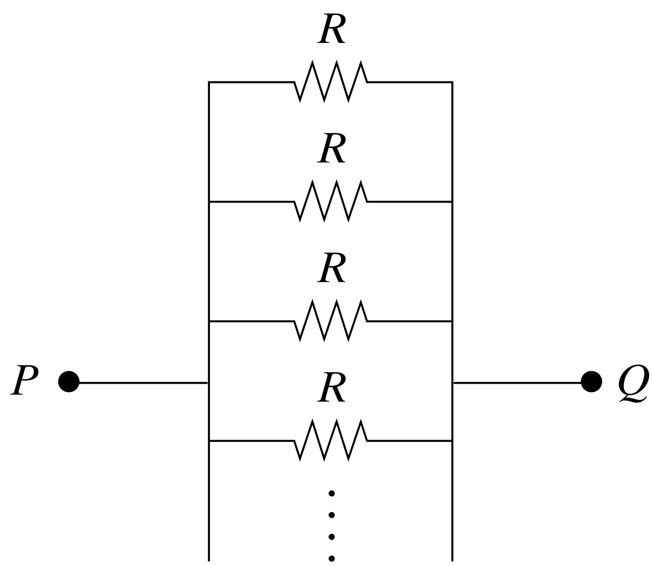
1. increases.
2. decreases.
3. remains the same.

Consider two identical resistors wired in series (one behind the other). If there is an electric current through the combination, the current in the second resistor is

1. equal to
2. half
3. smaller than, but not necessarily half

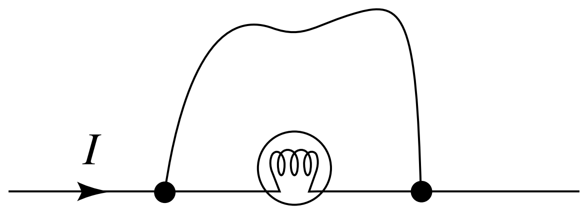
the current through the first resistor.

As more identical resistors R are added to the parallel circuit shown here, the total resistance between points P and Q



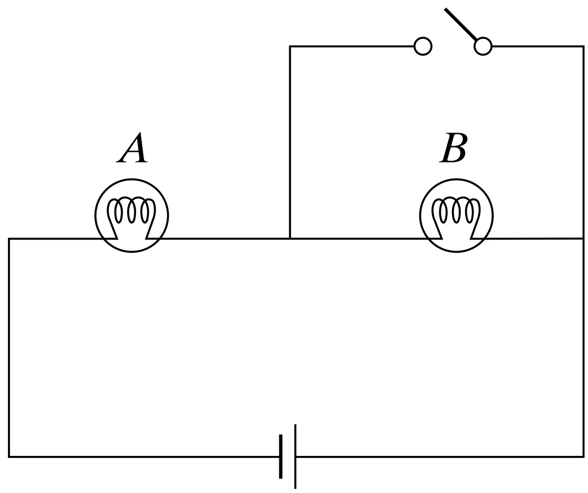
1. increases.
2. remains the same.
3. decreases.

Charge flows through a light bulb. Suppose a wire is connected across the bulb as shown. When the wire is connected,



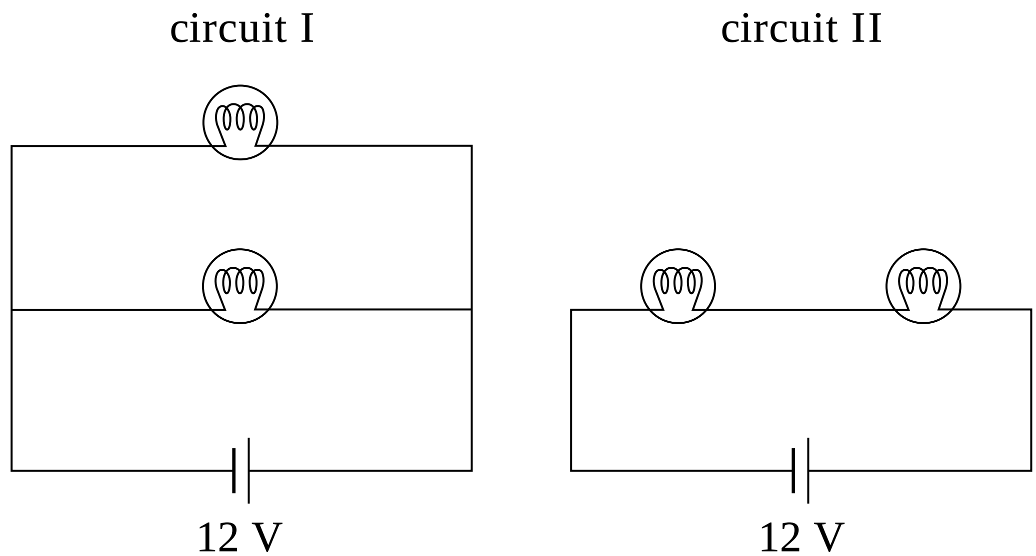
1. all the charge continues to flow through the bulb.
2. half the charge flows through the wire, the other half continues through the bulb.
3. all the charge flows through the wire.
4. none of the above

The circuit below consists of two identical light bulbs burning with equal brightness and a single 12 V battery. When the switch is closed, the brightness of bulb *A*



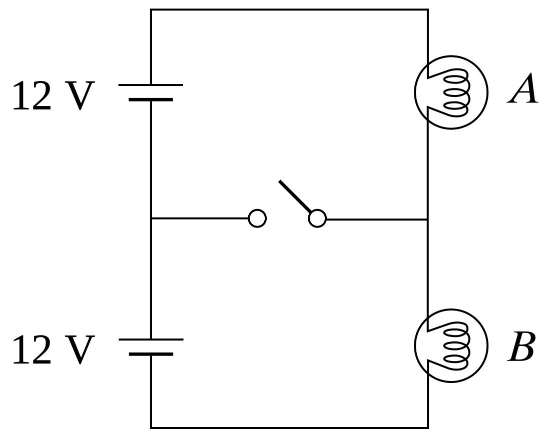
1. increases.
2. remains unchanged.
3. decreases.

If the four light bulbs in the figure are identical, which circuit puts out more light?



