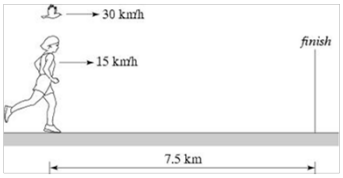
A marathon runner runs at a steady 15 km/hr. When the runner is 7.5 km from the finish, a bird begins flying from the runner to the finish at 30 km/hr. When the bird reaches the finish line, it turns around and flies back to the runner, and then turns around again, repeating the back-and-forth trips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

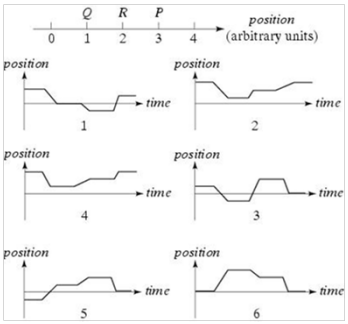
How many kilometers does the bird travel?



A. 10 km
B. 15 km
C. 20 km
D. 30 km
E. 35 km

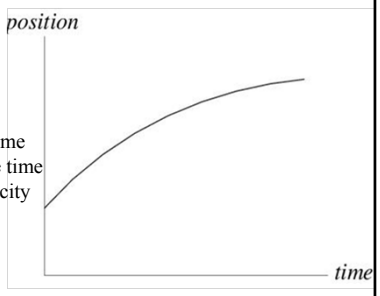
A person initially at point P in the illustration stays there a moment and then moves along the axis to Q and stays there a moment. She then runs quickly to R, stays there a moment, and then strolls slowly back to P.

Which of the graphs below correctly represents this motion?



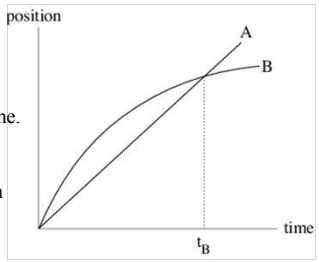
A train car moves along a long straight track. The graph shows the position as a function of time for this train. The graph shows that the train:

A. Speeds up always
B. Slows down always
C. Speeds up part of the time and slows down part of the time
D. Moves at constant velocity



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

Which is true?



A. At time t_B both trains have the same velocity
B. Both trains speed up all the time.
C. Both trains have the same velocity at some time before t_B
D. Somewhere on the graph, both trains have the same acceleration.

Which of the following necessarily means that an object is slowing down in one dimension?

a) The acceleration is negative

b) The velocity and acceleration are both negative

c) The velocity and acceleration have opposite signs

d) The velocity is negative

e) The velocity and acceleration are both positive

A vehicle moves north a constant speed, then turns and moves east at the same constant speed.

Which direction is the average acceleration for the turn?

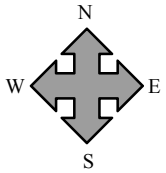
a. South East

b. East

c. North East

d. West

e. There is no acceleration



The engine of your car produces a force at the wheels when you use the gas pedal, accelerating the car from rest.

When cruising at constant speed on the highway, why is the gas peddle no longer causing the car to accelerate?

a) You are only resting your foot on it, not pushing
b) The gas peddle is decoupled from the wheels
c) The acceleration is taken up by the engine revs
d) There is a balancing force from air resistance
e) The acceleration is a change in direction, not speed

A moving heavy cart collides with a light stationary cart. The light cart moves forwards quickly and the heavy moves forwards slowly after the collision.

How do the forces each cart exerted on the other compare?

a) They are the same magnitude
b) The heavy cart exerts a greater force on the lighter cart
c) The lighter cart exerts a greater force on the heavy cart
d) It is not possible to tell without knowing more details about the collision process.

