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1. You step off a 10 meter cliff and fall into a deep ocean pool below. As you fall, the force of gravity on you...

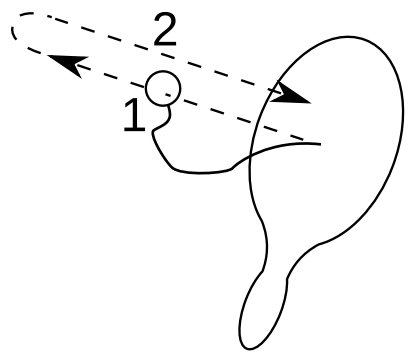
A. is constant.

B. increases as you speed up.

C. is what initially changes your state of motion, but then it stops once you stop accelerating.

D. equals your final velocity.

2. You hit the ball with the paddle, and when the rubber band becomes taut, it makes the ball come back to you.
The points marked 1 and 2 are at the midpoints of the outward and returning parts of the motion.

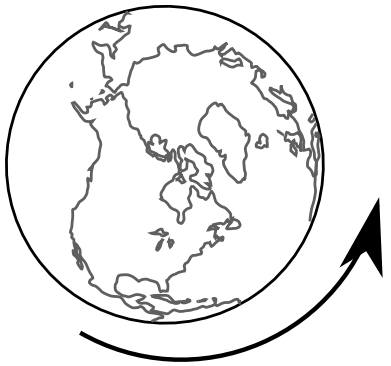


Consider these forces:

F_p, a force of the paddle on the ball, and
F_r, a force of the rubber band on the ball.

A. Both act at point 1 in the motion, and both also at 2.
B. F_p acts at 1, and F_r at 2.
C. F_p acts at 1, and both act at 2. At 2, F_r is stronger.
D. Neither force acts at 1 or 2.

3. The earth spins on its axis once every day. This is caused by...



A. the force of inertia.
B. the force created by its velocity.
C. the force of gravity.
D. none of the above

4. An astronaut on the moon, wearing a spacesuit, holds a wrench at chest height and then releases it. What does the wrench do?

A. It floats upward.

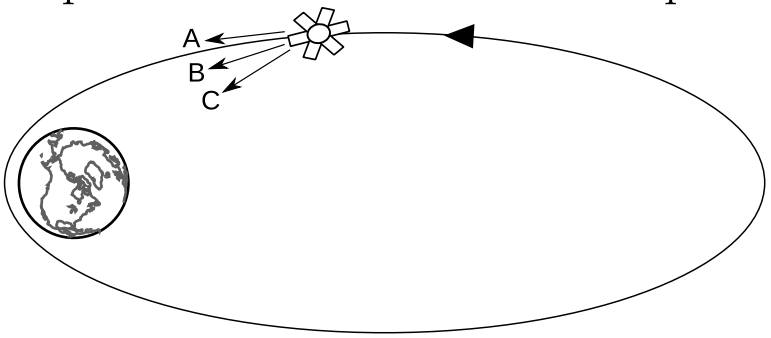
B. It floats, staying at about the same height.

C. It floats, but may also move horizontally.

D. It falls to the ground.

[Based on a question by Roger Feeley.]

5. The figure shows a communications satellite traveling counterclockwise in an elliptical orbit that lies in the plane of the page.



At the time indicated, the direction of the earth's gravitational force on the satellite is most nearly

A, B, C, or

D. There is no gravity in outer space.

6. A communications satellite is in a circular orbit around the earth. The satellite's gravitational force on the earth...

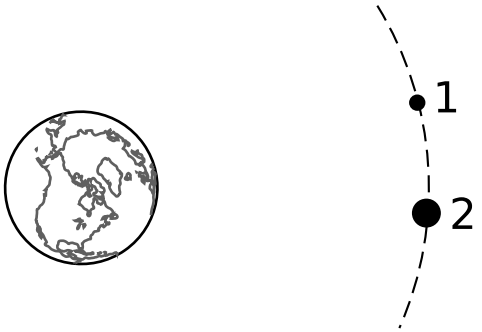
A. is zero.