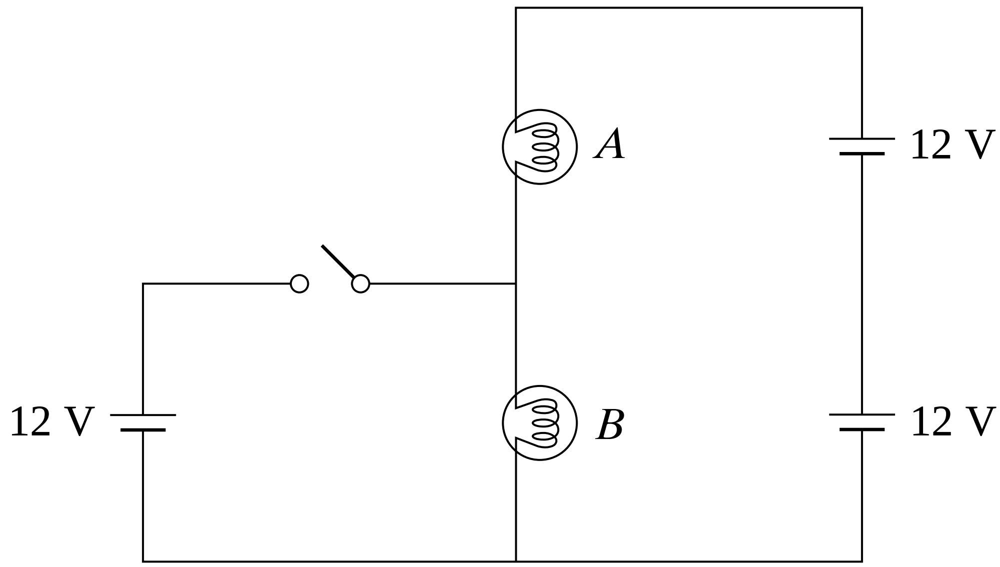
1. I.
2. The two emit the same amount of light.
3. II.

The light bulbs in the circuit are identical. When the switch is closed,



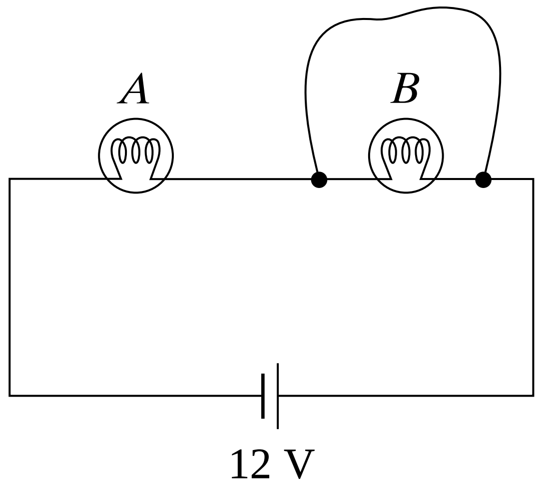
1. both go out.
2. the intensity of light bulb A increases.
3. the intensity of light bulb A decreases.
4. the intensity of light bulb B increases.
5. the intensity of light bulb B decreases.
6. some combination of 1–5 occurs.
7. nothing changes.

The light bulbs in the circuit are identical. When the switch is closed,



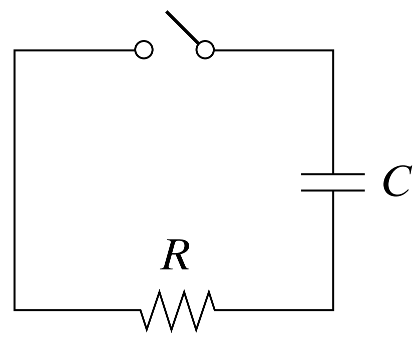
1. both go out.
2. the intensity of light bulb A increases.
3. the intensity of light bulb A decreases.
4. the intensity of light bulb B increases.
5. the intensity of light bulb B decreases.
6. some combination of 1–5 occurs.
7. nothing changes.

Two light bulbs A and B are connected in series to a constant voltage source. When a wire is connected across B as shown, bulb A



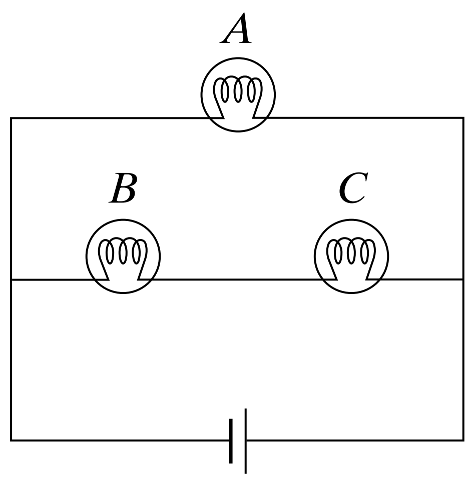
1. burns more brightly.
2. burns as brightly.
3. burns more dimly.
4. goes out.

A simple circuit consists of a resistor R, a capacitor C charged to a potential V_o, and a switch that is initially open but then thrown closed. Immediately after the switch is thrown closed, the current in the circuit is



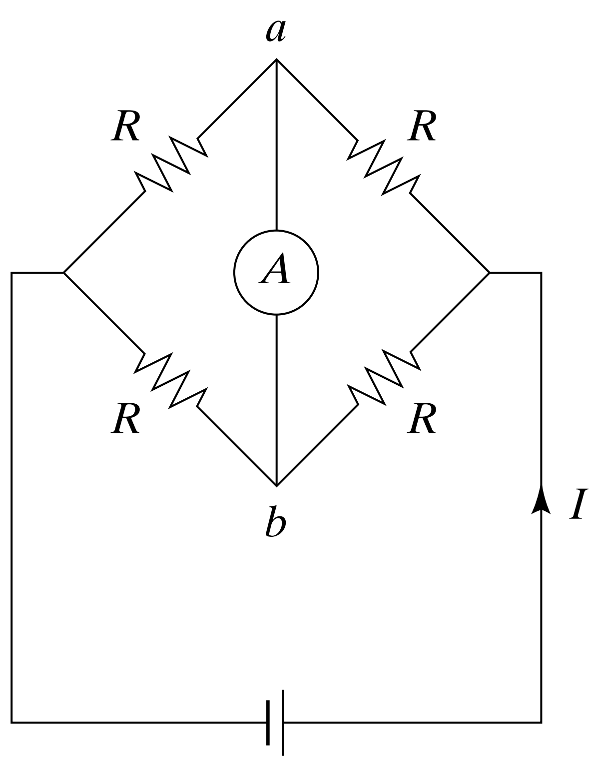
1. V_o/R.
2. zero.
3. need more information

The three light bulbs in the circuit all have the same resistance. Given that brightness is proportional to power dissipated, the brightness of bulbs B and C together, compared with the brightness of bulb A, is



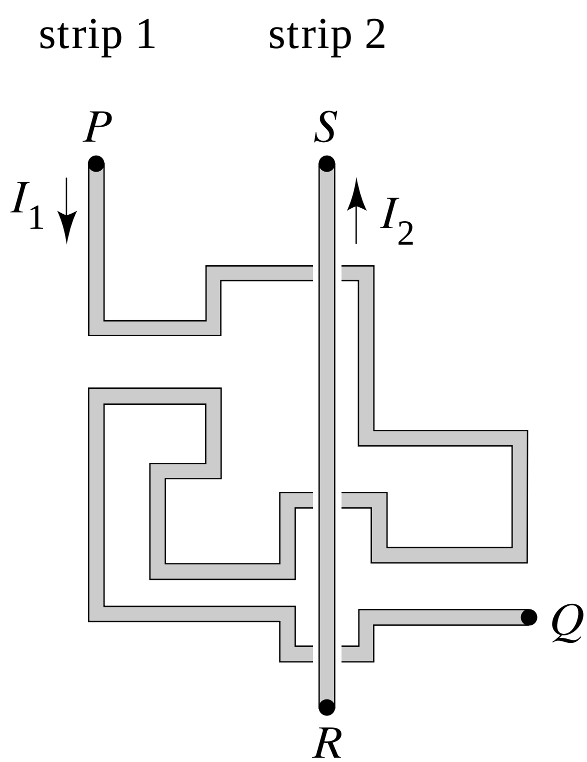
1. twice as much.
2. the same.
3. half as much.

