How Things Work - Practice Exam 2A Solutions

Avi Herman

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Question 1

You and a friend are studying the electrostatic interaction of two charges. If the distance between two electric charges doubles, how does the force they exert on each other change?

- **(a)** 4 times as large
- **(b)** 2 times as large
- **(c)** $\frac{1}{2}$ as large
- **(d)** $\frac{1}{4}$ as large

Solution:

The electrostatic force between two charges is described by **Coulomb's Law**:

$$F = k\frac{q_1 q_2}{r^2}$$

When the distance r is doubled, the new force is:

$$F_{\text{new}} = k\frac{q_1 q_2}{(2r)^2} = \frac{1}{4}F$$

Thus, the force becomes one-quarter of its original value. The correct answer is **(d)**: $\frac{1}{4}$ as large.

Question 2

You stick two pieces of tape on a window and pull them off. If you hold the pieces near each other, they:

- **(a)** repel because they have like charges.
- **(b)** repel because they have opposite charges.
- **(c)** attract because they have like charges.
- **(d)** attract because they have opposite charges.

Solution:

When you pull two identical pieces of tape off a surface like a window, they typically acquire similar charges due to the **triboelectric effect**. This means that both pieces of tape end up with the same type of charge (either both positive or both negative). Since like charges repel each other, the two pieces of tape will repel when held near each other.

Thus, the correct answer is **(a)**: repel because they have like charges.

Question 3

After running a plastic comb through your hair, you hold it above a small scrap of paper. The paper sticks to the comb because the paper becomes:

- **(a)** magnetic.
- **(b)** electrically charged.
- **(c)** conducting.
- **(d)** electrically polarized.

Solution:

The comb becomes negatively charged after running it through your hair. When the comb is brought near the paper, it induces a separation of charges in the paper, causing polarization. This leads to attraction between the comb and the paper. The correct answer is **(d)**: electrically polarized.

Question 4

A charged object is able to repel:

- **(a)** only charged objects
- **(b)** neutral objects and neutral particles
- **(c)** neutral objects but not neutral particles
- **(d)** only neutral particles

Solution:

A charged object can only repel other charged objects of the same sign, as neutral objects are attracted due to polarization but not repelled. The correct answer is **(a)**: only charged objects.

Question 5

Polarization:

- **(a)** maximizes the potential energy of a system.
- **(b)** minimizes the potential energy of a system.
- **(c)** does not change the potential energy of a system.
- **(d)** resets the potential energy of a system to zero.

Solution:

Polarization tends to arrange charges in such a way that attractive forces reduce the system's potential energy, aligning it in a more stable configuration. The correct answer is **(b)**: minimizes the potential energy of a system.

Question 6

A typical commercial jet has a sharpened metal rod projecting backward from the tip of each wing. These two rods prevent the airplane from accumulating a large net electric charge during flight by:

- **(a)** reducing sliding friction between the airplane and the passing air stream.
- **(b)** transferring any charge on the plane to the air behind the plane.
- **(c)** maintaining a steady electric current between the airplane's wings.
- **(d)** generating high voltages while passing quickly through Earth's magnetic field.

Solution:

The rods at the tips of the airplane wings allow any excess charge that accumulates during flight to be transferred to the surrounding air, thereby preventing large charges from building up on the airplane. The correct answer is **(b)**: transferring any charge on the plane to the air behind the plane.

Question 7

High voltage power lines are usually supported by glass insulators. An electric current cannot flow through a piece of glass because:

- **(a)** glass contains only positively charged particles.
- **(b)** glass contains only negatively charged particles.
- **(c)** the electrons in the glass are tightly bound to their atoms and are thus not able to transport charge through the glass.
- **(d)** glass does not contain any electrically charged particles.

Solution:

To explain why no current flows through glass, we can reference **Ohm's Law** from the formula sheet:

$$V = IR$$

Glass has an extremely high resistance, effectively infinite in most practical cases. This means that no matter the voltage applied, the current I will be nearly zero:

$$I = \frac{V}{R}$$

Since $R \to \infty$, $I \to 0$. Therefore, no current flows through the glass because its tightly bound electrons cannot transport charge. The correct answer is **(c)**: the electrons in the glass are tightly bound to their atoms and are thus not able to transport charge through the glass.