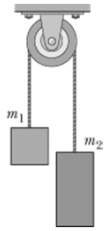
You are a passenger in a car and not wearing your seat belt. Without increasing or decreasing its speed, the car makes a sharp left turn, and you find yourself colliding with the right-hand door.
Which is the correct analysis of the situation?

a) There is a rightward force pushing you into the door.
b) Starting at the time of collision, the door exerts a leftward force on you.
c) both of the above
d) neither of the above

A person is standing in an elevator that is accelerating upward. *Compared to the downward force of gravity on the person, the upward normal force exerted by the elevator floor on the person is*

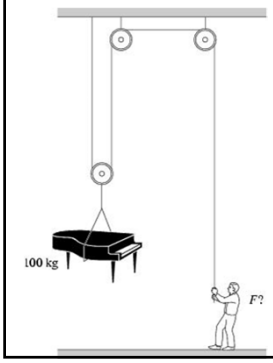
a) Larger
b) The same
c) Smaller

If mass $m_1 = m_2$
what happens when the masses are released from rest?



a) At constant speed, m_1 moves down and m_2 moves up
b) At constant speed, m_1 moves up and m_2 moves down
c) At constant acceleration, m_1 moves up and m_2 moves down
d) At constant acceleration, m_1 moves down and m_2 moves up
e) Neither mass moves.

A piano mover raises a 100-kg piano at a constant velocity using the frictionless pulley system shown here. With how much force is he pulling on the rope? Assume g = 10 m/s/s



a) 2000 N

b) 1000 N

c) 500 N

d) 250 N

e) Impossible to determine

The drawing shows the overhead view of a steel ball flying across a table at constant velocity from point A to point B. As it passes point B, for a short time a magnet exerts a force on it toward the magnet. Which of the following trajectories does the ball follow far beyond point B?

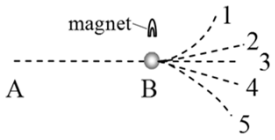
a) 1

b) 2

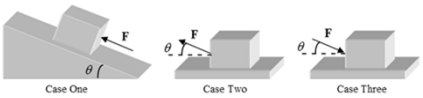
c) 3

d) 4

e) 5



In the drawings, a force of the same magnitude F is applied to a box of mass M. In which case(s) will the magnitude of the normal force on the box be equal to (F sin $\theta + Mg$)?



a) Case One only

b) Case Two only

c) Case Three only

d) Cases One and Two only

e) Cases Two and Three only

A box is held by a rope on a frictionless inclined surface as shown. What will the magnitude of the acceleration of the box be if the rope breaks?

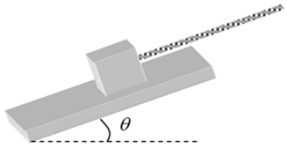
a) g

b) g sin θ

c) g cos θ

d) g tan θ

e) zero m/s^2



A plate is moving away from you on a pulled table cloth without slipping on the cloth. The table cloth maintains a constant speed.
The force of friction on the plate is

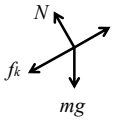
a. Away from you
b. Toward You
c. Vertically up
d. Vertically down
e. Zero

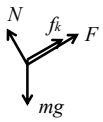
A heavy plate and a light plate made from the same material are slipping on a moving table cloth
The force of kinetic friction is

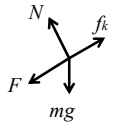
a) Larger on the heavy plate
b) The same on each plate
c) Larger on the light plate
d) Zero

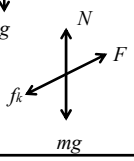
A block of mass m slides down a rough incline at a constant speed when an external force F is applied acting up the incline.
Which is the correct free body diagram?

f_k = friction
N = normal

a.


b.


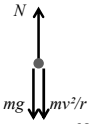
c.


d.


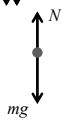
A ball is swung in a vertical circle at constant speed at the end of a taught string. At which point in the motion of the ball is the tension in the string minimum?

a) At the bottom
b) Half way up
c) At the top
d) The tension is the same everywhere
e) None of the above

A steel ball has a mass m and passes through the top of a loop-the-loop track of radius r. At the top of the loop, the ball has a speed of v. (ignore friction)
What is the free-body diagram for the ball at the top of the loop?

a.


b.


c.


d.


