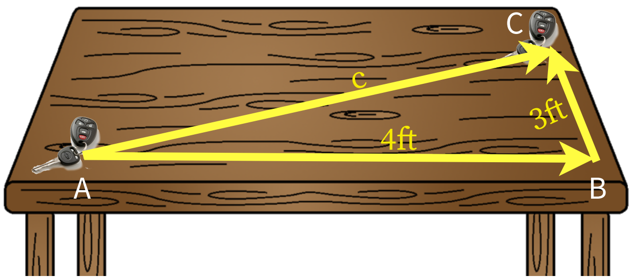
1. The **displacement** of an object
   A) is always exactly the same as the distance it has traveled.
   B) is a record of its absolute position, like coordinates on a graph.
   C) is a vector representing the change in the position of an object.
   D) measures total amount of distance traveled, without regard to direction.



The keys shown above are initially at rest on the table at point A. You slide them from A to B to C, and leave them again at rest at point C.

2. What is the **distance** traveled by the keys?
   A) 0 ft
   B) 3 ft
   C) 4 ft
   D) 5 ft
   E) 7 ft
   F) Unknown! Unknowable!!

3. What is the **displacement** of the keys?
   A) 0 ft
   B) 3 ft
   C) 4 ft
   D) 5 ft
   E) 7 ft
   F) Unknown! Unknowable!!

4. **True or false:** It is possible for an object to travel some non-zero distance, but have a zero displacement.

5. Velocity is an example of a **vector**. What exactly is a vector?
   A) A vector is a physical quantity for which both a size (or magnitude) and a direction are meaningful and relevant.
   B) A vector is a physical constant. A random number (like 5) is not a vector, but pi (3.14) is a vector because it has meaning.
   C) Vector is a unit, like meters or seconds. Vector just happens to be the name of the metric unit of force.
   D) Vector is another way of saying very, very large. A vector quantity must be written in scientific notation.

6. Which of the following is **not** a vector quantity?
   A) Displacement
   B) Velocity
   C) Acceleration
   D) Force
   E) Momentum
   F) Mass

7. The combination of speed and direction defines an object's
   A) instantaneous speed.
   B) average velocity.
   C) velocity vector.
   D) acceleration.

8. Car A drives **east** on College Avenue at **30 mph**. Car B drives **east** on Prince Street at **30 mph**. The cars have
   A) the same speed, but different velocities.
   B) the same direction, but different speed.
   C) the same speed, different direction.
   D) the same direction, but different velocities.
   E) the same velocity: speed and direction both match.

9. **True or false:** If your average velocity is zero, your average speed must also be zero.

10. You sit in your favorite chair and lace up your running shoes. You leave the house, run three miles, and return to your favorite chair to remove your shoes. The whole thing took you thirty minutes (0.5 hour).
    A) Your average speed was (3miles/0.5hr) = 6mph, but your average velocity was zero.
    B) Backwards! Your average velocity was 6 mph, but your average speed was zero.
    C) The average speed is exactly the same as average velocity, and both are 6 mph.
    D) Both your average speed and your average velocity are exactly zero.

11. Average speed
    A) is defined as total distance traveled divided by total time.
    B) is a vector representation of an object's instantaneous speed.
    C) cannot be determined without knowing the speed of the object during every instant of an interval.
    D) is always exactly the same as average velocity.

12. Which of the following units could not be used to express an acceleration?
    A) m/s^2
    B) m/s^3
    C) mph/s
    D) (km/h)/s