B. is nonzero but much less than the earth's gravitational force on it.

C. has a strength equal to the earth's gravitational force on it.

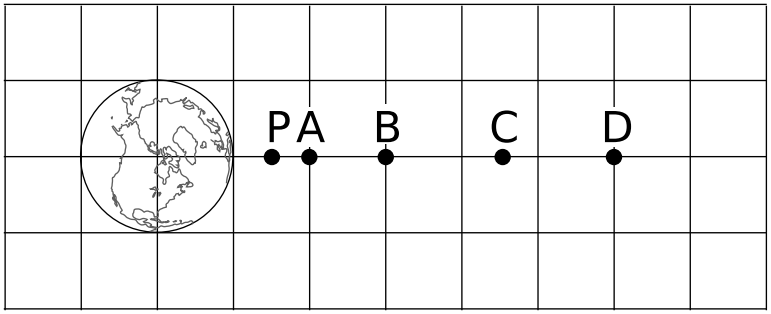
[Based on a question by Jack Dostal.]

7. The circular orbits of satellites 1 and 2 coincide. Satellite 2 has twice the mass of satellite 1. Compare their accelerations.

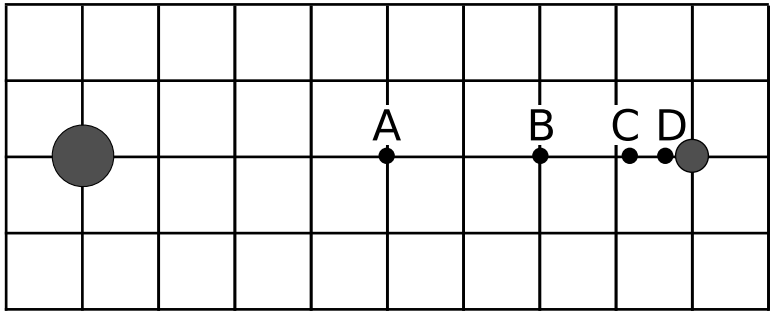


A. 1's acceleration is half as much.
B. 1's acceleration is the same as 2's.
C. 1's acceleration is twice as much as 2's.
D. It depends on the periods of their orbits.