A block slows down on a rough horizontal table. The work done by the force of friction exerted by the table on the block is

a) Positive
b) Zero
c) Negative

A block is pulled along a rough horizontal table at constant speed. Considering the block as a system, the net work done by the external forces on the system is

a) Positive
b) Zero
c) Negative

A block is sliding initially at 0.5 m/s on a rough table and comes to rest after traveling 1 m.
The experiment is repeated, but now the block is moving at 1 m/s initally.
How far does the block travel before coming to rest?

a) 1m
b) 2m
c) 3m
d) 4m
e) Impossible to determine

A book moves from rest vertically up 1 m until it is at rest again. The experiment is repeated, but the book moves first to the right by 1 m, then vertically up 1 m, then left by 1 m.
The work done by the force of gravity on the book is

a) Approximately equal in both experiments
b) Greater in the 2nd experiment
c) Greater in the 1st experiment
d) Equal to the work done by the person moving it
e) Answers b) and d)

A spring-loaded gun shoots a dart straight up. The dart reaches a maximum height of 24 m above the release point.
The same dart is shot straight up a second time from the same gun, but this time the spring is compressed only half as much before firing.
How far up from the release point does the dart go this time?

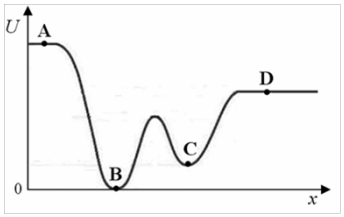
a) 96 m
b) 48 m
c) 12 m
d) 6 m
e) Impossible to determine

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

a) 50 N
b) 100 N
c) 0.2 N
d) 5 N
e) Impossible to determine

The graph shows the potential energy as a function of distance for an object moving along the *x* axis. At which of the labeled points does the force acting on the object have the least magnitude?

a) The force is the same at each of the four points.
b) A
c) B
d) C
e) D



The thermal energy of a system consisting of a thrown ball, Earth, and the air is most closely associated with:

a) motions of individual molecules within the ball and the air
b) the kinetic energy of the ball as a whole
c) motions of the individual molecules within the ball
d) the gravitational interaction of the Earth and the ball
e) the kinetic energy of Earth as a whole

Two identical uniform rods of length L are arranged in an L-shape with the origin of coordinates at the corner.
What are the coordinates of the center of mass of this system?

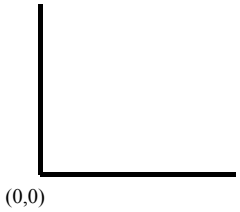
a) (L/2, L/2)

b) (L/4, L/2)

c) (L/2, L/4)

d) (L/4, L/4)

e) (L/8, L/8)



One person is at the front and the other at the rear of a canoe pointing North and at rest on a still lake. The person at the front walks to sit next to the person at the rear. What is the state of the canoe afterwards?

a) The canoe will be at rest, but it will be south of its original position.

b) The canoe will be at rest, but it will be north of its original position.

c) The canoe will be moving toward the south.

d) The canoe will be moving toward the north.

e) The canoe will be at rest at its original position.

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 needed to stop them compare?

a) It takes a shorter time to stop the bowling ball
b) It takes the same time to stop either ball
c) It takes a longer time to stop the bowling ball
d) Impossible to determine

A car travelling north makes a 90° turn to the east, emerging from the turn with the same speed that it entered.
What was the direction of the impulse on the car during this turn?

a) None of the below
b) East
c) North-East
d) The impulse is zero
e) South-East

When a larger stronger student and smaller less strong student on trolleys push off against each other

a) The larger student moves with greater initial speed

b) The smaller student moves with greater initial speed

c) The students move with the same initial speed.

d) Impossible to determine.