An ammeter A is connected between points a and b in the circuit below, in which the four resistors are identical. The current through the ammeter is



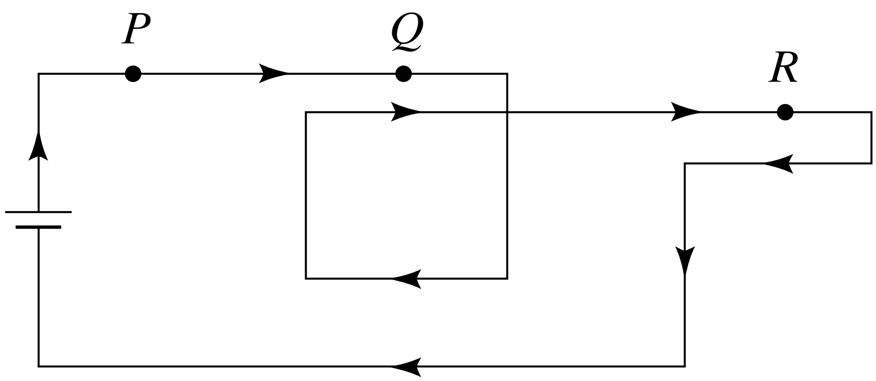
1. $I/2$.
2. $I/4$.
3. zero.
4. need more information

On a computer chip, two conducting strips carry charge from P to Q and from R to S. If the current direction is reversed in both wires, the net magnetic force of strip 1 on strip 2



1. remains the same.
2. reverses.
3. changes in magnitude, but not in direction.
4. changes to some other direction.
5. other

A battery establishes a steady current around the circuit below. A compass needle is placed successively at points P, Q, and R. The relative deflection of the needle, in descending order, is

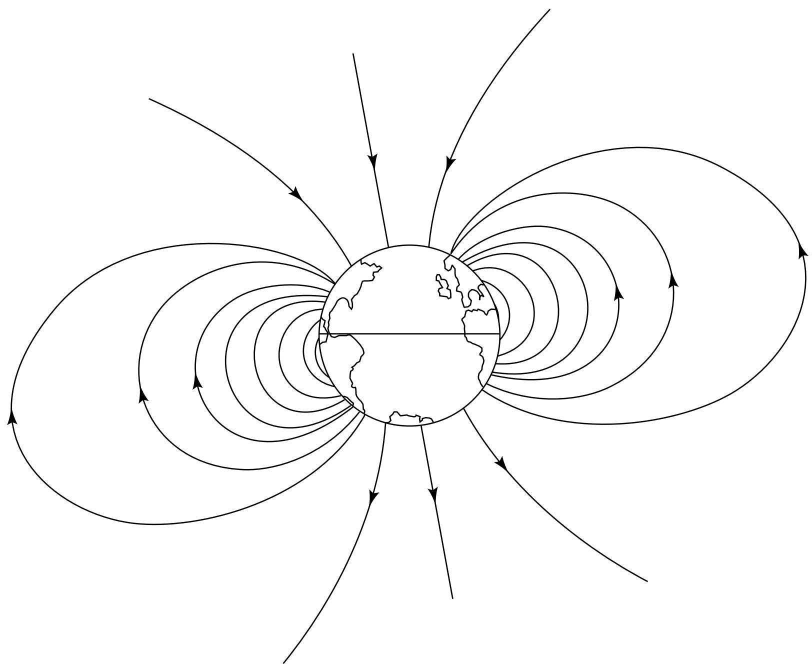


1. P, Q, R.
2. Q, R, P.
3. R, Q, P.
4. P, R, Q.
5. Q, P, R.

A charged particle accelerated to a velocity v enters the chamber of a mass spectrometer. The particle's velocity is perpendicular to the direction of the uniform magnetic field B in the chamber. After the particle enters the magnetic field, its path is a

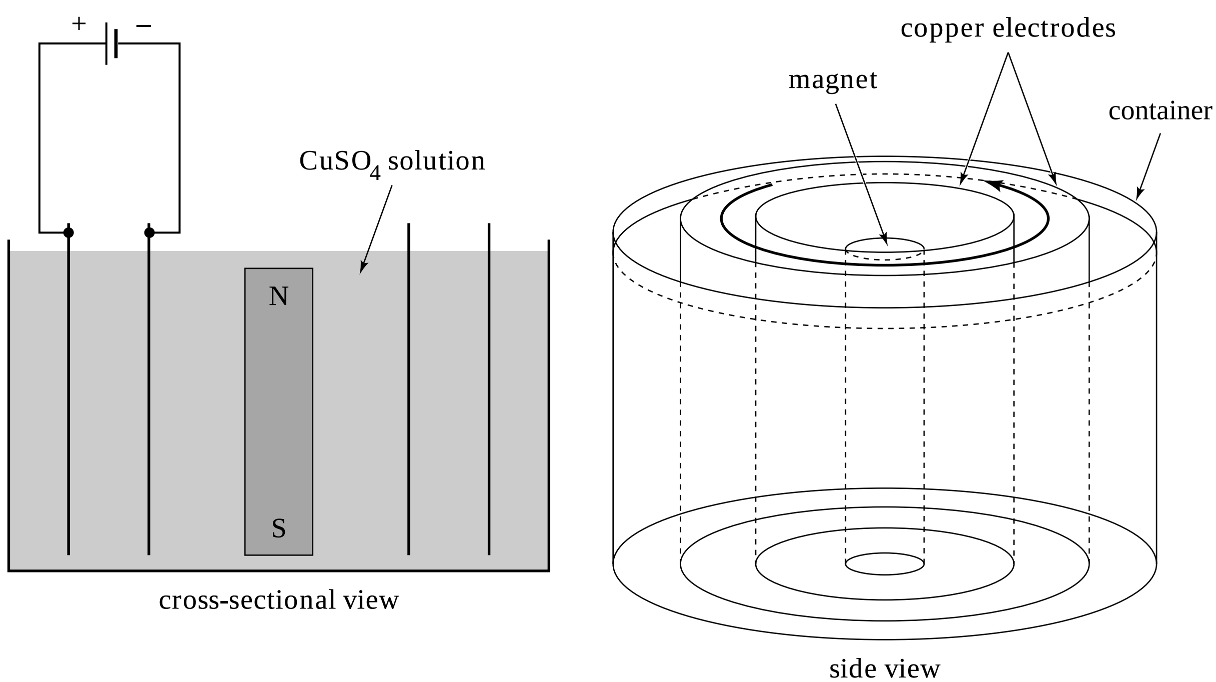
1. parabola.
2. circle.
3. spiral.
4. straight line.

