Question:

An object's momentum depends upon the object's

a. mass, speed, and acceleration
b. mass, speed, and direction of motion
c. speed and acceleration
d. velocity and direction of motion
e. mass and acceleration

Answer:

The correct answer is *b*. Momentum is a vector quantity that is determined by calculating mass times velocity, where velocity is also a vector quantity. The direction of the momentum is in the same direction as the velocity. Because velocity is a vector that includes both a speed and a direction, choice *b* above is the correct answer.

When we want to be very careful about indicating that a quantity is vector, some textbooks will write that variable in bold, and/or include a right-facing arrow above the variable.

$$\vec{\mathbf{p}} = m\vec{\mathbf{v}}$$

Question:
A 500 kg car is traveling at 5 m/s to the west, and a 1000 kg car is traveling at 2.5 m/s to the east. Which statement is true?

a. The 500 kg car has the greater momentum because it's traveling faster.
b. The 1000 kg car has the greater momentum because it has more mass.
c. The two cars have the same momentum.
d. The two cars have different momentums because they're traveling in different directions.
e. None of these is true.

Answer:
The correct answer is *d*. By definition, momentum is a vector quantity, so the direction of the momentum *is* a factor.

One could say that the two cars have the same ***magnitude*** of momentum:

$$p = mv$$

$$p = (500kg)(5m/s, West) = 2500kg \bullet m/s, West$$

$$p = (1000kg)(2.5m/s, East) = 2500kg \bullet m/s, East$$

But because their directions are different, they actually do have two different momenta. Interactions with these two cars will be different because of their different directions, so it's important to remember that direction *is* a factor in momentum.

Question:

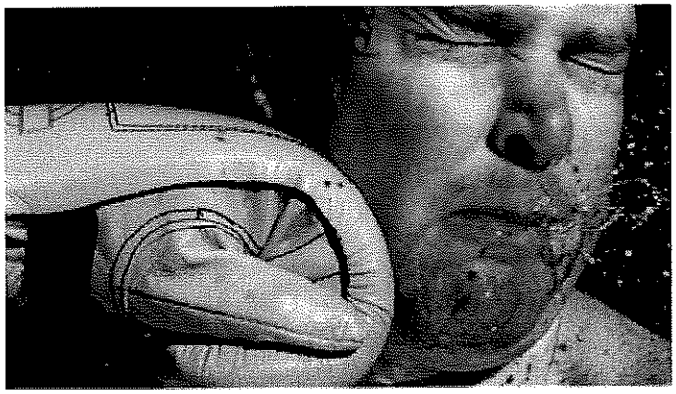
Two masses–*M* and *m*, with $M > m$–have the same speed at one moment in time. The two masses, at this moment, ***must*** also have:

a. the same kinetic energy
b. the same linear momentum
c. the same acceleration
d. the same instantaneous velocity
e. none of these

Answer:

The correct answer is ***e***. The two masses can't have the same kinetic energy *K* because their masses are different, so $K = \frac{1}{2}mv^2$ will be different. The two masses can't have the same linear momentum because $\vec{\mathbf{p}} = m\vec{\mathbf{v}}$ will be different, based on their different masses. The two masses don't necessarily have the same acceleration–we don't have enough information here to indicate whether that's true or not. And although the two masses have the same instantaneous ***speed***, we don't know whether or not they're travelling in the same ***direction***, so we can't guarantee that they're velocities are the same.

Question:



A yellow boxing glove traveling in the positive-*x* direction applies a Force to a boxer's face for a given amount of time. Which of the following statements is *false*?

a. The magnitude of the impulse on the face is greater than the magnitude of the impulse on the glove.
b. The glove and face apply forces to each other that are equal in magnitude and opposite in direction.
c. The force of the face on the glove causes it to accelerate in the negative-*x* direction.
d. The glove and the face each undergo a change in momentum during the impact.
e. The total momentum of the glove and face *before* the collision is the same as their total momentum *after* the collision.