When a larger stronger student and smaller less strong student on trolleys push off against each other.

a) The larger student exerts more force on the smaller student than vice versa

b) The smaller student exerts more force on the larger student than vice versa

c) The students exert the same amount of force on each other

d) Impossible to determine.

When only the smaller student pushes off against the larger student on trolleys.

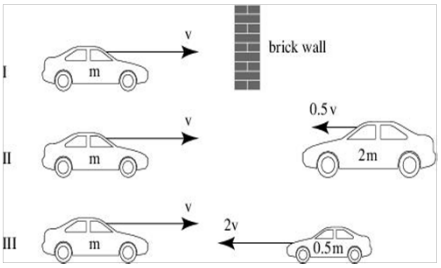
a) The larger student exerts more force on the smaller student than vice versa

b) The smaller student exerts more force on the larger student than vice versa

c) The students exert the same amount of force on each other

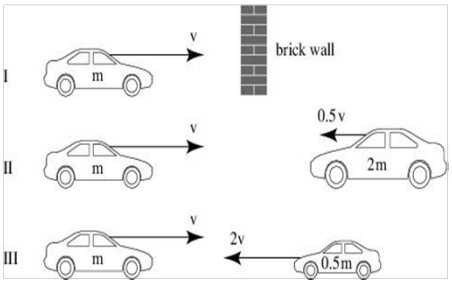
d) Impossible to determine.

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



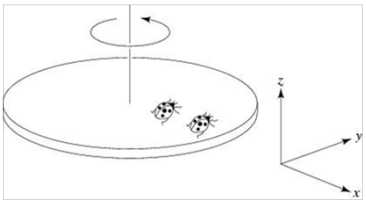
a) I
b) II
c) III
d) I and II
e) II and III
f) I and III
g) All three

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



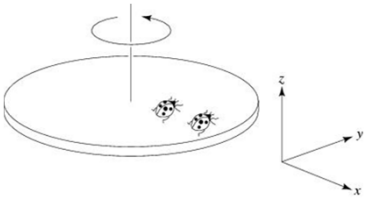
a) I
b) II
c) III
d) I and II
e) II and III
f) I and III
g) All same

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 gentleman bug's angular speed is



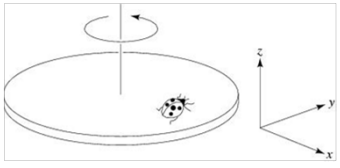
a) Half the ladybug's
b) The same as the ladybug's
c) Twice the ladybug's
d) None of the above

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 gentleman bug's linear speed is



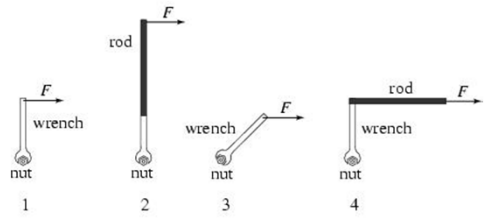
a) Half the ladybug's
b) The same as the ladybug's
c) Twice the ladybug's
d) None of the above

A ladybug sits at the outer edge of a merry-go-round that is turning as shown
The angular velocity vector of the ladybug points in the



a) $+z$ direction
b) $-z$ direction
c) $+y$ direction
d) $-y$ direction
e) $+x$ direction
f) $-x$ direction

You are using a wrench and trying to loosen a rusty nut.
List in order of decreasing torque the following arrangements:

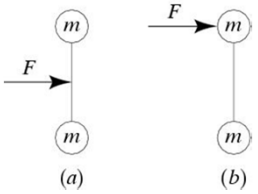


a) 2, 1=4, 3
b) 4=2, 1=3
c) 1, 3, 2, 4
d) 3, 1, 4, 2

Two identical point masses are placed on each side of a horizontal rotating arm, each distance *d* from the axis of rotation, and a constant torque applied. If the experiment is repeated with each mass at distance 2*d* from the axis, how does the angular acceleration change compared to the first experiment?