Cosmic rays (atomic nuclei stripped bare of their electrons) would continuously bombard Earth's surface if most of them were not deflected by Earth's magnetic field. Given that Earth is, to an excellent approximation, a magnetic dipole, the intensity of cosmic rays bombarding its surface is greatest at the



1. poles.
2. mid-latitudes.
3. equator.

A $CuSO_4$ solution is placed in a container housing coaxial cylindrical copper electrodes. Electric and magnetic fields are set up as shown. Uncharged pollen grains added to the solution are carried along by the mobile ions in the liquid. Viewed from above, the pollen between the electrodes circulates clockwise. The pollen is carried by ions that are

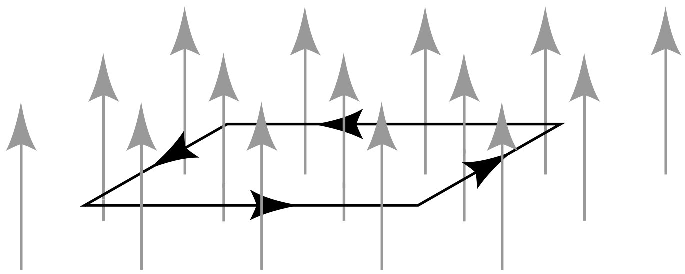


1. positive.
2. negative.
3. both positive and negative.
4. need more information

A sphere of radius R is placed near a long, straight wire that carries a steady current I. The magnetic field generated by the current is B. The total magnetic flux passing through the sphere is

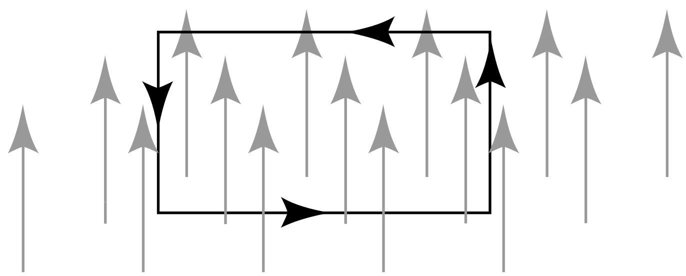
1. $\mu_o I$.
2. $\mu_o I/(4\pi R^2)$.
3. $4\pi R^2 \mu_o I$.
4. zero.
5. need more information

A rectangular loop is placed in a uniform magnetic field with the plane of the loop perpendicular to the direction of the field. If a current is made to flow through the loop in the sense shown by the arrows, the field exerts on the loop:



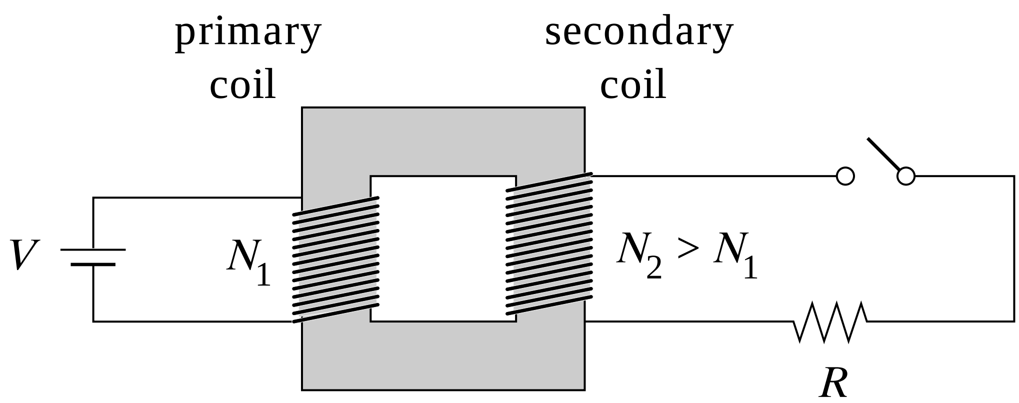
1. a net force.
2. a net torque.
3. a net force and a net torque.
4. neither a net force nor a net torque.

A rectangular loop is placed in a uniform magnetic field with the plane of the loop parallel to the direction of the field. If a current is made to flow through the loop in the sense shown by the arrows, the field exerts on the loop:



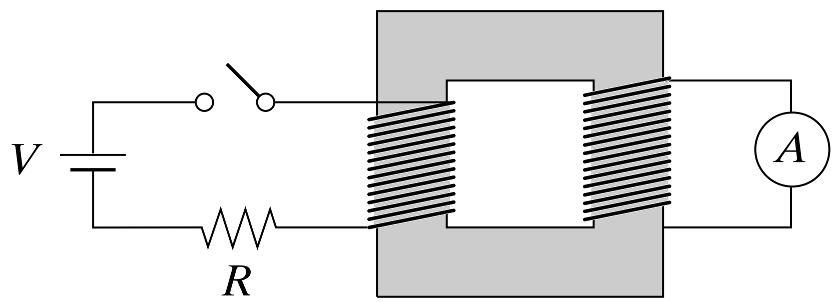
1. a net force.
2. a net torque.
3. a net force and a net torque.
4. neither a net force nor a net torque.

When the switch is closed, the potential difference across R is



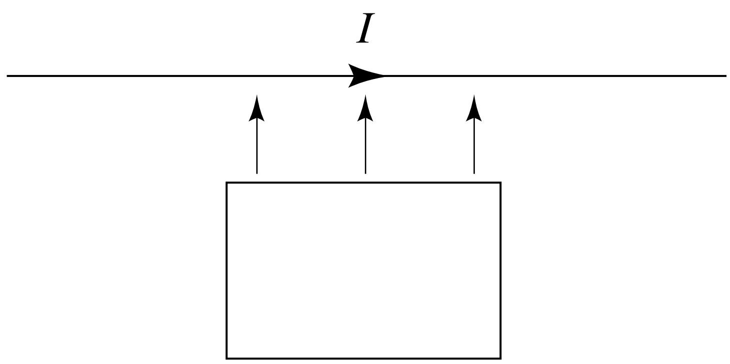
1. VN_2 /N_1.
2. VN_1/N_2.
3. V.
4. zero.
5. insufficient information

The primary coil of a transformer is connected to a battery, a resistor, and a switch. The secondary coil is connected to an ammeter. When the switch is thrown closed, the ammeter shows