Answer:
The correct answer is ***a***. The impulses that the glove and face apply to each other are *equal.*

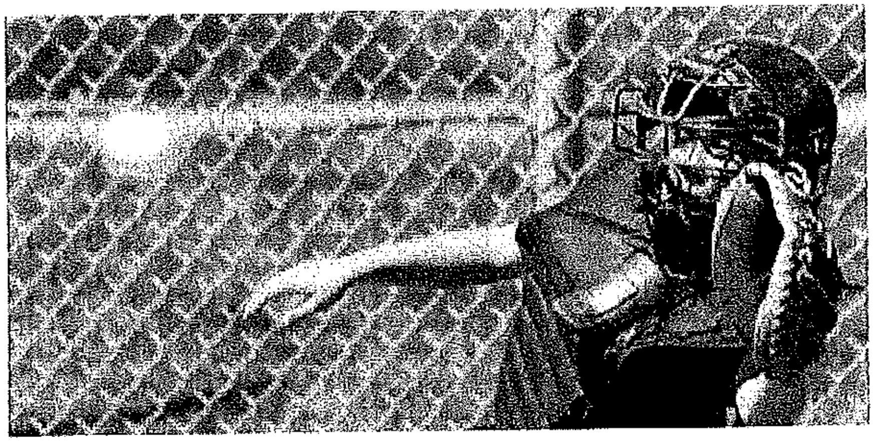
When the glove applies a force for a given amount of time, it is creating an *impulse* = **F***t*. Because the force the face applies *back* to the glove is equal in magnitude to the glove on the face (as described by Newton's Third Law of Motion) and because the two objects are in contact for equal amounts of time *t*, the impulses are equal in magnitude.

As a result of this, the change in momentum for the glove and face are equal in magnitude as well, and opposite in direction:

$$\mathbf{F}t = m\Delta\mathbf{v} = mv_f - mv_i$$

Finally, because these changes of momentum for the glove and face are equal, we can say that the net change in the total momentum of the glove-and-face "system" is 0. We say that "momentum is *conserved*" in this collision.

Focus Question



A baseball travelling with horizontal velocity v is caught by a glove. Which of the following statements is true?

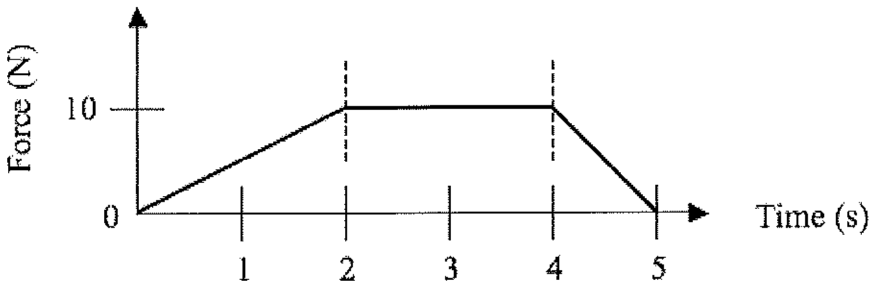
a) The glove applies a greater force to the ball than the ball applies to the glove.
b) The glove imparts a greater impulse to the ball than the ball imparts to the glove.
c) The glove's padding reduces the impulse imparted to the ball.
d) The glove's impulse changes the ball's momentum more than the ball's impulse on the glove.
e) None of the above

Answer

e

a) Newton's 3rd law describes that when the ball and glove interact, they exert equal forces on one another.
b) Impulse = Change in Momentum, so each one imparts the same magnitude of impulse resulting in the same magnitude change in momentum. These impulses and momentum changes are of course in opposite directions.

Question:



An object of mass m = 2.0kg experiences a force in Newtons according to the *Force* vs. *time* graph shown here. For the time interval shown, what is the total change in momentum of the object?

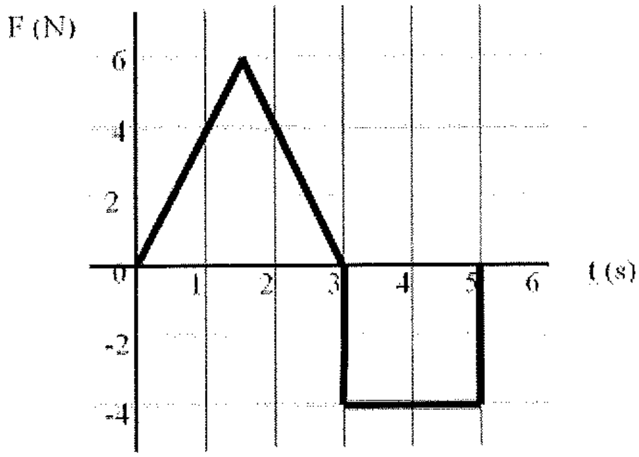
a. 35 kg•m/s
b. 70 kg•m/s.
c. -35 kg•m/s
d. -70 kg•m/s
e. none of these.