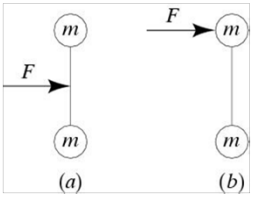
a) It is twice as much
b) It is four times as much
c) It is the same
d) It is half as much
e) It is one quarter as much

A dumbbell rests on a frictionless table. A constant force ***F*** is applied in the two ways shown.
In which case does the dumbbell acquire the greater CoM speed?



a) *a*
b) *b*
c) No difference
d) Depends on the distance between the masses

A dumbbell rests on a frictionless table. A constant force ***F*** is applied in the two ways shown.
In which case does the dumbbell acquire the greater total kinetic energy?



a) *a*
b) *b*
c) No difference
d) Depends on distance between the masses

A bicycle tire rolls to the north.
What is the direction of its angular velocity?

a) North

b) South

c) East

d) West

e) Up

f) Down

When a student on a spinning chair draws in their outstretched arms, their rotational kinetic energy

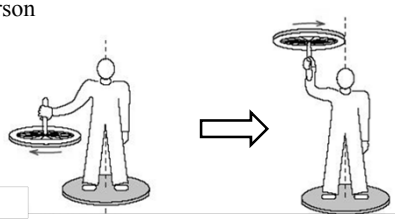
a) Increases

b) Decreases

c) Remains constant

d) Need more details to know

When a stationary person on a frictionless swivel platform inverts the axis of a spinning wheel they are holding, as shown below, the person

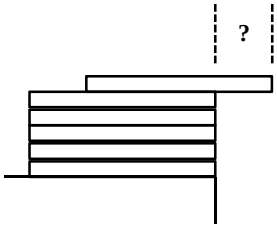


a) Remains stationary

b) Spins in the same direction the wheel was originally spinning

c) Spins in the opposite direction the wheel was originally spinning

What is the maximum fraction of its length that the 1st (top) block can be moved from the right end and still be in equilibrium?



a) 1/4

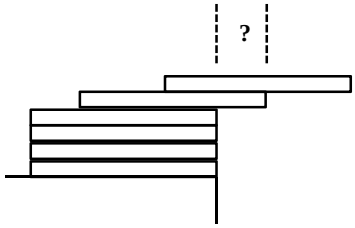
b) 1/3

c) 1/2

d) 2/3

e) 3/4

What is the maximum fraction of its length that the 2nd block can now be moved from the right end and still be in equilibrium?



a) 1/8

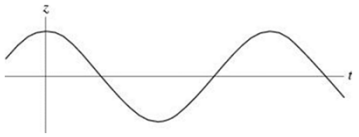
b) 1/6

c) 1/4

d) 1/3

e) 1/2

An object suspended from a spring is oscillating up an down. Consider two possibilities:
(i) at some point during the oscillation the mass has zero velocity but non-zero acceleration;
(ii) at some point during the oscillation the mass has zero velocity and zero acceleration.



a) Both occur sometime during the oscillation
b) Neither occurs during the oscillation
c) Only (i) occurs
d) Only (ii) occurs

An object hanging on a spring is pulled a distance *d* below its equilibrium position and released from rest. It takes a time *t* to get back to the equilibrium point.