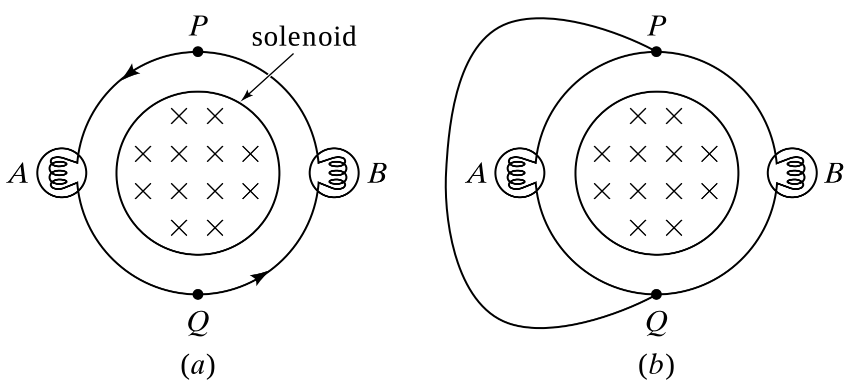
1. zero current.
2. a nonzero current for a short instant.
3. a steady current.

A long, straight wire carries a steady current I. A rectangular conducting loop lies in the same plane as the wire, with two sides parallel to the wire and two sides perpendicular. Suppose the loop is pushed toward the wire as shown. Given the direction of I, the induced current in the loop is

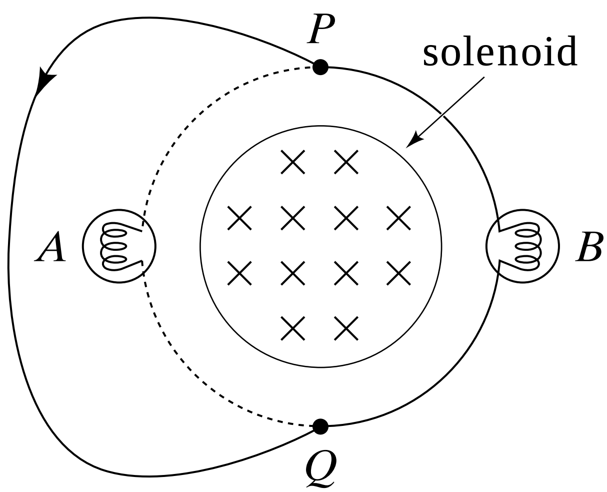


1. clockwise.
2. counterclockwise.
3. need more information

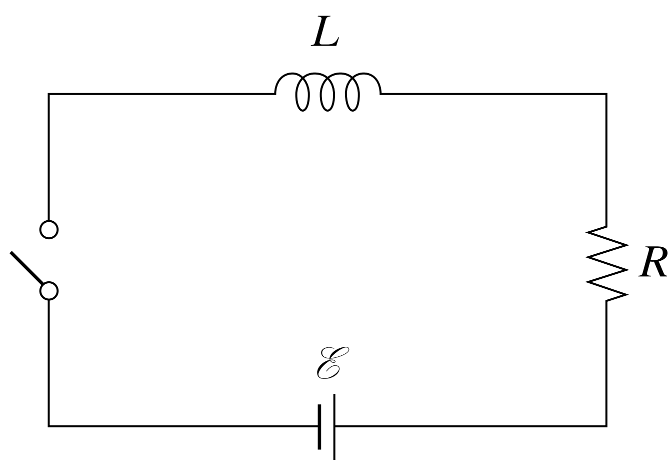
In figure (a), a solenoid produces a magnetic field whose strength increases into the plane of the page. An induced emf is established in a conducting loop surrounding the solenoid, and this emf lights bulbs A and B. In figure (b), points P and Q are shorted. After the short is inserted,



1. bulb A goes out; bulb B gets brighter.
2. bulb B goes out; bulb A gets brighter.
3. bulb A goes out; bulb B gets dimmer.
4. bulb B goes out; bulb A gets dimmer.
5. both bulbs go out.
6. none of the above

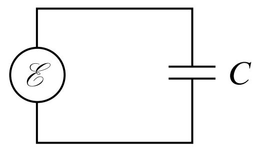

P
solenoid
A
B
Q

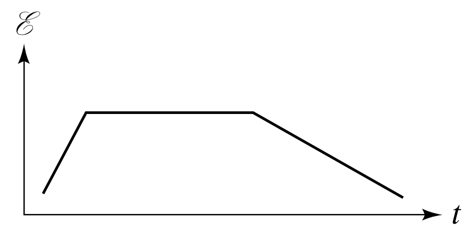
When the switch is closed, the current through the circuit exponentially approaches a value $I = \mathcal{E}/R$. If we repeat this experiment with an inductor having twice the number of turns per unit length, the time it takes for the current to reach a value of $I/2$

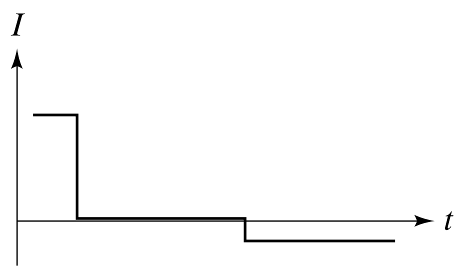


1. increases.
2. decreases.
3. is the same.

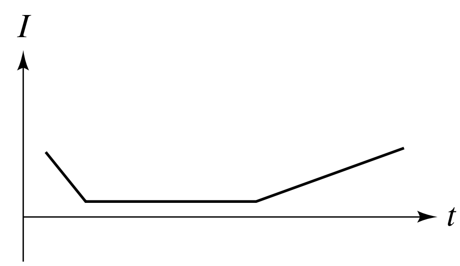
A capacitor is connected to a varying source of emf. Given the behavior of $\mathscr{E}$ shown, the current through the wires changes according to:



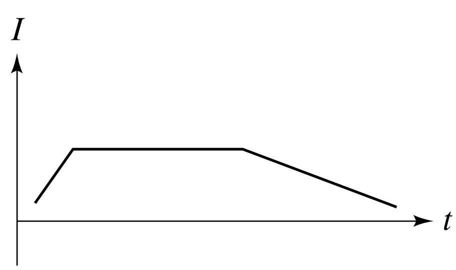




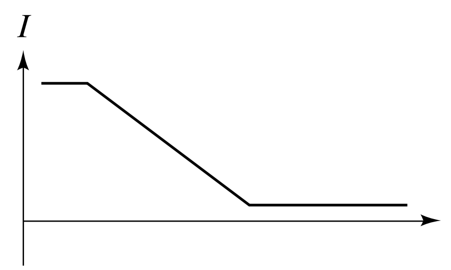
1



2



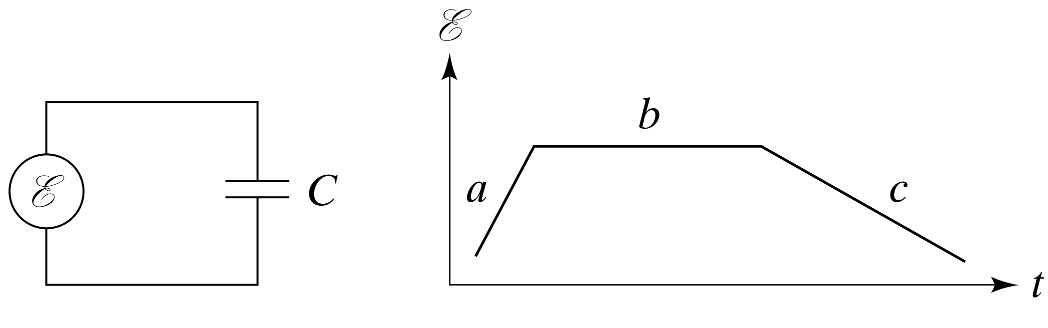
3



4

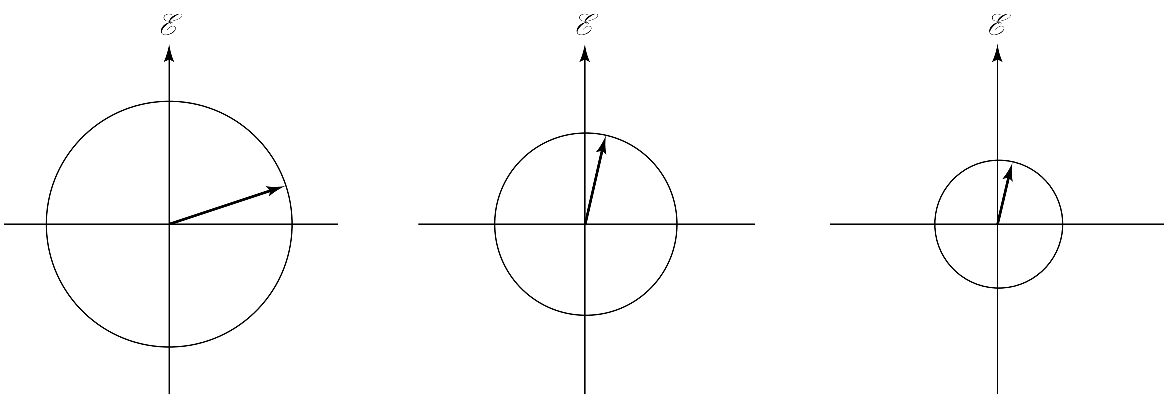
5. none of the above

A capacitor is connected to a varying source of emf. The work done by the source during the time intervals *a*, *b*, and *c* is



1. positive, negative, and zero, respectively.
2. negative, positive, and zero, respectively.
3. always positive.
4. positive, zero, and negative, respectively.
5. always negative.
6. zero, positive, and zero, respectively.
7. zero, negative, and zero, respectively.

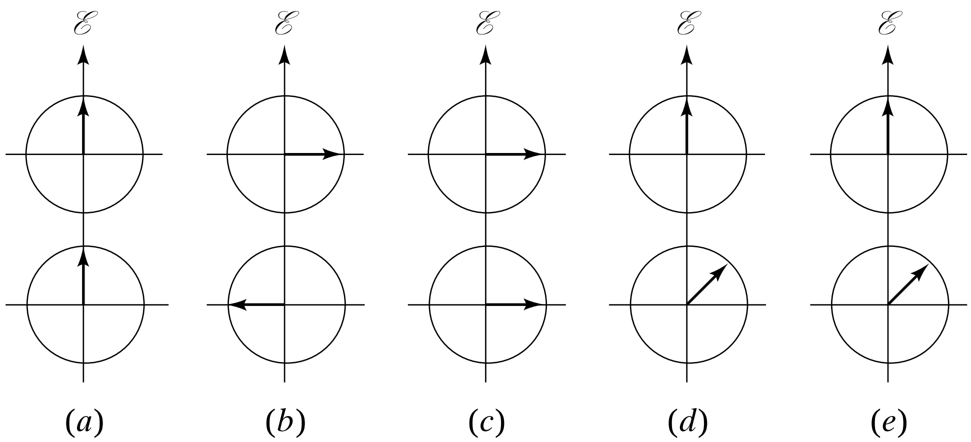
The phasor diagrams below represent three oscillating emfs having different amplitudes and frequencies at a certain instant of time $t = 0$. As t increases, each phasor rotates counter-clockwise and completely determines a sinusoidal oscillation. At the instant of time shown, the magnitude of $\mathcal{E}$ associated with each phasor given in ascending order by diagrams



(*a*) (*b*) (*c*)

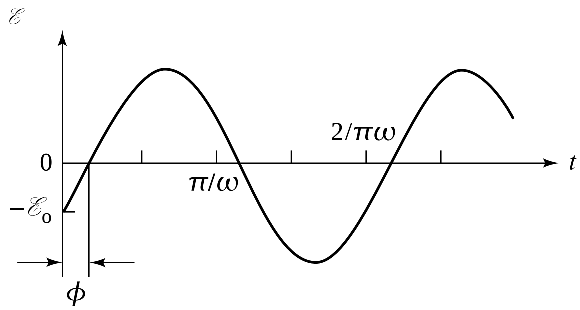
1. (*a*), (*b*), and (*c*).
2. (*a*), (*c*), and (*b*).
3. (*b*), (*c*), and (*a*).
4. (*c*), (*a*), and (*b*).
5. none of the above
6. need more information

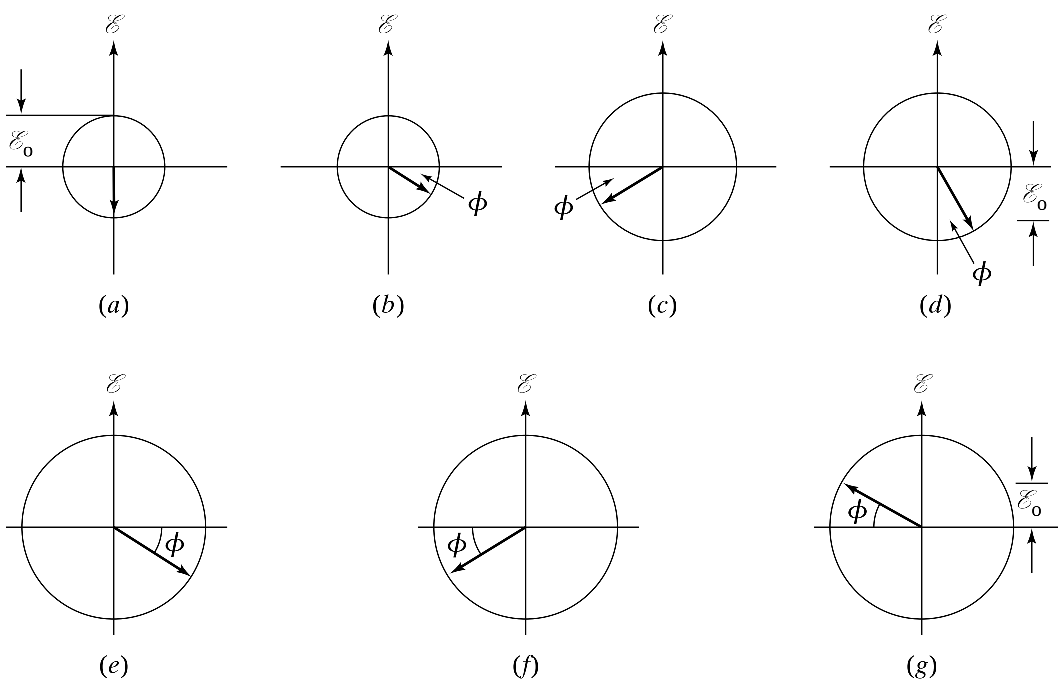
Consider the pairs of phasors below, each shown at $t = 0$. All are characterized by a common frequency of oscillation ω. If we add the oscillations, the maximum amplitude is achieved for pair