8. At which point is the earth's gravitational field 1/4 as strong as at P?

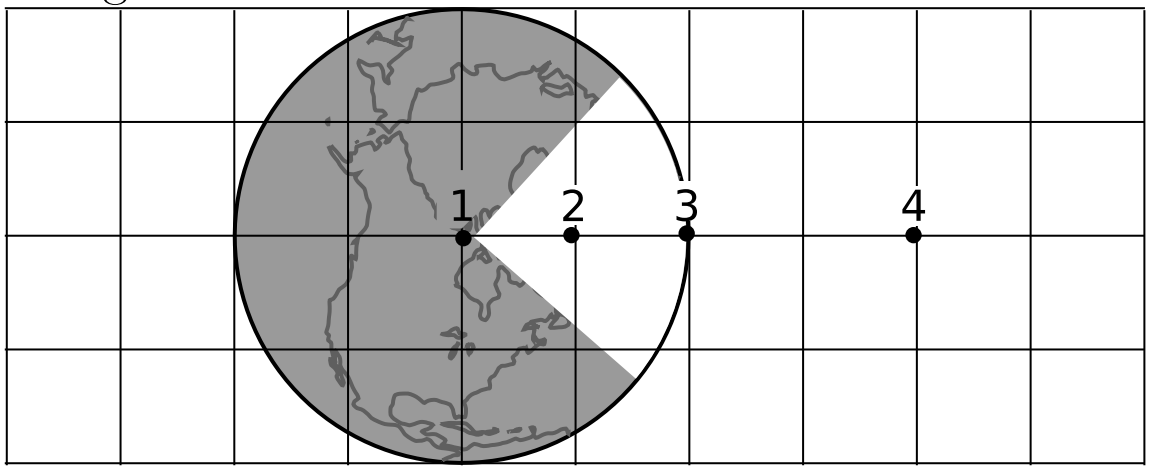


9. The large planet has 9 times more mass than the small one. At which location is the gravitational field zero?



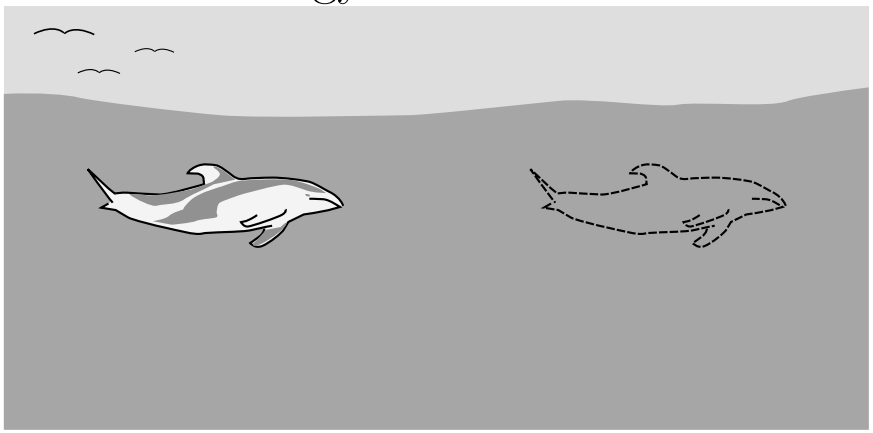
10. A wedge has been cut out of the earth to let us see inside it. Points 1, 2, 3, and 4 all lie along the same radial line. Point 1 is at the earth's center, 3 at its surface, and 2 in the interior of the earth at the midpoint between 1 and 3.

Rank the points by the strength of their gravitational fields, from weakest to strongest.



A. 4, 3, 2, 1
B. 4, 2, 3, 1
C. 1, 4, 2, 3
D. 1, 2, 4, 3

11. The dolphin is initially moving underwater, staying just below the surface, but it then coasts to a halt and spends some time thinking about dolphin stuff. Describe the energy transformation.



A. PE to heat
B. KE to PE and heat
C. KE and PE to heat
D. KE to heat

12. Some buses in Switzerland contain massive flywheels that store kinetic energy when the bus goes downhill, then release it when it needs to go up again. If the velocity of the spinning wheel could be doubled, its mass could be cut by a factor of

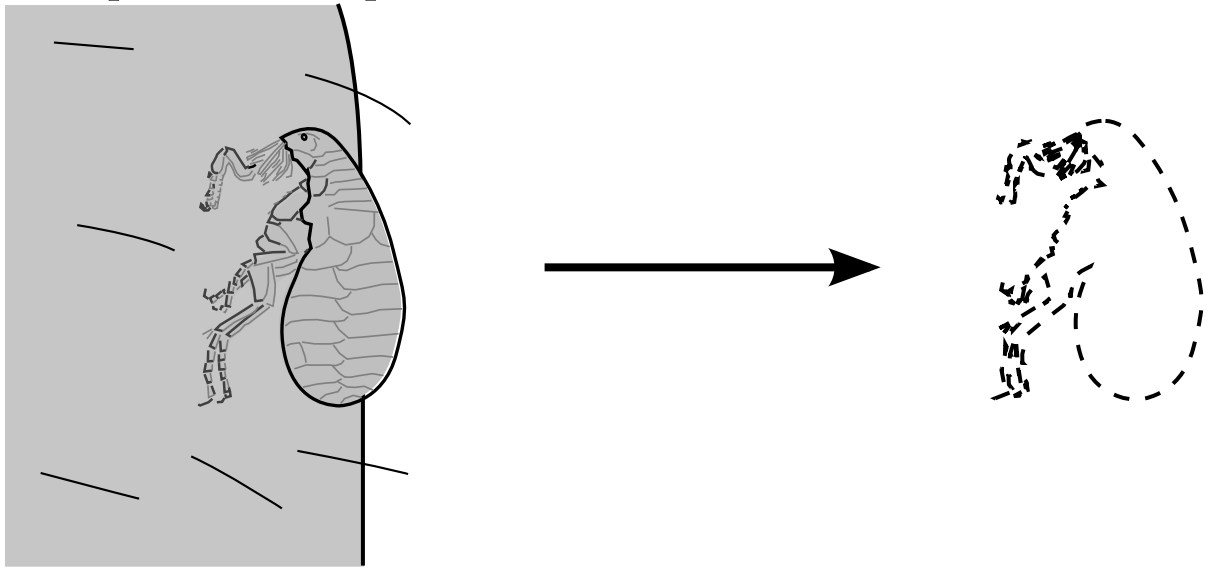
A. $\sqrt{2}$.