Answer:
The correct answer is ***a***. This is an impulse problem, and requires using the equation $Ft = m\Delta v$. Although we don't know the change in velocity to calculate change in momentum, we can easily determine the impulse by adding up the total area under the curve of the *Force-time* graph.

For the first line segment, $Area = \frac{1}{2}(10N \bullet 2s) = 10N \bullet s$
For the second line segment, $Area = (10N \bullet 2s) = 20N \bullet s$
For the third line segment, $Area = \frac{1}{2}(10N \bullet 1s) = 5N \bullet s$

The total change in momentum is the sum of these areas, or 35N•s.

Question:



According to the **F** vs **t** graph above, which of the following statements is correct?

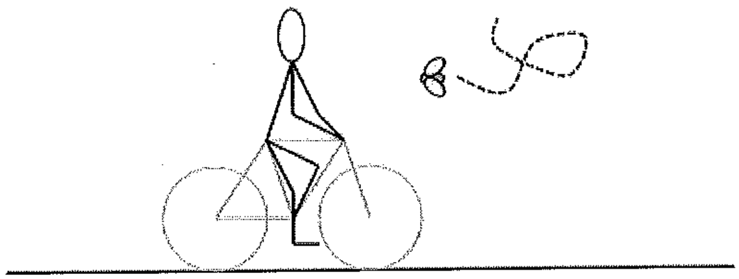
I. The total change in momentum during the 5 s interval is negative.
II. The total impulse imparted during the 5 s interval is positive.
III. The acceleration during the 5 s interval remains constant.

a. I only
b. II only
c. III only
d. I and II
e. I, II and III

Answer:

b.

Question:



A student riding a bicycle in one direction runs into a small insect that was flying in the opposite direction. Which statement is true?

a. The student and the insect will only exert equal forces on each other if they're going in opposite directions.
b. The student and the insect exert equal forces on each other according to Newton's Third Law, but they don't exert equal magnitudes of impulses on each other.
c. The bug experienced a change in momentum that was bigger than that experienced by the student.
d. The bug experienced a Force that was bigger than that experienced by the student.
e. The bug experienced the same mpulse that the student experienced.

Answer:
The correct answer is *e*. The bug and the student exerted equal magnitudes of Forces (in opposite directions) on each other, and because their time of contact was the same, their impulse ($Force \times time$) was the same as well.

Continuing our thinking on this, if the impulse is the same on the two bodies, the change in momentum must be the same as well (but in opposite directions). So what *is* different? The *changes in velocity* are different, because the masses of the two bodies are different.

Remember, the same impulse can affect a small mass by giving it a large change in velocity, or it can affect a large mass by giving it a small change in velocity. It might help to visualize the impulse equation like this:

$$\text{Impulse} \quad Ft = m\Delta v = m\Delta v$$

Question:

A baseball travelling with horizontal velocity v is caught by a glove. Which of the following statements is true?

a. The ball applies a greater force to the glove than the glove applies to the ball.
b. The glove applies a greater impulse to the ball than the ball applies to the glove.
c. This is an example of an elastic collision.
d. The padding of the glove reduces the impulse of the ball on the glove.
e. The padding of the glove reduces the force of the ball on the glove.

Answer:

The correct answer is *e*. Although the total impulse of the ball on the glove remains a constant $\mathbf{F}t = m\Delta\mathbf{v}$, the padding of the glove allows that impulse to be applied over a greater period of time t. As t increases, the Forces applied by the ball decreases correspondingly. This is why catchers use catcher's mitts with more padding in them, why boxers wear boxing gloves, and why air bags in cars are used to increase the amount of time over which an impulse acts. The bigger the time of contact, the smaller the contact Force.

Question:

A 0.500 kg rock is dropped from the top of a house, and is traveling at 10 m/s down just before it lands on the ground. It hits the ground and stops moving. A 0.500 kg ball is then dropped the same distance, and is also traveling at 10 m/s down just before it hits the ground, after which it bounces back up at 10 m/s. Which object experienced the greater change in momentum? Which object experienced the greater impulse?

a. The rock had a greater change in momentum; the ball had a greater impulse.
b. The rock had a greater change in momentum and a greater impulse.
c. The ball had a greater change in momentum; the rock had a greater impulse.
d. The ball had a greater change in momentum and a greater impulse.
e. More information is needed to solve this problem.