1. (a).
2. (b).
3. (c).
4. (d).
5. (e).
6. (a), (b), and (c).
7. (a) and (c).
8. (b) and (c).
9. need more information

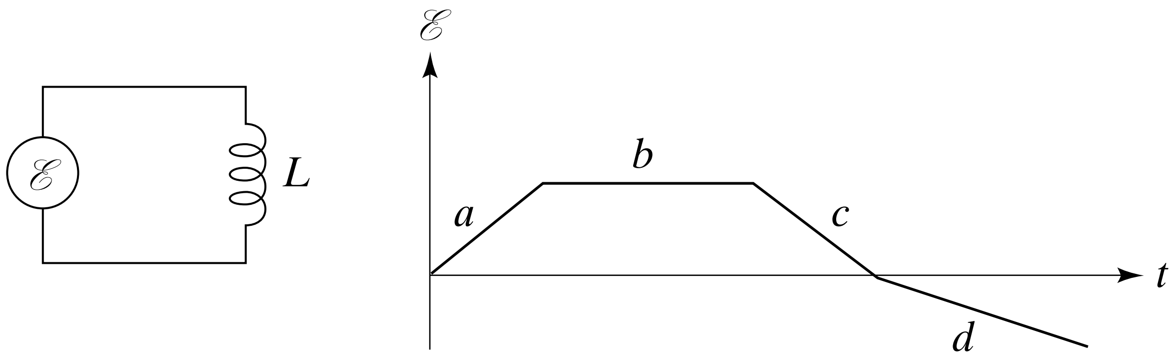
Consider the oscillating emf shown below. Which of the phasor diagrams correspond(s) to this oscillation:





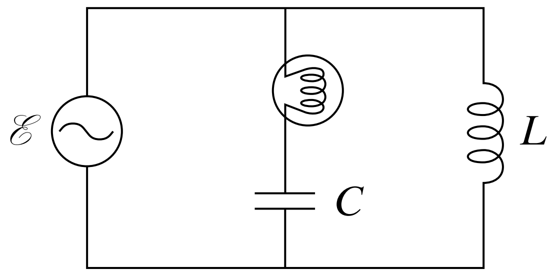
1. all but (b) and (c)
2. all
3. (e), (f), and (g)
4. (d)
5. (e)
6. all but (a) and (d)
7. (d) and (e)
8. none

Consider an inductor connected to a source of varying emf. If the graph below represents the current through the inductor, the work done by the source is:



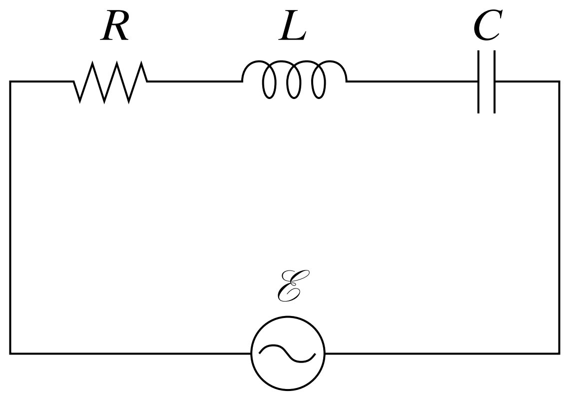
1. positive during time intervals a, b, and c.
2. zero during b, positive during d.
3. negative during d, negative during d.
4. positive during b, negative during d.
5. positive during a, zero during b, negative during c and d.
6. none of the above

The light bulb has a resistance R, and the emf drives the circuit with a frequency ω. The light bulb glows most brightly at



1. very low frequencies.
2. very high frequencies.
3. the frequency $\omega = 1/\sqrt{LC}$.

For the RLC series circuit shown, which of these statements is/are true:



(i) Potential energy oscillates between C and L.

(ii) The source does no net work: Energy lost in R is compensated by energy stored in C and L.

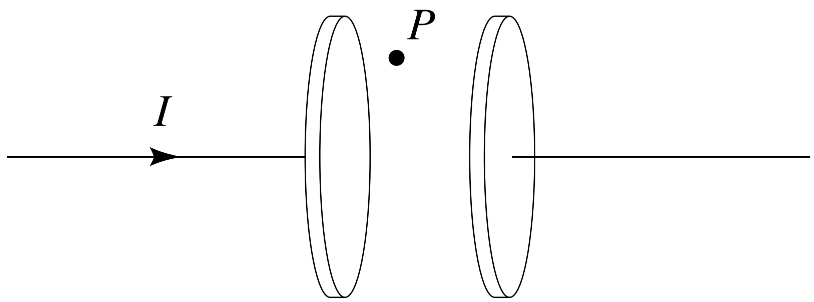
(iii) The current through C is 90° out of phase with the one through L.

(iv) The current through C is 180° out of phase with the one through L.

(v) All energy is dissipated in R.

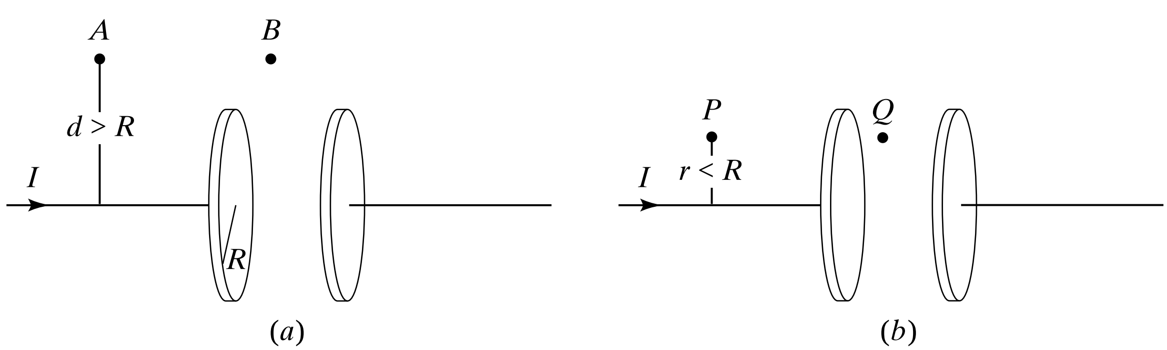
1. all of them
2. none of them
3. (v)
4. (ii)
5. (i), (iv), and (v)
6. (i) and (v)
7. none of the above

As the capacitor shown below is charged with a constant current I, at point P there is a



1. constant electric field.
2. changing electric field.
3. constant magnetic field.
4. changing magnetic field.
5. changing electric field and a magnetic field.
6. changing magnetic field and an electric field.
7. none of the above.