B. 2.

C. 4.

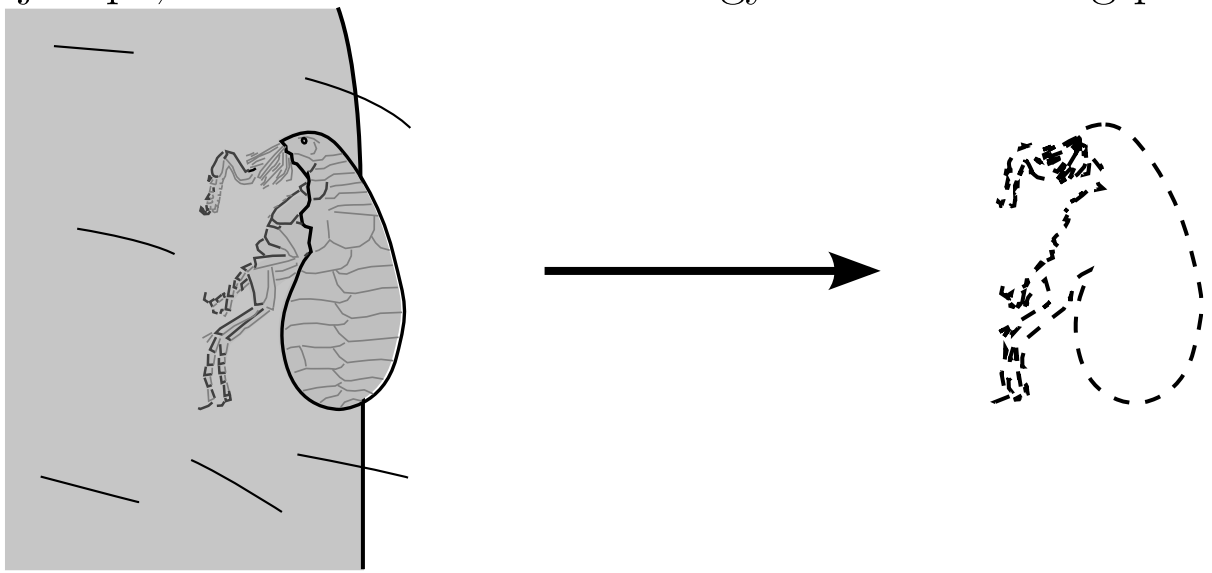
D. It would still have to have the same mass.

13. Joe is asleep in the library. The flea gets bored and leaps off of his arm. The flea's mass is smaller than Joe's by a factor of 10^8. After the flea is in the air, compare Joe's speed to the flea's.



A. Joe isn't moving, but the flea is.
B. Joe recoils at a speed 10^{-8} that of the flea.
C. Joe recoils at a speed 10^{-16} that of the flea.
D. The whole planet earth recoils at an unmeasurably small speed.

14. We adopt the frame of reference in which Joe is initially at rest. After the flea jumps, describe the kinetic energy of the recoiling planet earth.



A. The earth's KE is zero.

B. The earth gains much more KE than the flea.

C. The earth's larger mass and smaller speed give it the same KE as the flea.

D. The earth gains much less KE than the flea.

E. Energy is conserved, so the earth loses an amount of KE the same as what the flea gains.

[Based on a question by Eric Mazur.]