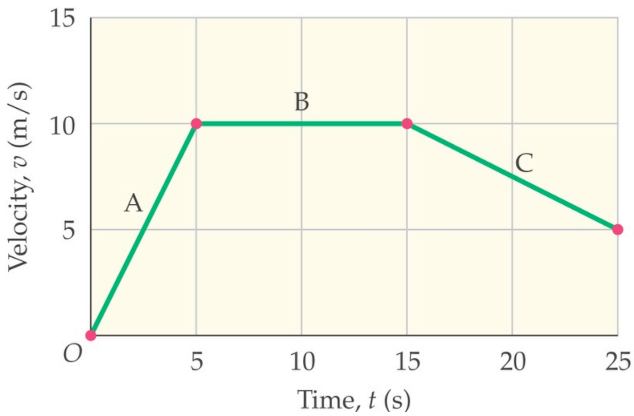
13. Your lab partner tells you that the cart you are analyzing has an average speed $v = +0.087$m/s, and an average acceleration $a = -0.348\text{m/s}^2$. How is this possible?
    A) It's not. Either the equipment malfunctioned, or the person reading the display made a mistake.
    B) If the velocity is positive and the acceleration is negative, the cart was simply slowing down. Totally possible. What's the big deal?
    C) When the sign (+ or –) of the acceleration does not match the sign (+ or –) of the velocity, it means an object is speeding up, not slowing down.
    D) The signs (+ or –) of the velocity and acceleration have nothing to do with what direction the cart travels, or whether it speeds up or slows down. The signs are just math, nothing to do with physics!

14. One of the statements below is incorrect. Mark the incorrect statement.
    A) Acceleration is the result of a change in speed.
    B) Acceleration is the result of a change in direction.
    C) An object with constant speed can never be accelerating.
    D) An object traveling in a straight line can be accelerating.

15. An automobile with a velocity of 45 mph east experiences an acceleration of 5 mph/s west.
    A) The car gains 5 mph of speed every second.
    B) The car loses 5 mph of speed every second.
    C) No way. The car can't go two directions at once.
    D) The car is traveling at a constant speed on a circular track.

16. You are jogging on a circular track.
    A) Your speed may be constant.
    B) Your velocity may be constant.
    C) Your acceleration is zero if your speed is constant.
    D) Your acceleration is 9.8 m/s^2, due to gravity.

17. A car navigates a curved freeway offramp with a constant speed of 35 mph.
    A) Because the car maintains a constant speed, it is not accelerating.
    B) Not possible, because there is no way any vehicle can navigate any curve without speeding up.
    C) Even if the speed remains constant, the changing direction of the vehicle means it has an acceleration.



18. The graph above shows the velocity of a car as function of time. Describe what is happening over intervals A, B and C.
    A) The car has negative acceleration during interval A, positive acceleration over interval B, and zero acceleration during interval C.
    B) A: $a > 0$; B: $a = 0$; C: $a < 0$.
    C) A: $a = 0$; B: $a > 0$; C: $a = 0$.
    D) A: $a < 0$; B: $a = 0$; C: $a > 0$.
    E) There is no way to tell from reading the graph!

19. Use the definition of acceleration $a = \Delta v/\Delta t$ to determine the acceleration of the car during interval A.
    A) $a = (10\text{m/s}–0)/(5\text{s}–0)=(10\text{m/s})/(5\text{s}) = 2\ \text{m/s}^2$
    B) $a = (10\text{m/s}–10\text{m/s})/(15\text{s}–5\text{s})=(0\text{m/s})/(10\text{s}) = 0\ \text{m/s}^2$
    C) $a = (5\text{m/s}–10\text{m/s})/(25\text{s}–15\text{s})=(–5\text{m/s})/(10\text{s}) = –0.5\ \text{m/s}^2$
    D) $a = (5\text{m/s}–0\text{m/s})/(25\text{s}–0\text{s})=(5\text{m/s})/(25\text{s}) = 0.2\ \text{m/s}^2$
    E) The definition cannot be used to make calculations!

20. In 2.5 seconds, a car increases its velocity from 60 km/h to 65 km/h. A bicycle goes from rest to 5 km/h in the same 2.5 seconds. Which undergoes the greater acceleration?
    A) The car, because it is going faster.
    B) The bicycle, because it started from rest.
    C) Neither; the acceleration of each is zero.
    D) Neither; the acceleration of both is 2 (km/h)/s.