If instead the object is pulled down a distance 2*d* and then released from rest, the amount of time it takes to get back to the equilibrium point is

a) 2 *t*
b) √2 *t*
c) *t*
d) *t* / √2
e) *t* / 2

An object hangs motionless on a spring at its equilibrium point. If it is pulled down, the sum of the elastic potential energy of the spring and the gravitational potential energy of the object

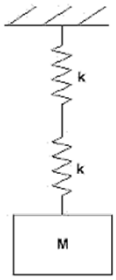
a) increases
b) stays the same
c) decreases

Each spring would separately produce SHM with angular frequency ω. When two are combined in parallel, what is the new angular frequency?

a) 2 ω
b) √2 ω
c) ω
d) ω / √2
e) ω / 2

Each spring would separately produce SHM with angular frequency ω. When two are combined in series, what is the new angular frequency?

a) 2 ω
b) √2 ω
c) ω
d) ω / √2
e) ω / 2



When a syringe is filled with ideal* fluid, how does the force that must be exerted to depress the plunger compare to when the syringe is empty?

a) Larger
b) The same
c) Smaller

*Ideal = incompressible and non-viscous

The plunger of a syringe has an area of 100 mm². Neglecting friction, what force must be exerted on the plunger to inject a patient whose blood pressure is 10,000 N/m² (about 75 Torr)?

a) 1 N
b) 10 N
c) 100 N
d) 1,000 N
e) insufficient information

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

a) larger

b) the same as

c) smaller

Two cups are filled to the same level with water. One of the two cups has a plastic ball (density less than water) floating in it. Which weighs more?

a) The cup without the ball.

b) The cup with the ball.

c) The two weigh the same.

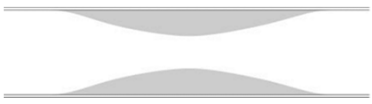
A boat carrying a heavy mass is floating on water. The heavy mass is thrown overboard and sinks. The water level

a) rises.

b) drops.

c) remains the same.

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?



a) The narrow part.

b) The wide part.

c) The flow speed 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 flux (volume of blood per unit time) largest?

a) The narrow part.

b) The wide part.

c) The flux is the same in both parts.

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

a) an increase in pressure.

b) no change in pressure.

c) a decrease in pressure.

If you were to hold two strips of paper about 1 inch apart and blow between them, what would happen?

a) They would move together

b) They would move apart

c) They would remain in the same position

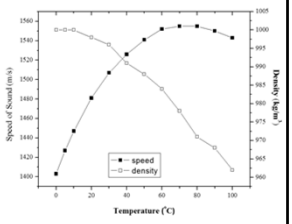
The graph shows measured data for the speed of sound in water and the density of the water versus temperature. From the graph and your knowledge of the speed of sound in liquids, what can we infer about the bulk modulus of water in the temperature range from 0 to 100 °C?

a) The bulk modulus of water increases linearly with temperature.

b) The bulk modulus of water decreases non-linearly with temperature.

c) The bulk modulus of water is constant with increasing temperature.

d) The bulk modulus of water increases non-linearly with increasing temperature.



e) The bulk modulus of water increases with increasing temperature until it peaks around 60 °C after which it slowly decreases.

A particle of dust is floating in the air in front of a speaker. The speaker is then turned on produces a sound wave of frequency 226 Hz. Which one of the following statements correctly describes the subsequent motion of the dust particle?

a) The particle of dust will oscillate left and right with a frequency of 226 Hz.

b) The particle of dust will oscillate up and down with a frequency of 226 Hz.

c) The particle of dust will be accelerated toward the right and continue moving in that direction.

d) The particle of dust will move toward the right at constant velocity.

e) The dust particle will remain motionless as it cannot be affected by sound waves.

The sound level of sounds below the standard threshold of hearing at a frequency of 1 kHz is

a) zero

b) positive

c) negative

d) 1 kHz

e) None of the above

If a sound increases in intensity by a factor 100 times, the sound level

a) increases by a factor of 100 times

b) increases by 100 dB

c) increases by 20 dB

d) increases by 10 dB

e) decreases by a factor 100 times

A child is swinging back and forth in front of a stationary horn. At which position(s) will the child hear the lowest frequency for the sound from the horn?

a) at **B** when moving toward **A**

b) at **B** when moving toward **C**

c) at **C** when moving toward **B**

d) at **C** when moving toward **D**

e) at both **A** and **D**