1. How does the charge of an electron differ from the charge on a proton?
   A) It doesn't; they are exactly the same in all respects.
   B) The electron has a negative charge and the proton has a positive charge.
   C) The charges are the same sign, but the proton is bigger, so it carries more charge.
   D) The electron is less massive, so it makes up for it by carrying more charge than the proton.
2. **True or false:** The electron has exactly the same charge as a proton, except an electron is negative and a proton is positive.
3. Compare an electron to a proton.
   A) The electron has a negative charge and large mass, while the proton has a positive charge and tiny mass.
   B) The masses are the same, but the proton carries more positive charge. The electron carries less positive charge.
   C) The electron is much less massive than the proton. The charges are equal in size, but opposite in sign.
   D) Protons and electrons are exactly the same: same mass, same charge. They are just called something different depending on their location: protons in the nucleus, electrons in orbits.
4. **True or false:** The proton is many times more massive than the electron.
5. **True or false:** The electrostatic force between a proton and a neutron will be exactly zero.
6. Every lithium atom has 3 protons in its nucleus. If one electron is added to a neutral lithium atom,
   A) a positive ion is created with charge $+1.6\text{x}10^{-19}$C.
   B) a positive ion is created with a net charge of +1C.
   C) a negative ion is created, and the net charge is -1C.
   D) a negative ion is created. The net electrical charge will be $-1.6\text{x}10^{-19}$C.
7. To say that charge is **quantized** means that an object
   A) can possess any amount of charge; the quantity just needs to be measured.
   B) can have fractional amounts of charge from partial particles, i.e., half an electron.
   C) can only have whole number of protons or electrons, so there are specific amounts, or quanta, of charge that are allowable; you cannot have half an electron.
   D) cannot possess any extra charge: the number of negative charges must always equal the number of positive charges in every atom.
8. To say that charge is **conserved** means that
   A) an object always has an equal number of (+) and (–) charges; you cannot add or subtract charge from it.
   B) if you add a (–) charge to an atom, you must also add a (+) charge to its nucleus, to conserve the balance.
   C) charge, like mass, can neither be created nor destroyed. All the charge that exists now will continue to exist—you can move the charges to and from different atoms, but they will still exist.
   D) charge, like mass, is being continuously created. Conservation means that for every (+) charge created, there is also a (–) charge created.
9. When you scuffle across the carpet in your socks, you are
   A) using friction to scrape some negative electrons off the carpet fibers. You accumulate some excess (–) charge.
   B) using polarization to pull some protons out of the nuclei of the carpet fibers. You accumulate some excess (+) charge.
   C) using induction to repel the negative carpet fibers away fro your negative socks.
   D) using magic to levitate the neutrons out of the carpet and onto your socks. *Accio neutronium!*
10. You rub a balloon vigorously on your hair, then stick it to the wall. While you are rubbing the balloon, you are using
    A) insulation to prevent charges from moving either to or from your hair or the balloon.
    B) induction to transfer negative charges from the balloon to your hair.
    C) conduction to move positive charges from the balloon to your hair.
    D) friction to transfer negative charges from your hair to the balloon.
11. The balloon sticks to the wall because
    A) the negatively charged balloon polarizes atoms in the wall to create a positively charged surface.
    B) the balloon and the wall are both insulating materials: the balloon's charges transfer to the wall.
    C) the balloon is positive and the wall is negative.
    D) the wall has an excess of positive charges.
12. You rub a second balloon on your hair, and stick it to the metal frame of the chalk board.
    A) This balloon sticks much better than the first one, because the metal sucks up the excess charge.
    B) The metal does take the excess charge from the balloon, but this is why the balloon doesn't stick!
    C) This balloon will stick to the metal for just as long as the balloon on the wall; there is no difference between the two situations.
13. Why are materials like glass or rubber good electrical **insulators**?
    A) Insulators are composed of atoms with no electrons; there are no charges available to move.
    B) Insulators are always crystalline; the ordered arrangement of atoms makes it hard to move electrons.
    C) Insulators are usually light-colored. Glass or rubber can be made white or light beige, while metallic materials will be darker (gray or brownish).
    D) Insulators typically have full outermost electron shells; it is more difficult to pull an electron off, and if you manage to pull one off, the next atom over has no place to put it.
14. According to **Coulomb's Law**, what happens to the electrostatic force between two charged particles as the distance increases?
    A) The magnitude of the force decreases, and the direction is unchanged.
    B) The magnitude of the force increases, and the direction is unchanged.
    C) Both the magnitude and direction of the force stay the same.
    D) The magnitude of the force stays the same, but the direction reverses.