21. Upon doing experiments with inclined planes and dropping objects from tall towers, Galileo concluded that
    A) the world is not flat, but spherical.
    B) the acceleration due to gravity is a constant.
    C) the speed of light in a vacuum is constant.
    D) the Sun, Moon, and other planets all orbit the Earth.
    E) for every action, there is an equal and opposite reaction.

22. In the absence of air, freely falling objects
    A) have zero acceleration.
    B) have accelerations proportional to their mass.
    C) have accelerations that cannot be predicted, only measured.
    D) have the same constant, non-zero acceleration.

23. In a vacuum tube, a penny and a feather are released from rest. There are two correct statements below.
    A) The force of gravity on the penny is greater.
    B) The force of gravity on both objects is equal.
    C) The acceleration of the penny is greater.
    D) The acceleration of both objects is equal.

24. What does an object's **inertia** (measured by mass) tell you?
    A) The size of the object. The greater the inertia, the smaller the size.
    B) The value of the object. The greater the inertia, the more valuable the object is.
    C) The resistance to change. The greater the inertia, the more an object resists a change in its motion.
    D) The resistance to electricity. The greater the inertia, the more the object resists electrical current.

25. According to **Newton's First Law of Motion**, objects at rest
    A) will remain at rest, unless acted upon by an unbalanced force.
    B) will begin to move spontaneously, as motion is the natural state for all mass.
    C) cannot be made to move; there are no circumstances under which stationary objects can change their state of motion. Once you're stuck, you're stuck.
    D) cannot experience forces. That's why they are at rest, because it is not possible to exert any force upon them. Not even The Force.

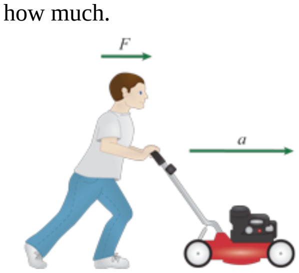
26. You watch as a hockey puck slides across the ice, traveling several meters before coming to rest. According to **Newton's First Law**,
    A) objects in motion want to be at rest, so the puck naturally stops moving.
    B) objects in motion want to remain in motion, so some force must have acted upon the puck to stop it moving.
    C) objects without mass cannot move, so the puck must have zero mass.

27. According to **Newton's Second Law of Motion** (and assuming an object with constant mass),
    A) applying a larger force will create a larger acceleration.
    B) applying a smaller force will create a larger acceleration.
    C) applying any force, large or small, creates the same acceleration.
    D) force and acceleration are unrelated.

28. You notice that when you apply a horizontal force to a an object with mass $m_1 = 4\text{kg}$, its acceleration is $a_1 = 1\text{m/s}^2$. How much horizontal force must you apply to a second object with $m_2 = 2\text{kg}$ to give it the same acceleration?
    A) If the accelerations are the same, the force applied to each object must also be the same.
    B) If Object 2 has half the mass, you only need to apply half the amount of force applied to Object 1.
    C) If Object 2 has half the mass, you must apply twice the amount of force applied to Object 1.

29. You must apply a horizontal force of 20 N to the left for a 15 kg crate of books to move with a constant speed. Mark each correct statement (there may be more than one).
    A) The crate's acceleration is zero.
    B) The crate's acceleration $a = 1.33\ \text{m/s}^2$.
    C) Friction exerts a 20 N force to the right on the crate.
    D) Friction exerts a force, but you don't have enough information to figure out how much.

30. Calculate the **acceleration** of the lawnmower if your friend pushes it with a horizontal force $F = 50\text{N}$. The mass of the mower is $m = 20\text{kg}$. Answer numerically with **one decimal place**.



31. So, while you are waiting for your friend to finish his chores, you decide to measure the motion of the mower. Much to your surprise (or maybe not), you calculate that the mower is moving with a **constant speed** of just about v = 1.5m/s. How is this possible?
    A) If there is another horizontal force (perhaps friction with the ground?) acting on the mower, the net force might be zero. Zero net force means no acceleration, but it doesn't mean no motion at all!
    B) If any object is measured to move at a constant speed, it means that Newton's Second Law has been violated. Since this is impossible, the best explanation here is that none of your calculations are correct.
    C) Magic. Everyone knows that mechanical objects (especially yard tools like mowers, hedge clippers, and edge trimmers) are infused with an unknowable something that makes them difficult to use and impossible to use quickly.