Question 8

You notice that a light at home keeps going out but you are certain that the bulb is good. Such behavior could result from:

- **(a)** either an open circuit or a short.
- **(b)** an open circuit only.
- **(c)** a short circuit only.
- **(d)** the bulb's resistance being cut in half.

Solution:

A faulty connection could cause either an open circuit (where no current flows) or a short circuit (where too much current flows), leading to the light going out intermittently. The correct answer is **(a)**: either an open circuit or a short.

Question 9

The principal advantage of sending electric power across long distances using low current is that:

- **(a)** the charge can get from one point to another faster.

- **(b)** electric power lost in the wires is greatly reduced.
- **(c)** the transmission lines are less likely to get in the way than low voltage transmission lines—which are much closer to the ground.
- **(d)** low current means low resistance in the lines.

Solution:

Low current reduces the power lost due to heating (which is proportional to I^2R). Reducing current thus reduces energy losses in the transmission lines. The correct answer is **(b)**: electric power lost in the wires is greatly reduced.

Question 10

You remove the batteries from a working flashlight, turn both of them around as a pair, and reinsert them in the flashlight. They make good contact with the flashlight's terminals at both ends, so that there is no mechanical problem preventing the flashlight from working. If you now switch on the flashlight, it will:

- **(a)** not work because only electrons can actually move through a circuit. The positively charged atomic nuclei are immobile.
- **(b)** work properly, although current will now be flowing backward through its circuit.
- **(c)** not work because the batteries can't send current backward through the flashlight's circuit.
- **(d)** not work because the light bulb can only carry electric current in one direction.

Solution:

Reversing the batteries changes the polarity of the voltage supplied to the flashlight's bulb. However, many flashlight bulbs, especially incandescent bulbs, are not polarized components and can operate regardless of the direction of current flow. In this case, the flashlight will work properly because the bulb can handle current flowing in either direction.

Thus, the flashlight will work properly, although current will now be flowing backward through its circuit. The correct answer is **(b)**: work properly, although current will now be flowing backward through its circuit.

Question 11

Your flashlight has three identical 1.5V batteries in it, arranged in a chain to give a total of 4.5V. Current passes first through the first battery, then through the second battery, then through the third, on its way to the bulb. When you operate the flashlight, the batteries provide power to the flowing charges and they gradually use up their chemical potential energy. Which battery will run out of chemical potential energy first?

- **(a)** All three will run out at the same time.
- **(b)** The first battery will run out first.
- **(c)** The second battery will run out first.
- **(d)** The third battery will run out first.

Solution:

Since the batteries are identical and the current flows through all three batteries equally, they will all run out of chemical potential energy at the same time. The correct answer is **(a)**: all three will run out at the same time.

Question 12

You somehow damaged the cord of your desk lamp: one of the two wires in the cord is completely cut in half and cannot carry any current. However, the other wire still connects the lamp to the electric socket. If you turn on the lamp:

- **(a)** the normal amount of current will flow through both wires and the lamp will glow at its normal brightness.
- **(b)** the normal amount of current will flow through the one remaining wire and the bulb will glow at its normal brightness.
- **(c)** no current will flow through the bulb.
- **(d)** only half the normal current will flow through the bulb.

Solution:

Using **Ohm's Law** again:

$$V = IR$$

With one wire severed, the circuit becomes open, causing the resistance R to effectively become infinite. With $R \to \infty$, the current I becomes zero:

$$I = \frac{V}{R} \to 0$$

No current can flow through the circuit, and therefore the bulb will not light up. The correct answer is **(c)**: no current will flow through the bulb.

Question 13: BONUS!

Your new toaster has two separate toasting units, each of which consumes 600W of power when it is in use. When you operate one unit, a current of 5A flows through the wiring in your home and the wires waste about 1 watt of power handling that current. If you operate both toasting units at once, your toaster consumes 1200W and the current flowing through the wiring in your home doubles to 10A. How much power will the wires in your home waste now?

- **(a)** about 0.5W.
- **(b)** about 4W.
- **(c)** about 2W.
- **(d)** about 1W.