For a charging capacitor, the total displacement current between the plates is equal to the total conduction current I in the wires. The capacitors in the diagram have circular plates of radius R. In (a), points A and B are each a distance $d > R$ away from the line through the centers of the plates; in this case the magnetic field at A due to the conduction current is the same as that at B due to the displacement current. In (b), points P and Q are each a distance $r < R$ away from the center line. Compared with the magnetic field at P, that at Q is



1. bigger.
2. smaller.
3. the same.
4. need more information.

A planar electromagnetic wave is propagating through space. Its electric field vector is given by $\mathbf{E} = E_o \cos(kz - \omega t)\hat{\mathbf{x}}$. Its magnetic field vector is

1. $\mathbf{B} = B_o \cos(kz - \omega t)\hat{\mathbf{y}}$
2. $\mathbf{B} = B_o \cos(ky - \omega t)\hat{\mathbf{z}}$
3. $\mathbf{B} = B_o \cos(ky - \omega t)\hat{\mathbf{x}}$
4. $\mathbf{B} = B_o \cos(kz - \omega t)\hat{\mathbf{z}}$

At a fixed point, P, the electric and magnetic field vectors in an electromagnetic wave oscillate at angular frequency ω. At what angular frequency does the Poynting vector oscillate at that point?

1. 2ω
2. ω
3. $\omega/2$
4. 4ω

Which gives the largest average energy density at the distance specified and thus, at least qualitatively, the best illumination

1. a 50-W source at a distance *R*.
2. a 100-W source at a distance 2*R*.
3. a 200-W source at a distance 4*R*.

The best color to paint a radiator, as far as heating efficiency is concerned, is

1. black.
2. white.
3. metallic.
4. some other color.
5. It doesn’t really matter.

A beam of ultraviolet light is incident on the metal ball of an electroscope. Which statement(s) is/are true?

1. If the electroscope was initially positively charged, it discharges.
2. If the electroscope was initially negatively charged, it discharges.
3. Both of the above.
4. Neither of the above.

A beam of ultraviolet light is incident on the metal ball of an electroscope that is initially uncharged. Does the electroscope acquire a charge?

1. Yes, it acquires a positive charge.
2. Yes, it acquires a negative charge.
3. No, it does not acquire a charge.

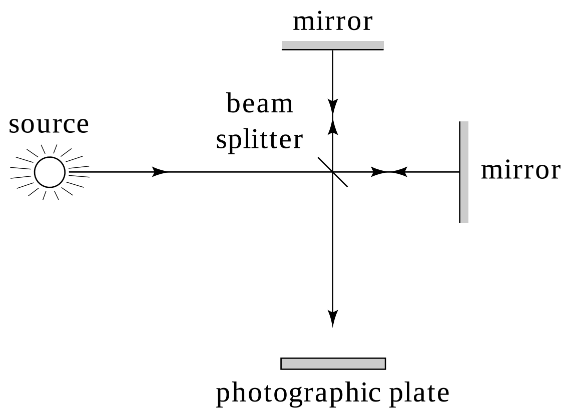
A xenon arc lamp is covered with an interference filter that only transmits light of 400-nm wavelength. When the transmitted light strikes a metal surface, a stream of electrons emerges from the metal. If the intensity of the light striking the surface is doubled,

1. more electrons are emitted in a given time interval.
2. the electrons that are emitted are more energetic.
3. both of the above.
4. neither of the above.

A xenon arc lamp is covered with an interference filter that only transmits light of 400-nm wavelength. When the transmitted light strikes a metal surface, a stream of electrons emerges from the metal. The interference filter is then replaced with one transmitting at 300 nm and the lamp adjusted so that the intensity of the light striking the surface is the same as it was for the 400-nm light. With the 300-nm light,

1. more electrons are emitted in a given time interval.
2. the electrons which are emitted are more energetic.
3. both are true.
4. both are false.

In a Michelson interferometer, a beam of light is split into two parts of equal intensity, and the two parts are subsequently recombined to interfere with one another. When a single photon is sent through the interferometer, the photographic plate shows



1. a single dot somewhere on the plate because the photon chooses one of the two paths through the splitter and then returns and strikes the plate.
2. a single dot, which is more likely to lie in some regions than others, because of the interference between the two paths.
3. an interference pattern because the interferometer splits the photon into two waves that subsequently interfere at the plate.

Single photons are directed, one by one, toward a double slit. The distribution pattern of impacts that make it through to a detector behind the slits is identical to an interference pattern. We now repeat this experiment, but block slit 1 for the first half of the experiment and slit 2 for the second half. The distribution of impacts in the second experiment is

1. the same as in the first experiment.
2. the sum of the distributions one gets for each slit separately.
3. neither of the above.

Thompson observed that cathode beams can pass undeflected through crossed electric and magnetic fields. Which of the following quantities must then be common to the particles making up these beams

1. mass
2. size
3. magnitude of charge
4. sign of charge
5. sign and magnitude of charge
6. velocity

A cathode beam passes undeflected through crossed electric and magnetic fields. When the electric field is switched off, the beam splits up in several beams. This splitting is due to the particles in the beam having different

A. masses.
B. velocities.
C. charges.
D. none of the above

Cathode rays are beams of electrons, but the electrons are not deflected downward by gravity because

1. the effect of gravity on electrons is negligible.
2. the electrons go so fast there’s no time to fall.
3. of air resistance.
4. the electrons are quantum particles and not classical particles.
5. the electric charge prevents electrons from feeling gravity.
6. other

An emission spectrum for hydrogen can be obtained by analyzing the light from hydrogen gas that has been heated to very high temperatures (the heating populates many of the excited states of hydrogen). An absorption spectrum can be obtained by passing light from a broadband incandescent source through hydrogen gas. If the absorption spectrum is obtained at room temperature, when all atoms are in the ground state, the absorption spectrum will

1. be identical to the emission spectrum.
2. contain some, but not all, of the lines appearing in the emission spectrum.
3. contain all the lines seen in the emission spectrum, plus additional lines.
4. look nothing like the emission spectrum.