32. **True or false:** Mass and weight are the same thing.

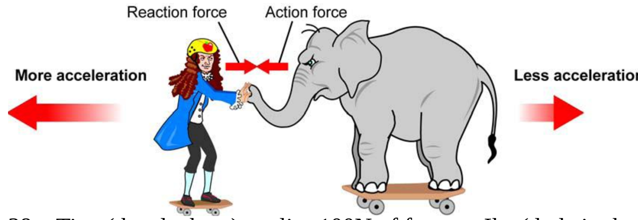
33. On July 20, 1969, Neil Armstrong became the first man to walk on the moon.
    A) While in space, he had no mass.
    B) He had less mass on the moon than on Earth.
    C) His weight remained the same on Earth, in space, and on the moon.
    D) His mass remained the same on Earth, in space, and on the moon.

34. You have 1 kg of feathers, and 1 kg of lead birdshot (is that how you got the feathers?). Mark each correct statement (there may be more than one).
    A) The lead is more massive.
    B) The feathers have less inertia.
    C) The lead has greater density.
    D) The feathers have more volume.

35. Two separate forces are acting on the same object.
    A) This is always an example of Newton #3. Any two forces acting on the same object form an action-reaction pair.
    B) This might be an example of Newton #3, but only if the two forces act in opposite directions.
    C) This might be an example of Newton #3, but only if the forces act in the same direction.
    D) This is never an example of Newton #3, because an action-reaction force pair always acts on two different objects.

36. Which of the following is an example of a **Newton's Third Law** action-reaction force pair?
    A) The force of gravity on a skydiver and the air resistance on him as he falls.
    B) The force of gravity on the Earth due to the Sun and the force of gravity on the Sun due to the Earth.
    C) The tension in a rope and the weight of the object it supports.
    D) The force of gravity on a block and the frictional force on it as it slides down a rough incline.
    E) These are all excellent examples of Newton #3!

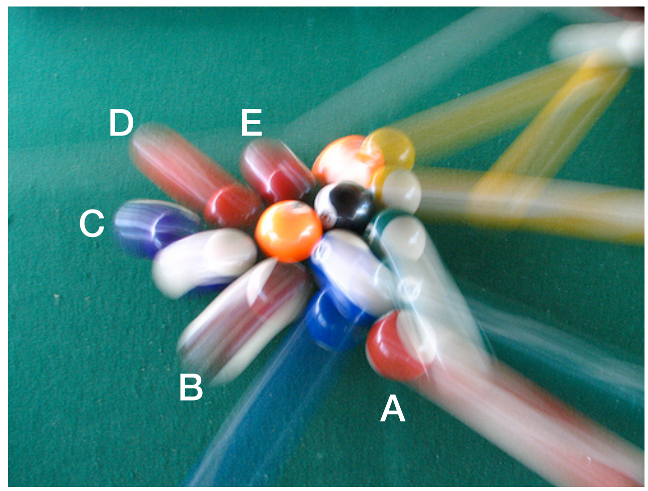
37. A train collides head-on with an unlucky horsefly. There are two correct statements below.
    A) Train exerts more force on bug than bug exerts on train.
    B) Bug exerts more force on train than train exerts on bug.
    C) The force on the bug is equal to (but in the opposite direction of) the force on the train.
    D) Train experiences a greater acceleration than bug.
    E) Bug experiences a greater acceleration than train.



38. Tiny (the elephant) applies 100N of force to Ike (dude in the wig). How much force does Ike apply to Tiny?
    A) Exactly 0N.
    B) Maybe 50N.
    C) About 75N.
    D) Exactly 100N.
    E) More than 100N.
    F) No way to tell!