15. According to **Coulomb's Law**, what happens to the electrostatic force between two charged particles if the amount of charge increases? If you double the charge,
    A) the force increases by a factor of two.
    B) the force increases by a factor of four.
    C) the force remains constant and unchanging.
    D) the force decreases to ½ its previous magnitude.
    E) the force decreases to only ¼ its previous value.

16. Two identical spheres carry the same amount of charge. Both spheres are negative.
    A) The spheres will repel each other.
    B) No force will exist between the spheres.
    C) The spheres will be attracted to each other.
    D) A force will exist, but you can't predict it.

17. Two identical spheres carry the same amount of charge. One is negative, the other positive.
    A) The spheres will repel each other.
    B) No force will exist between the spheres.
    C) The spheres will be attracted to each other.
    D) A force will exist, but you can't predict it.

18. You have two charged particles. q_1 = +3C, and q_2 = -5C separated by r = 10cm. Describe the force between charges.
    A) The force is attractive: q_1 and q_2 are each pulled toward the other.
    B) The force is repulsive: q_1 and q_2 are each pushed away from each other.
    C) q_1 is positive, so it is attracted to q_2. But q_2 is negative, so it is repelled away from q_1.
    D) Backwards! q_1 will be repelled away from q_2, and q_2 will be attracted towards q_1.

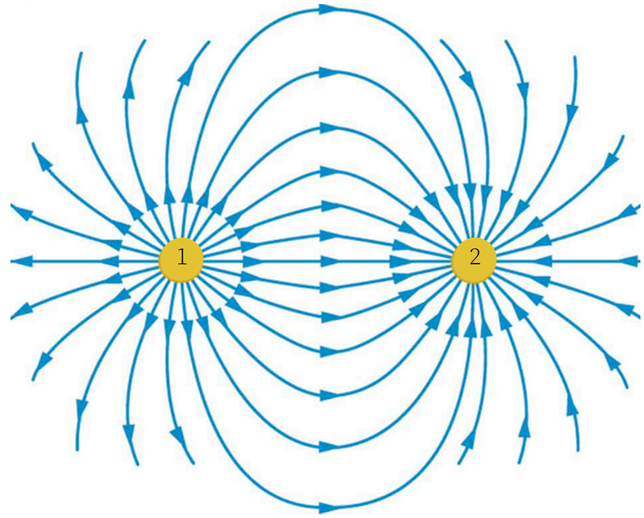
19. The charges are moved so that the separation is now 20cm. How has the force changed?
    A) It hasn't. If the charges have not changed, it does not matter where you put them. The force is constant.
    B) Bigger distance means bigger force. If you double the distance, you double the force as well.
    C) Bigger distance actually means smaller force: double the distance, half the force.
    D) Doubling the distance means the force is reduced to 1/4 of its original value.

Charge $q_1 = +4\text{x}10^{-6}$C, and it is located at r = 15 cm from charge $q_2 = +3.5\text{x}10^{-6}$C. The magnitude (absolute value) of the force is F = 36N. Use this information to answer questions 40 and 41.

20. **True or false:** These charges repel each other.

21. When the distance between the charges is **decreased** by a factor of **three** (from 15cm to 5cm), what is the result? The new force is
    A) decreased by a factor of three (from 36N to 12N).
    B) decreased by a factor of 9 (from 36N to 4N).
    C) unchanged. The magnitude of the force is independent of the charge separation.
    D) increased by a factor of three (from 36N to 108N).
    E) increased by a factor of 9 (from 36N to 524N).

22. In the context of physics, what is a **field**?
    A) A field describes the effect something has on the surrounding space.
    B) A field is any region of empty space: the vacuum of interstellar space, for example.
    C) A field is the same thing as a force: it is the effect that one object has on another object



23. An electric field is created by two equal charges fixed in the positions shown above. Given that the field lines represent the force experienced by a positive test charge, what do you know about the signs of the fixed charges?
    A) Nothing. The two charges might be any sign at all.
    B) Both charges must be negative.
    C) Both charges must be positive.
    D) Charge q_1 is (+) and q_2 is (–).
    E) Charge q_1 is (–) and q_2 is (+).

24. Electric potential, or voltage, is defined as
    A) electric potential energy per charge.
    B) potential energy per unit of mass.
    C) total charge per total electric potential energy.
    D) total electric current per electron per unit of energy

25. For electric charges to flow,
    A) they must be pulled by a gravitational force.
    B) the resistance of the medium must be extremely high.
    C) a potential difference must exist. Charges flow from low to high potential.
    D) a potential difference must exist. But the charges flow from high to low potential!

26. One **amp** (or ampere) of electrical current is defined as
    A) one coulomb of charge per second of time.
    B) one electron traveling at a speed of 1 m/s.
    C) one coulomb of charge per electron.
    D) one electron per m2 of cross–sectional area of wire.