Solution:

Power loss in the wires is proportional to the square of the current ($P = I^2R$). Doubling the current increases the power loss by a factor of four. If the original loss was 1W, the new loss is:

$$P_{\text{new}} = 4 \times 1 = 4W$$

The correct answer is **(b)**: about 4W.

Question 14

A power line carries current 10A and has resistance 2Ω. What is the power loss as heat in the line?

- **(a)** 200W
- **(b)** 20W
- **(c)** 10W
- **(d)** 5W

Solution:

The power loss due to resistance can be calculated using the formula:

$$P = I^2 R$$

Given $I = 10\,\text{A}$ and $R = 2\,\Omega$:

$$P = (10)^2 \times 2 = 100 \times 2 = 200\,\text{W}$$

The correct answer is **(a)**: 200W.

Question 15

A typical bar magnet has an "N" stamped on its north pole end and an "S" stamped on its south pole end. With the right tools, you might be able to change this bar magnet in one or more of the following ways: (1) remove its magnetic poles altogether, (2) reverse its magnetic poles so that it has a north pole at the end stamped "S" and a south pole at the end stamped "N", (3) convert its north pole into a south pole so that it has south poles at both ends and no north poles. Which of those three options is physically possible?

- **(a)** Only (1) and (2)
- **(b)** None of them is possible.
- **(c)** Only (2) and (3)
- **(d)** All three are possible.

Solution:

Magnetic poles always come in north-south pairs; you cannot isolate a single pole (monopole). However, certain manipulations are possible:

1. **Remove its magnetic poles altogether:** This can be achieved by **demagnetizing** the bar magnet. Techniques such as heating the magnet above its Curie temperature or subjecting it to a strong alternating magnetic field can randomize the magnetic domains, effectively removing the net magnetic poles.

2. **Reverse its magnetic poles:** This is possible by **remagnetizing** the bar magnet in the opposite direction, effectively swapping the north and south poles.

3. **Convert its north pole into a south pole so that it has south poles at both ends and no north poles:** This is **impossible** because it would require creating a magnetic monopole, which does not exist in classical magnetism.

Therefore, only options (1) and (2) are physically possible. The correct answer is **(a)**: Only (1) and (2).

Question 16

A magnet factory is making bar magnets, each about the size and shape of an ordinary ruler. After forming each bar of metal, that bar must be magnetized. The bar is placed in a coil of wire and a huge pulse of current is sent through the coil. During the pulse, current is only sent in one direction through the coil: a pulse of direct current or DC. If, instead, the current reversed directions rapidly during the pulse—a pulse of alternating current or AC, then:

- **(a)** the bar magnet would end up with two south poles and no north poles.
- **(b)** the poles of the bar magnet would also reverse rapidly and would end up with a magnetization that depends upon what the AC current was at the precise moment it was shut off.
- **(c)** the bar would become overmagnetized because AC is much more magnetic than DC.
- **(d)** the bar magnet would end up with two north poles and no south poles.

Solution:

When a magnet is magnetized using a direct current (DC), the magnetic domains align consistently. If alternating current (AC) is used instead, the poles of the magnet would flip rapidly as the current direction changes. The final magnetization would depend on the current direction at the moment the AC was turned off. The use of **angular momentum** to describe the magnetization could be tied to the equation:

$$\Delta L = \tau \Delta t$$

where τ is the torque acting on the magnetic domains. The correct answer is **(b)**: the poles of the bar magnet would also reverse rapidly and would end up with a magnetization that depends upon what the AC current was at the precise moment it was shut off.

Question 17

You are working on an experiment involving a very strong permanent magnet, and your data suggests that your magnet's field suddenly decreased during some interval in time. Such a decrease could have been caused by the magnet:

- **(a)** having overheated substantially.
- **(b)** being hit hard.
- **(c)** both (A) and (B).
- **(d)** being grounded out.

Solution:

A magnet's field can weaken if it is subjected to significant physical stress, such as being hit hard or overheated, both of which can disrupt the alignment of its magnetic domains. The correct answer is **(c)**: both (A) and (B).

Question 18

A steel refrigerator door is not permanently magnetic because:

- **(a)** All the magnetic domains are oriented randomly.
- **(b)** There are no magnetic domains.
- **(c)** The electrons are bound and cannot move around much.
- **(d)** The door is usually grounded out and loses all its magnetism.