Answer:

The correct answer is *d*. The ball had a greater change in momentum, as can be shown by calculating the change in momentum of both objects.

$$\Delta p = m(v_f - v_i)$$

$$\Delta p_{rock} = (0.5kg)(0-(-10m/s)) = 5kg \bullet m/s$$

$$\Delta p_{ball} = (0.5kg)(+10m/s-(-10m/s)) = 10kg \bullet m/s$$

One of the lessons here is that an object that bounces off a surface experiences a greater change in momentum than if it just hit the surface and stuck there. Another point to note is that Impulse *is* "change in momentum"—when you're calculating impulse, you're also calculating change in momentum, and when you're calculating change in momentum, that's also the impulse.

FOLLOW-UP QUESTION: "The units for Impulse are $kg \bullet m/s$."—True or False?

FOLLOW-UP ANSWER: True. Although we often think of impulse as having the units [N]•[s], that's just because we often calculate Impulse using the equation

$$\text{Impulse} = F \bullet t$$

Because Impulse is equal to a change in momentum, we can also use the units $kg \bullet m/s$, which are the common units for momentum. We can see that they're really the same thing by doing an analysis of the units:

$$[N][s] = \frac{[kg][m]}{[s]} \ ?$$

$$[N] = \frac{[kg][m]}{[s]^2}$$

$$\frac{[kg][m]}{[s]^2}[s] = \frac{[kg][m]}{[s]} \ !$$

Question:

Which has the greater magnitude of momentum: a large (massive) person running very slowly, or a smaller (less massive) person running very fast?

a. The large person, because he or she has more mass.
b. The smaller person, because he or she has more velocity.
c. The large person, because it will take more force to stop him or her.
d. The large person, because he or she will do more damage in a collision.
e. The question can't be answered without more information.

Answer:

The correct answer is *e*. We don't know which person has more momentum without knowing the relationship between their masses and velocities.

Let's plug some numbers into the momentum equation. We can make up any numbers we want, but here it's easy to see how a smaller person could have a greater momentum based on the relative factors of mass and velocity.

$$p = mv$$

$$p_{\text{larger person}} = (100kg)(1m/s) = 100kg \bullet m/s$$

$$p_{\text{smaller person}} = (50kg)(3m/s) = 150kg \bullet m/s$$

Thus, we really can't answer the question without knowing more specific information about the relative masses and velocities of the two people in this problem.

Question:

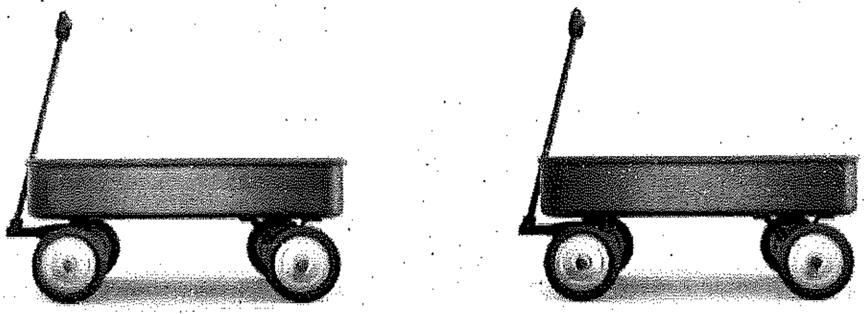
A net Force is acting on a mass. All of the following statements are true, except

a. "The mass *must* be accelerating."
b. "The mass *must* be experiencing an impulse."
c. "The mass *must* be experiencing a change in velocity."
d. "The momentum of the mass *must* be changing."
e. "The potential energy of the mass *must* be changing."