15. In the planetary model of the hydrogen atom, the electron is like a little planet in a circular orbit around the proton. The electron's force on the proton...

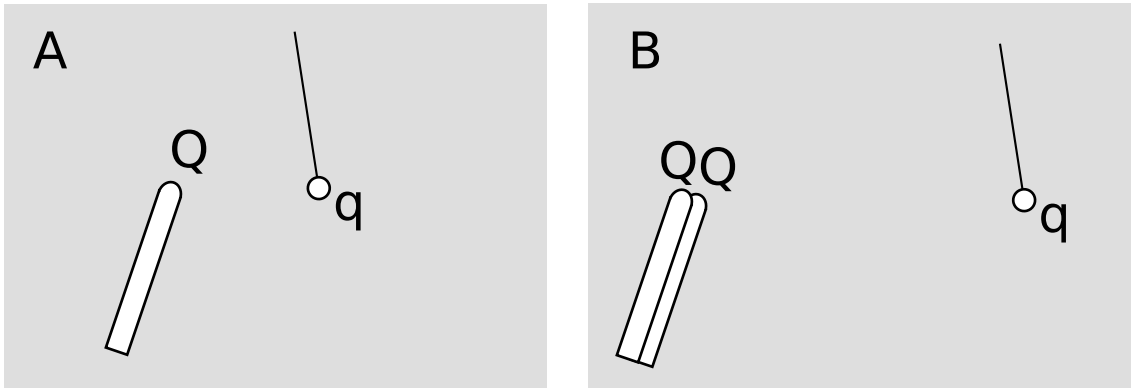
A. is zero.

B. is nonzero but much less than the proton's force on it.

C. has a strength equal to the proton's force on it.

[Based on a question by Jack Dostal.]

16. In figure A, a charged rod acts on a charged ball from a certain distance. In B, two such rods act from twice the distance on the same ball.



The deflections θ_A and θ_B of the strings from the vertical are

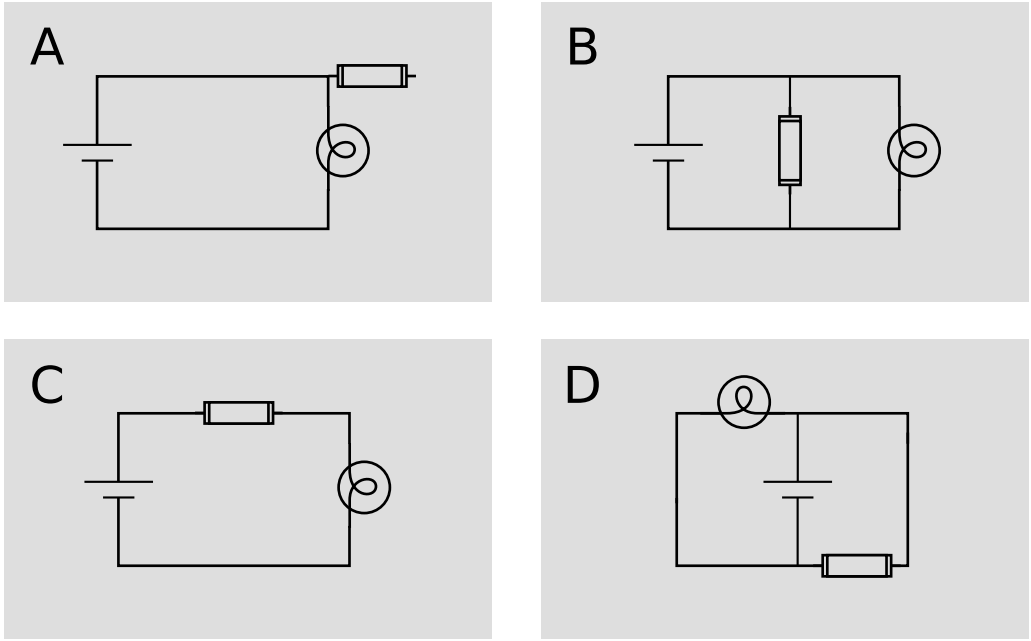
A. equal

B. unequal, with $\theta_A < \theta_B$

C. unequal, with $\theta_A > \theta_B$

D. need more information

17. Electrical fuses are discussed in the text, without an explicit circuit diagram. They work by heating to the point where they melt, opening the circuit. The schematic symbol for a fuse is  . Logically, which of the following arrangements would protect the lightbulb from being burned out?