39. If Ike has a mass of 60kg, then that 100N push gives him an acceleration of 1.67m/s^2. Tiny, though, has a whopping mass m = 2000kg! What's the magnitude of **Tiny's acceleration**?
    A) 0 m/s^2
    B) 0.05 m/s^2
    C) 1.67 m/s^2
    D) 20 m/s^2
    E) 50 m/s^2
    F) 100 m/s^2

40. **True or false:** Momentum is a vector quantity.

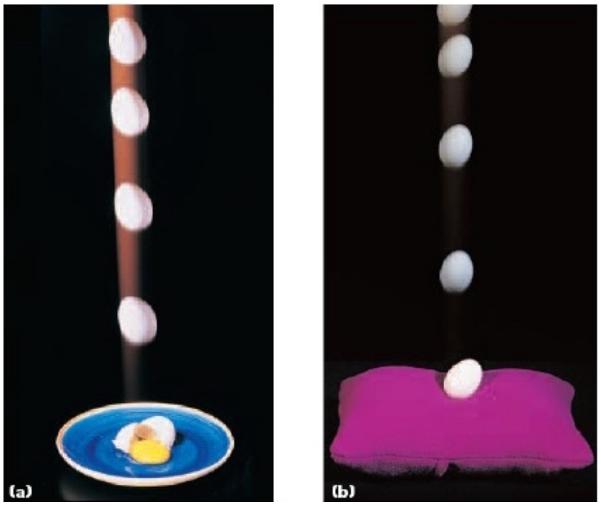


41. Billiard balls having identical mass are shown above in a long-exposure photograph. Of the balls labeled **A** through **E**, which has the **largest momentum**?

42. Compare the momentum vectors for **Ball C** and **Ball E**.
    A) Both vectors have the same magnitude and direction.
    B) The magnitudes of both are almost identical, but the vector directions are different.
    C) The magnitudes of the vectors are very different, but the directions are identical.
    D) The magnitudes of the vectors are very different, and their directions are different as well.
    E) There cannot be a comparison, because Ball C has momentum, but Ball E does not.

43. Object A has momentum = **+p**, while Object B has momentum = **–p**. From this information, you know that both
    A) have the same speed.
    B) have the same mass.
    C) are both at rest.
    D) are traveling in the same direction.
    E) are traveling in opposite directions.

44. A car (m = 3000 kg) traveling **north** (v = +9 m/s) has momentum $p = mv$ = +27,000 kg·m/s. The same car, now traveling **south** at the **same speed**
    A) has exactly the same momentum: p = +27,000 kg·m/s.
    B) has the opposite momentum: p = –27,000 kg·m/s.
    C) has zero momentum: p = 0 kg·m/s.
    D) has some momentum, but who knows how much?



45. Shown above, two eggs are released from rest from the same height. **Egg A** strikes a ceramic plate and shatters. **Egg B**, however, strikes a fluffy pillow and lives to see another day. (Hint: The pillow is a crumple zone!)
    A) It's luck, not physics; both eggs had a 50-50 chance of breaking. Egg B just got lucky. Poor Egg A.
    B) Because the plate is harder, it changed the momentum of Egg A more than the pillow changed Egg B.
    C) Same drop, same momentum for both eggs. But the pillow allowed a smaller force to be applied for a longer time to Egg B, which kept it intact.

46. If Egg A was dropped from a height of 1m above the plate, it would be traveling at a speed v = 4.4m/s at the instant it struck the plate. The mass of Egg A was m = 60g = 0.06kg. Calculate the **momentum** of the egg as it strikes the plate. (Hint: Watch your units!)
    A) p = 0 kg·m/s
    B) p = 0.014 kg·m/s
    C) p = 0.264 kg·m/s
    D) p = 0.733 kg·m/s
    E) p = 1.36 kg·m/s
    F) p = 264 kg·m/s

47. How much **impulse** did the **plate** apply to Egg A to **completely stop** its motion? (Hint: $mv_f = 0$)
    A) $F\Delta t$ = 0 kg·m/s
    B) $F\Delta t$ = –0.014 kg·m/s
    C) $F\Delta t$ = –0.264 kg·m/s
    D) $F\Delta t$ = –0.733 kg·m/s
    E) $F\Delta t$ = –1.36 kg·m/s
    F) $F\Delta t$ = –264 kg·m/s

