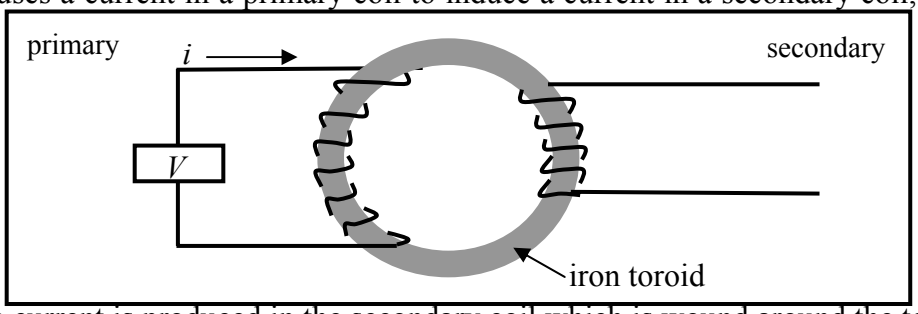
Workshop Tutorials for Physics

ER9: **Applications of Electromagnetism**

A. Qualitative Questions:

1. A transformer uses a current in a primary coil to induce a current in a secondary coil, as shown in the diagram below.



a. Explain how a current is produced in the secondary coil which is wound around the toroid when there is no external magnetic field around the toroid.

The ratio of the voltage across the primary coil to the voltage across the secondary coil is equal to the ratio of the number of turns on the primary coil to the number of turns on the secondary coil, i.e. $\frac{V_P}{V_S} = \frac{N_P}{N_S}$.

b. Explain why this is the case.

(Hint: think about the magnetic field in the toroid.)

2. Electric motors are used in thousands of applications, from electric toothbrushes to electric cars, drills, pumps, fans and vacuum cleaners. A simple electric toothbrush comes with rechargeable batteries and a charger which the toothbrush sits on when not in use. The toothbrush circuitry is completely enclosed in a plastic cylinder so that moisture can't get in.

a. Describe the basic circuit components that the toothbrush must have to function.

The cylindrical handle of the toothbrush has an indent in the base which fits over a peg on the charger, allowing it to sit upright on the charger. There is no direct electrical connection between the charger and the toothbrush.

b. Explain how the batteries are charged without a direct electrical connection.

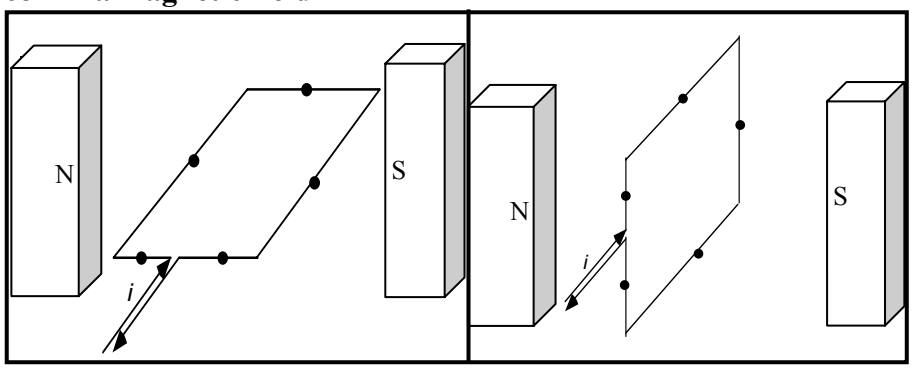
Some cordless electric jugs also work this way.

B. Activity Questions:

1. Torque on a current carrying coil in a magnetic field

Draw the magnetic force at the points marked by dots on the diagrams opposite.

If held stationary prior to release, in which of the above cases is the loop more likely to start turning on its own?



2. Simple electric motor
Connect the battery to the motor. You may need to give it a nudge to start it spinning.
Draw a diagram showing the current traveling through the loop and the force due to the magnets.
Using your diagram, explain why the loop spins.

3. Electricity generator
Turn the handle so that the LED lights up.
Explain what is happening to produce a current.
How is this similar and different to the electric motor?

4. Power plants
Examine the diagrams showing how electricity is produced using geothermal power, nuclear power and hydroelectric power. How are these methods different?
How are they similar?
Can you think of a way of commercially producing electricity which does not use a generator?

C. Quantitative Question:

1. A backup power generator for a hospital needs to produce an *emf* of 240 V RMS so that the medical equipment will run even in a power failure. The coil rotates at 50 Hz. The coil consists of 500 m of wire wrapped into a rectangular coil of side lengths 20 cm and 15 cm.
a. What magnetic field is necessary to produce an RMS *emf* of 240V?
This generator is to be modified to power a 120 V (RMS) piece of equipment from a US manufacturer. The cheapest way to do this is by unwinding some of the wire that makes up the coil and reconnecting it.
b. How much wire should be removed?

2. Rebecca has left her car head lights on again and the battery has gone flat. Brent suggests that rather than using his car to recharge the battery they build a battery charger so she can recharge it herself. He suggests that she modify an old transformer that they don't need anymore to do the job. The old transformer has a primary coil of 300 turns. It will need to be connected to mains voltage, 240 V, and put out a voltage of 12 V to charge the battery.
a. How many turns should Rebecca wind to make the secondary coil?
Rebecca finishes winding the coil, and checks the output just to be sure. She measures the input current and voltage, and also the output current and voltage.
b. If the primary current is 2.5A and the secondary current is 4.0 A, what is the efficiency of the transformer?
When the transformer is finished Rebecca suggests that they give it a go. Brent points out that the mains power supply from the wall socket is an alternating current supply, and hence the transformer can't be connected straight onto the battery.
c. Why is this a problem?
Brent quickly puts together a rectifier circuit which converts AC to DC at the cost of 3 V. This will allow the transformer to be connected to the battery, but unfortunately it now doesn't supply enough voltage to charge the battery enough to start the car.
d. How many turns need to be added to the secondary coil to get 12 V out of the finished battery charger now?