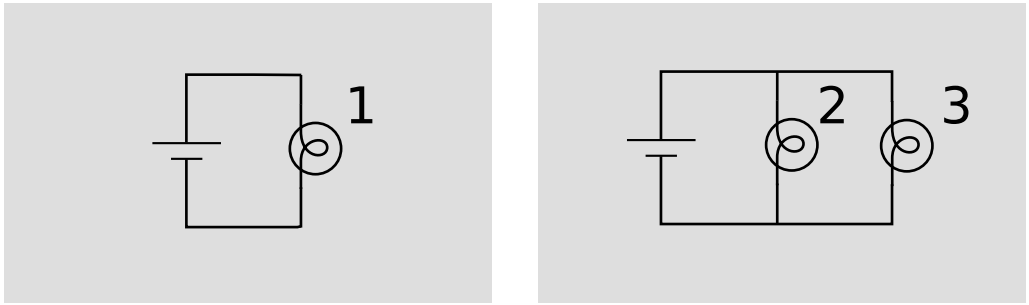


18. The rear window in many cars has an electrical defroster consisting of a grid of thin silver-ceramic lines that are essentially painted onto the glass. A fixed voltage difference of 12 V from the car's battery is applied across the defroster, which acts as a resistor with a resistance of on the order of one ohm.

Suppose that as a certain car gets older, physical changes in the grid cause its resistance to *decrease*. The amount of heat generated

A. goes down.
B. stays the same.
C. goes up.
D. There is no way to tell without more data.

19. The two circuits are different, but they're made out of identical batteries and lightbulbs. How do the currents compare?



A. I_2 and I_3 are each about half as big as I_1.
B. I_2 and I_3 are each about the same as I_1.
C. I_2 and I_3 are each about twice as big as I_1.
D. There is no way to tell without more data.

20. The inductance of an ideal solenoid is $L = (4\pi k/c^2)N^2A/\ell$, where N is the number of turns, A is the cross-sectional area, and ℓ is the length. Inductance is defined by $U = (1/2)LI^2$. Suppose that a solenoid has values of the variables B, N, I, U, and L. We now chop it in half along a line perpendicular to its axis, forming two smaller, equal solenoids, and we connect these two smaller solenoids in series. Then each small solenoid has values —

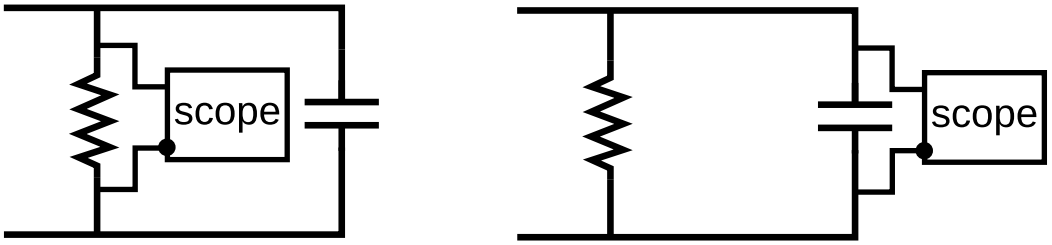
A. $B/2$, $N/2$, $I/2$, $U/4$, and $L/4$
B. B, $N/2$, I, $U/2$, and $L/2$
C. $B/2$, $N/2$, $I/2$, $U/2$, and $L/2$
D. $2B$, N, I, U, and $L/2$

21. Huddle with your group around a sheet of paper.

- List the basic principles that were the foundations for correct reasoning about DC circuits.
- Which are still true for AC? Do any need to be modified?