48. Since the mass and speed of Egg B is the same as Egg A, how much **impulse** did the **pillow** apply to Egg B to **completely stop** its motion? (Hint: $mv_f = 0$)
    A) $F\Delta t$ = 0 kg·m/s
    B) $F\Delta t$ = –0.014 kg·m/s
    C) $F\Delta t$ = –0.264 kg·m/s
    D) $F\Delta t$ = –0.733 kg·m/s
    E) $F\Delta t$ = –1.36 kg·m/s
    F) $F\Delta t$ = –264 kg·m/s

A car with mass m_A = 2000 kg is traveling **east** with a speed $\mathbf{v_A}$ **= +8 m/s**. A second car (**m_B = 3000 kg**) also travels **east**, but with a speed $\mathbf{v_B}$ **= +10 m/s**. Unfortunately, car B runs right into the back of car A.

49. What is the **total system momentum** (car A + car B) at the instant **just before** the collision?
    A) Zero.
    B) 18 kg·m/s.
    C) 14,000 kg·m/s.
    D) 16,000 kg·m/s.
    E) 30,000 kg·m/s.
    F) 46,000 kg·m/s.

50. What is the **total system momentum** (car A + car B) at the instant **just after** the collision?
    A) Zero.
    B) 18 kg·m/s.
    C) 14,000 kg·m/s.
    D) 16,000 kg·m/s.
    E) 30,000 kg·m/s.
    F) 46,000 kg·m/s.

51. **True or false:** After the collision, the momentum of car A (by itself) will be unchanged. However much momentum it had prior to the collision, it will have exactly the same amount afterwards.

52. Which of the following is a **not** characteristic of the force of gravity between two masses?
    A) The force is directly proportional to mass: the larger the mass, the bigger the force. Doubling the mass doubles the force.
    B) The force is inversely proportional to distance: the larger the separation between masses, the smaller the force between them.
    C) The force is exclusively attractive. All mass is attracted to all other mass.
    D) The force may either attract or repel. Positive mass attracts positive mass, but repels negative mass.

53. **True or false:** With gravity (and all inverse-square relationships), when you triple the distance between two objects, the amount of force increases by a factor of nine.

54. When two masses (m_1 and m_2) are separated by a distance of **10cm**, the gravitational force between them is **20N**. Increasing mass m_1 by a **factor of two** (while leaving m_2 unchanged) results in how much gravitational force between the masses?
    A) 0 N.
    B) 5 N.
    C) 10 N.
    D) 20 N.
    E) 40 N.
    F) 80 N.

55. When two masses (m_1 and m_2) are separated by a distance of **10cm**, the gravitational force between them is **20N**. Increasing the separation between the masses to **20cm** results in how much gravitational force between the masses?
    A) 0 N.
    B) 5 N.
    C) 10 N.
    D) 20 N.
    E) 40 N.
    F) 80 N.

56. When two masses (m_1 and m_2) are separated by a distance of **10cm**, the gravitational force between them is **20N**. Decreasing the separation between the masses to **5cm** results in how much gravitational force between the masses?
    A) 0 N.
    B) 5 N.
    C) 10 N.
    D) 20 N.
    E) 40 N.
    F) 80 N.

57. The Earth has an acceleration due to gravity $g = 9.8$ m/s^2. However, the Moon's value for $g = 1.62$ m/s^2. Compare the weight of a 100kg mass on the Earth vs. on the Moon.
    A) A 100kg mass weighs exactly 100lb, whether it is on the Earth or the Moon.
    B) The 100kg mass weighs 9.8kg on the Earth, but only 1.62kg on the Moon.
    C) On Earth, 100kg weighs w=(100kg)(9.8m/s^2)=980N. On the Moon, w=(100kg)(1.62m/s^2)=162N.
    D) On Earth, 100kg weighs w=(100kg)(1.62m/s^2)=162N. On the Moon, w=(100kg)(9.8m/s^2)=980N.