Solution:

A steel refrigerator door has magnetic domains, but they are oriented randomly, canceling out any net magnetic field. The correct answer is **(a)**: All the magnetic domains are oriented randomly.

Question 19

You are working in a laboratory over the summer and you measure the magnetic field in a coil to be 3T. You insert a steel rod which has a pole strength of 500Am. The amount of force on the rod is:

- **(a)** 0
- **(b)** 3N
- **(c)** 1500N
- **(d)** 1500Nm

Solution:

The force on a magnetic pole in a magnetic field is given by:

$$F = B \times p$$

where $B = 3T$ (magnetic field strength) and $p = 500\ \mathrm{Am}$ (pole strength). Using this equation, the force is:

$$F = 3 \times 500 = 1500\,\mathrm{N}$$

The correct answer is **(c)**: 1500N.

Question 20

A step-up transformer has 20 primary turns and 400 secondary turns. If the primary current is 30 A, what is the secondary current?

- **(a)** 12000 A
- **(b)** 600 A
- **(c)** 30 A

- **(d)** 1.5 A

Solution:

The current in a transformer is inversely proportional to the number of turns in the coil:

$$I_s = I_p \times \frac{N_p}{N_s}$$

Given $I_p = 30A$, $N_p = 20$, and $N_s = 400$:

$$I_s = 30 \times \frac{20}{400} = 1.5A$$

The correct answer is **(d)**: 1.5A.

Question 21

Electricity produced in a generating plant passes through a large step-up transformer. This step-up transformer produces the high voltages needed to send electric power long distances across the countryside. Which of the following is transferred from the transformer's primary coil to its secondary coil while the transformer is operating?

- **(a)** Negative electric charges and power.
- **(b)** Positive electric charges, negative electric charges, and power.
- **(c)** Power alone.
- **(d)** Positive electric charges and power.

Solution:

In a transformer, the primary coil transfers energy (in the form of power) to the secondary coil, but no electric charges are transferred between the coils. The correct answer is **(c)**: Power alone.

Question 22

A step-down transformer transfers power from the 120V alternating current passing through its primary coil to the 12V alternating current passing through its secondary coil. If you interchange the primary and secondary coil, and send the 120V alternating current through the new primary coil:

- **(a)** a 12V alternating current will pass through its new secondary coil.
- **(b)** a 12V direct current will pass through its new secondary coil.
- **(c)** no current will pass through its new secondary coil.
- **(d)** a 1200V alternating current will pass through its new secondary coil.

Solution:

The voltage ratio in a transformer is determined by the turns ratio. Reversing the primary and secondary coils in a step-down transformer turns it into a step-up transformer, which will increase the voltage. Given the original ratio of $\frac{120}{12} = 10$, the new voltage will be:

$$V_{\text{new secondary}} = 120 \times 10 = 1200\,\text{V}$$

The correct answer is **(d)**: a 1200V alternating current will pass through its new secondary coil.

Answer Key

1. **(d)** $\frac{1}{4}$ as large
2. **(a)** repel because they have like charges
3. **(d)** electrically polarized
4. **(a)** only charged objects
5. **(b)** minimizes the potential energy of a system
6. **(b)** transferring any charge on the plane to the air behind the plane
7. **(c)** the electrons in the glass are tightly bound to their atoms and are thus not able to transport charge through the glass
8. **(a)** either an open circuit or a short
9. **(b)** electric power lost in the wires is greatly reduced
10. **(b)** work properly, although current will now be flowing backward through its circuit
11. **(a)** all three will run out at the same time
12. **(c)** no current will flow through the bulb
13. **(b)** about 4W
14. **(a)** 200W
15. **(a)** Only (1) and (2)
16. **(b)** the poles of the bar magnet would also reverse rapidly and would end up with a magnetization that depends upon what the AC current was at the precise moment it was shut off
17. **(c)** both (A) and (B)
18. **(a)** All the magnetic domains are oriented randomly
19. **(c)** 1500N
20. **(d)** 1.5A
21. **(c)** Power alone
22. **(d)** a 1200V alternating current will pass through its new secondary coil