27. How is the **direction** of electrical current defined?
    A) Trick question! There is no standard convention for defining the direction of current flow.
    B) Current flows from (–) to (+). This is opposite the direction which the actual electrons will move.
    C) Current flows from (+) to (–). This is the direction which the actual electrons will move.
    D) Current flows from (+) to (–). This is opposite the direction which the actual electrons will move.

28. **True or false:** When the switch is closed on a circuit, electrons will pour out of the negative terminal of the battery, and flow completely around the circuit until they pour back into the positive terminal of the battery.

29. **True or false:** The electrical resistance of a thicker wire will be greater than that of a thinner wire of the same length made of the same material.

30. According to **Ohm's Law**, increasing the voltage
    A) increases the current: double the voltage, double the current.
    B) decreases the voltage: double the voltage, half the current.
    C) does not affect the current, but the resistance increases: double the volts, double the resistance.
    D) does not affect the current, but decreases the resistance: double the volts, half the resistance.

31. Which of the following is **not** a good way to **increase** the resistance of the filament in a light bulb?
    A) Increase the length of the filament wire.
    B) Increase the temperature of the filament.
    C) Increase the thickness of the filament wire.
    D) All of these will increase the resistance!

32. What is the **resistance** of an electric frying pan that draws a current I = 20A when connected to a V = 120V household circuit?
    A) $R = 0.167\ \Omega$ C) $R = 60\ \Omega$ E) $R = 120\ \Omega$
    B) $R = 6\ \Omega$ D) $R = 100\ \Omega$ F) $R = 240\ \Omega$

33. What is the **resistance** of an electric blow dryer that draws a current I = 15.9A when connected to a V = 120V household circuit?
    A) $R = 7.5\Omega$ C) $R = 8.5\Omega$ E) $R = 9.5\Omega$
    B) $R = 8\Omega$ D) $R = 9.0\Omega$ F) $R = 10\Omega$

34. How much **power** does this blow dryer use?
    A) P = 1500W C) P = 1700W E) P = 1900W
    B) P = 1600W D) P = 1800W F) P = 2000W

35. An 1800W blow dryer is connected to a V = 120V household circuit. How much **current** does it draw?
    A) I = 2A C) I = 10A E) I = 15A
    B) I = 5A D) I = 12A F) I = 20A

36. What is the **resistance** of this 1800W blow dryer?
    A) $R = 2\Omega$ C) $R = 6\Omega$ E) $R = 10\Omega$
    B) $R = 4\Omega$ D) $R = 8\Omega$ F) $R = 12\Omega$

37. A 1500W hair dryer is draws I = 6.8A of current when plugged in and turned on.
    A) This is standard for an American appliance plugged into a 120-V wall outlet.
    B) Sacre bleu! Vous êtes à Paris, oú le voltage est 220-V. Or maybe you are in London, where they also use 220-V as the standard.
    C) You can't be plugged into either a 120-V or 220-V outlet; wherever you are, you are plugged into a 10,200-V circuit. Don't stick a fork in this outlet!

38. Which of the following does **not** create a magnetic field?
    A) The orbital motion of electrons.
    B) Electrons spinning.
    C) An electric current through a wire.
    D) The gravitational attraction between protons and electrons.
    E) All of the above are related, therefore all create magnetic fields.

39. The magnetic force causes like poles to
    A) cancel each other. C) repel each other.
    B) attract each other. D) destroy each other.

40. Which of the following is most responsible for creating the magnetic field of a typical refrigerator magnet?
    A) The orbital motion of electrons.
    B) Gravitational attraction between protons and electrons.
    C) Electrons spinning.
    D) Convection currents as the denser metal sinks.

41. Which of the following materials could **not** be used in its pure form to make a compass needle?
    A) Aluminum. C) Cobalt.
    B) Nickel. D) Iron.

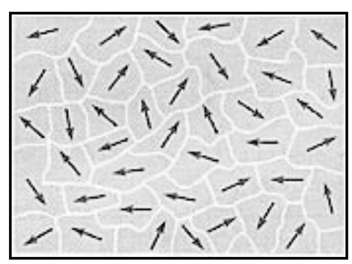
42. A friend hands you a rectangular piece of metal, and claims that it has a single magnetic pole, located exactly at its center.
    A) Not possible; magnetic poles always occur in pairs.
    B) Not possible; if it only had one pole, that pole would have to be located on one end.
    C) Possible; magnetic monopoles are actually quite common.
    D) Quite possible, but quite rare. It can only happen if you have exactly the right number (Avogadro's number, actually) of iron atoms making up your magnet, which is almost impossible to achieve.
    E) Winner of the 2017 Nobel Prize for Physics: You! Well, your friend, unless you nonchalantly tell him that the metal is worthless, offer him a dollar for it, then publish your amazing findings in a reputable peer-reviewed journal.