5 minutes

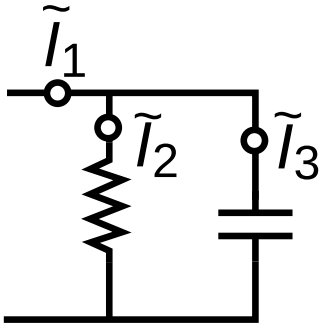
22. A sinusoidal AC voltage is being used to drive the circuit, and the oscilloscope measures the voltages, which we represent as complex numbers. The black dot shows the grounded side of the scope's input. The measurement shows that $\widetilde{V}_R$ is real and negative.

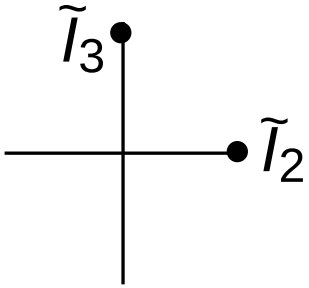


$\widetilde{V}_C$ is therefore

A. real and positive.
B. positive imaginary.
C. real and negative.
D. negative imaginary

23. The left-hand figure shows an AC circuit driven by a sinusoidal voltage. There are three currents that could be measured. The right-hand figure shows the results of two of these measurements in the complex plane.

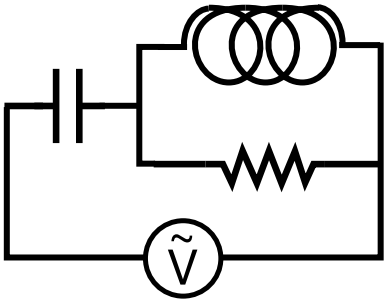




Both $\widetilde{I}_2$ and $\widetilde{I}_3$ have magnitudes of 1.0 A. The magnitude of $\widetilde{I}_1$ is approximately

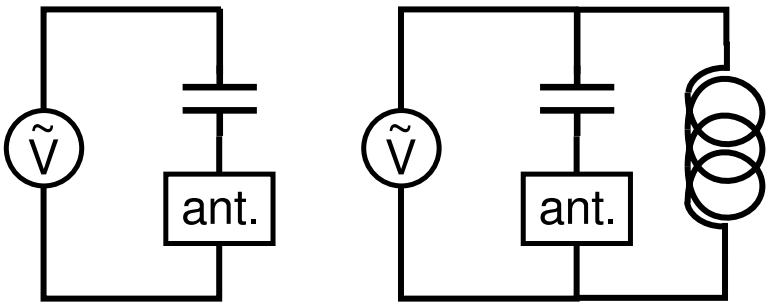
A. 0.7 A.
B. 1.0 A.
C. 1.4 A.
D. 2.0 A.

24. If we "smoke test" this circuit, which elements might get hot?



A. all three
B. only R
C. R and L
D. L and C
E. C and R

25. The capacitor is used to filter out DC and low frequencies coming from the voltage source, so that only radio-frequency signals get to the transmitting antenna.



Suppose we add the inductor as shown. What is the effect on the signal *felt by the antenna?*

A. There is no effect.

B. The coil is not needed for DC, but improves filtering of low frequencies.

C. The filtering gets worse because we're adding a big impedance at high frequencies.

D. The filter now acts as a bandpass filter centered on $\omega = (LC)^{-1/2}$.

26. Eddie has always been his grandmother's favorite grandchild, so he gets invited with her on an interstellar cruise. After the ship has accelerated to 30% of the speed of light, Eddie unbuckles his seatbelt, hops out of his acceleration couch, and extracts a folding meter-stick from his suitcase. Using the meter-stick, he measures the length of the cabin from front to back.

A. The cabin measures more meters than before the ship accelerated.

B. The cabin measures fewer meters than before.

C. The cabin measures the same.

D. The effect is too small to be observable, because the ship's speed is still small compared to the speed of light.

27. Correct the mistakes.