Answer:

The correct answer is *e*. A net Force on a mass causes it to accelerate according to Newton's Second Law of Motion, $F_{net} = ma$. Because the object is accelerating, it must have a change in velocity: $a = \frac{\Delta v}{\Delta t} = \frac{v_{final} - v_{initial}}{t}$. And if its velocity is changing, its momentum, where $p = mv$ must be changing as well. A changing momentum is produced by an impule, a Force applied to an object over time, which is happening as well. The only possibility is the last statement, the potential energy of the mass much be changing. While a net Force might be acting on an object or raise or lower its potential energy, it could be that the Force is instead acting to change just the kinetic energy of the object. The net Force doesn't mean that the potential energy *must* be changing.

Question:



In one experiment, a red wagon at rest is pushed to the left with a force of 100 N for 1.0 seconds. In a second experiment, a blue wagon with the same mass as the red wagon is pushed from rest to the left with a force of 100 N for 2.0 seconds. Which statement below is true?

a. The red wagon had a smaller impulse and a smaller change in momentum than the blue.
b. The red wagon had a smaller impulse but a larger change in momentum than the blue.
c. The red wagon had the same impulse and the same change in momentum as the blue.
d. The red wagon had a larger impulse but a smaller change in momentum than the blue.
e. The red wagon had the same impulse but a larger change in momentum than the blue.

Answer:

The correct answer is *a*. The Force acted on the red wagon for less time, so there was less total impulse, according to the formula for impulse:

$$\text{Impulse} = Ft$$

$$\text{Impulse}_{red} = (100N)(1s) = 100N \bullet s$$

$$\text{Impulse}_{blue} = (100N)(2s) = 200N \bullet s$$

An *Impulse* produces a *change in momentum*—the greater the impulse, the greater change in momentum for the wagon—so if the red wagon has a smaller impulse applied to it, it undergoes a smaller change in momentum.

Question:

A heavy 2.0 kg ball is traveling at 10 m/s when it is caught. A light 1.5 kilogram ball is traveling at 20 m/s when it is caught. Which ball required the greater impulse to catch?

a. The 2.0 kg ball because it is more massive.
b. The 2.0 kg ball because it had more momentum.
c. The 1.5 kg ball because it was traveling faster.
d. The 1.5 kg ball because it had more momentum.
e. The question can't be answered without more information.

Answer:

The correct answer is *d*. The *impulse* experienced by an object is determined by finding out what kind of change in momentum the object experienced.

$$\text{Impulse} = \textit{change in momentum}$$

$$\text{Impulse} = \Delta p$$

$$\text{Impulse} = mv_{final} - mv_{initial}$$

$$\text{Impulse} = m\left(v_{final} - v_{initial}\right)$$

In this case, both object's ended up with a momentum of zero after they were caught, so the smaller ball with the larger momentum also experienced the greater *change* in momentum, and thus the greater *impulse.*

Impulse can also be calculated by examining the Force applied to an object, and how long that Force was applied for.

$$\text{Impulse} = \textit{Force} \bullet \textit{time} = Ft$$

$$Ft = mv_{final} - mv_{initial}$$

Thus, if asked to find *impulse*, there are actually two ways to calculate that: Ft or $mv_{final} - mv_{initial}$. Likewise, if asked to determine *change in momentum*, there are two ways to calculate that: Ft or $mv_{final} - mv_{initial}$. *Impulse* and *change in momentum* are equal to each other.

Question:

Momentum is a vector quantity based on mass and velocity: $\mathbf{p} = m\mathbf{v}$. Which statement is true?

a. More massive objects always have greater momentums.
b. A weightless object moving in space has no momentum.
c. A net force on a mass will always cause a change in its momentum.
d. An object that isn't moving can still have a momentum that is not zero.
e. *Impact* on an object can be calculated as *Force* times *time.*

Answer:

The correct answer is *c*. A net Force on an object will always cause it to accelerate, which is defined as a change in velocity, and a changing velocity implies a change in momentum:

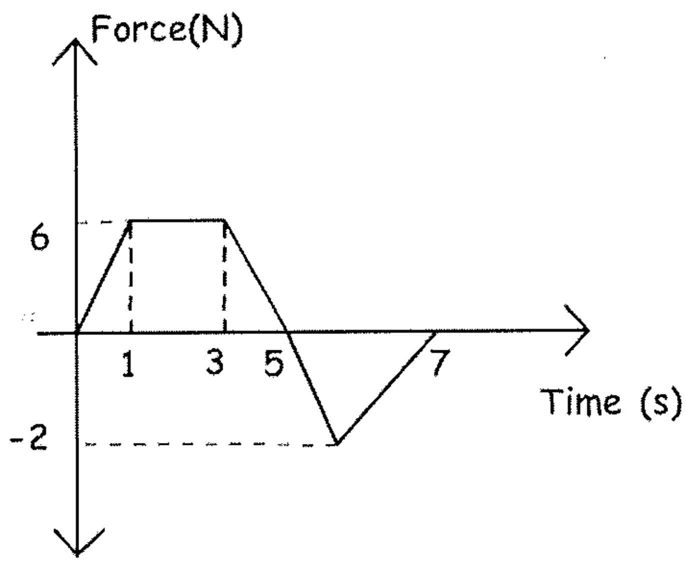
$$\mathbf{p} = m\mathbf{v}$$

$$\Delta\mathbf{p} = m\Delta\mathbf{v} = m(\mathbf{v}_f - \mathbf{v}_i)$$

The other choices are false. More massive objects do not necessarily have greater momentum, because velocity is a factor as well. A weightless object in space still has mass, and if it is moving, it still has momentum. An object that is not moving has a velocity of 0, and therefore a momentum of 0. And *Impulse*, a force applied over a time to cause a change in momentum, is calculated as *Ft*. "Impact" refers to a contact force, which is not the same thing.

Question:

A force acts for 7s on a 2kg object initially at rest. The value of the force as a function of time is shown in the graph below.



a. For which time interval is the impulse imparted to the object negative?
b. For which time interval is the object's momentum change a minimum?
c. What is the object's total momentum change during the 7s time interval?
d. What is the speed of the object at 7s?
e. True or False: The total impulse imparted to the object during the 7s interval is equal to the object's total momentum change.

Answer:

a. **5 – 7 s**
b. **5 – 7 s**
c. **19 Ns**

The total momentum change is equal to the total impulse imparted. The total impulse is equal to the total area under the curve.

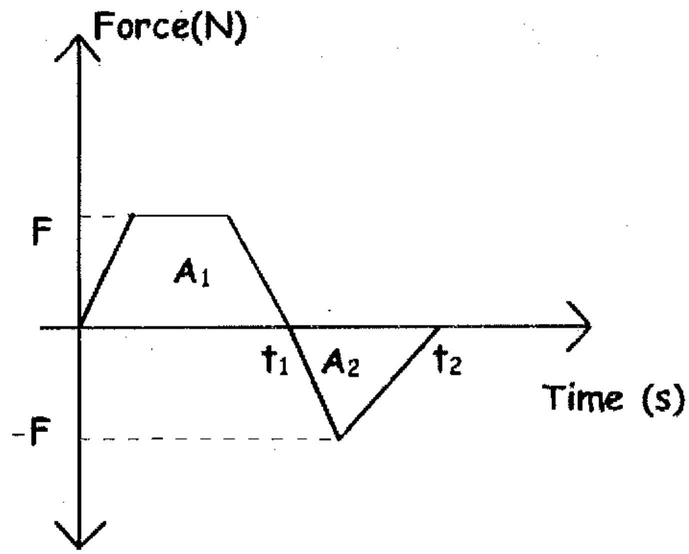
d. **9.5 m/s**

This can be calculated by using the impulse – momentum principle equation and the equation for Δp.

e. **True**

Question:

A car, starting from rest and confined to move along a straight road, is acted upon by a force shown in the graph below. Which of the statements that follow are true regarding the car's motion? *Assume positive direction to the right.*



I. **The car's total momentum change is positive and the car will come to rest at t_2.**

II. **The impulse imparted during time 0 to t_1 will cause it to speed up and the impulse imparted during time t_1 to t_2 will cause it to slow down.**

III. **The impulse imparted during time 0 to t_1 will cause it to move positively and the impulse imparted during time t_1 to t_2 will cause it to move negatively.**

a. I only **b.** II only **c.** III only **d.** II and III **e.** I, II and III

Answer:

b.

Question:

In an automobile collision, how does a car's airbag work to reduce injury or death?

- **a.** It increases the impact force by decreasing the impact time.
- **b.** It decreases the impact force by decreasing the impact time.
- **c.** It increases the impact force by decreasing the impact time.
- **d.** It decreases the impact force by increasing the impact time.
- **e.** Studies have actually shown that airbags do not reduce injuries or death suffered in auto accidents.

Answer:

d.