43. Every magnet has
    A) two poles, either a pair of North poles or a pair of South poles.
    B) two poles, one negative and one positive.
    C) a pair of poles, one North and one South.
    D) at least 50% iron in its composition.

44. What happens if you break a bar magnet into four pieces?
    A) You have four complete magnets, each one having a north and a south pole.
    B) You have four magnets: two with only south poles and two with only north poles.
    C) One magnet has a south pole, one has a north pole, and two pieces are unmagnetized metal.

45. A **magnetic domain** is a region
    A) within a substance where there are no electrons, so there is no magnetic field.
    B) within a substance where electron spins are in alignment, creating a magnetic field.
    C) of space in which you can feel a magnetic force, even when you are not touching a magnet.
    D) of space where solar particles are deflected by the earth's magnetic field.

46. The figure on the right shows the domains of a piece of metallic material.



    A) This object is probably not magnetic.
    B) This object is definitely a very strong magnet.
    C) If this metallic object is iron, it's clearly a magnet. If it's any other metal, it's not.
    D) The picture as nothing to do with metals or magnetism! The arrows represent the force of gravity on the individual areas of the object shown.

47. **True or false:** An electric current could be used to induce the alignment of the domains in the material shown above.

48. Can a magnet attract a piece of iron that is not magnetized? Why or why not?
    A) No; iron does not have a good structure for magnetism.
    B) No; non-magnetic material will not show attractive or repulsive forces to a magnet.
    C) Yes; all metals are attracted to magnets.
    D) Yes; the domains in the iron are induced into alignment and one pole is attracted to the magnet

49. The Earth's magnetic field is generated
    A) by the gravitational deflection of charged particles from the sun.
    B) by the alignment of the domains within the iron core of the planet.
    C) by convection currents deep within the molten iron-nickel outer core of the planet.
    D) by the energy beams of the aliens who have secret bases on the far side of the moon.

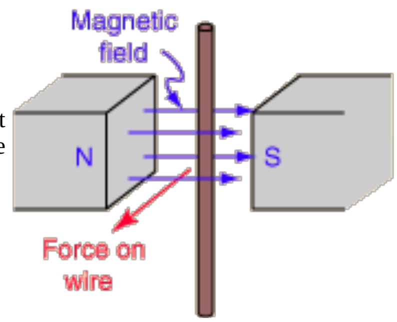
50. How stable is the earth's magnetic field?
    A) It seems stable to us, but there is evidence that the field has reversed polarity many times.
    B) The field is rapidly and constantly changing; this is what causes the aurora borealis to have such beautiful colors.
    C) Extremely stable; there is geologic evidence that the field orientation and strength have remained unchanged for literally billions of years.

51. When a current is passed through a long straight wire,
    A) a magnetic field is generated. The field lines form circles around the wire.
    B) a magnetic field is generated. The field lines are radial, pointing away from the wire.
    C) no magnetic field is generated. There is no connection between electricity and magnetism.
    D) no magnetic field is generated; moving electrons de–magnetize the wire by destroying domain alignment.

52. You wind a copper wire around an iron nail. Next, you attach a battery, and the current through the wire is $I_1 = 1$ amp. Awesome! You made an electromagnet! What happens if you increase the current through the wire to $I_2 = 2$ amps?
    A) Nothing; you cannot use electricity to make magnets. They are unrelated phenomena.
    B) You still have an electromagnet, but increasing the current doesn't change how strong the magnet is.
    C) Increasing the current actually decreases the strength of the electromagnet.
    D) Doubling the current should increase the strength of the electromagnet.

53. What ultimately limits the strength of an electromagnet?
    A) Nothing; you can make electromagnets infinitely strong.
    B) The amount of current you use: the strength decreases with increasing amount of current.
    C) The resistance of the wire: the greater the resistance, the stronger the electromagnet will be.
    D) The iron core: once all the domains are aligned, you cannot make the magnet any stronger.

54. A wire placed in a constant magnetic field is pushed forward (out of the page) when a current is passed through the wire. For the wire shown on the right, what is the direction of the **current**?



    A) Straight up.
    B) Straight down.
    C) To the right.
    D) To the left.

55. Reversing the direction of the current
    A) pushes the wire into the page.
    B) causes less deflection, in the same direction (out of the page).
    C) causes exactly the same deflection (out of the page) in the wire.
    D) pushed the wire sideways (it could be left or right, you don't know).

56. An electrical **generator**
    A) produces more energy than it consumes.
    B) converts mechanical energy to electrical energy.
    C) converts electrical energy into chemical energy.
    D) converts mechanical energy to electrical energy.

57. An electric **motor**
    A) produces more energy than it consumes.
    B) converts mechanical energy to electrical energy.
    C) converts electrical energy into chemical energy.
    D) converts electrical energy to mechanical energy.