Section	Group	Name	Signature
Grade			
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Materials: • *Induction Demonstration Videos*

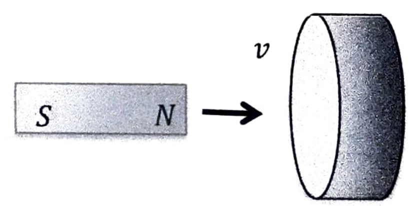
After this activity you should know: • *to become familiar with some consequences and applications of electromagnetic induction including energy transmission, eddy currents, magnetic braking, and levitation*

1. Solenoid and Magnet: The solenoid is hooked to an ammeter (current probe) to form a complete circuit. See video clip: Magnet and Solenoid.

   a. No current is observed when the bar magnet is held stationary near the solenoid. Is there a magnetic flux through the solenoid? If there is, why don't we see a current in the solenoid when the magneti is held stationary?

   yes, current only occurs when flux changes.

   b. Assume the magnet is oriented as with the north pole next to the solenoid. The magnet is then pushed to the right toward the solenoid.

   i. What direction is the magnetic field (due to the magnet) through the solenoid?

   • to the right • to the left • there is no field

   ii. What happens to the magnetic flux through the coil as the magnet is pushed toward the coil?

   • the flux increases • the flux decreases • the flux is unchanged.

   iii. What is the direction of the induced magnetic field generated through the solenod generated by the induced current?

   • to the right • to the left • there is no field

   iv. What direction is the current induced in the solenoid (use the figure!)?

   • in at the top and out at the bottom • out at the top and in at the bottom

   v. What is the direction of the magnetic force on the solenoid? *Hint: The easiest way to do this is to think of the induced current in the coil as a small electromagnet. Figure out which end of the coil is the north magnetic pole.*

   • toward the magnet • away from the magnet

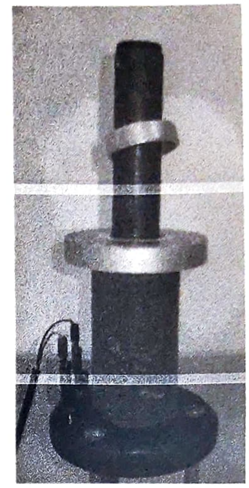
   c. The experiment is repeated except that the magnet is pulled to the left away from the solenoid. Use the same logical steps as above to determine the direction of the induced current in the solenoid and of the direction of the magnetic force on the solenoid.

   towards the magnet

2. **Jumping and Levitating Ring** -- A 60 Hz alternating (AC) voltage is applied to a solenoid wrapped around a cylindrical iron core. The iron core amplifies and directs the magnetic field. An aluminum ring is placed around the iron core. See Jumping Ring for a video of this experiment.

   a. The AC voltage is suddenly turned on from zero to 100 Volts. The aluminum ring jumps off the apparatus. Why is there such a strong repulsive force on the ring?

   The apparatus crates a magnetic force on the ring.



   b. The AC voltage is increased slowly from zero. This time the ring does not jump off the core but rather levitates as shown in the picture. The height at which the ring floats increases with increasing the voltage.

      i. Why does the ring continue to float even after we stop turning the dial on the power supply?

      It is a constant magnetic field

      ii. ii. Why does the ring float instead of jumping off the coil like we saw earlier?

      The force depends on distance so instead of a lot of force at once, it slowly amps up so it = mg

   c. The jumping ring and levitating ring experiments are repeated with a DC power supply instead of AC.

      i. Which experiment(s) (the one where we quickly change the dial or the one where we turn it up slowly and let the ring levitate) will work? Why?

      quickly change thedial B/c it mimics a change in flux

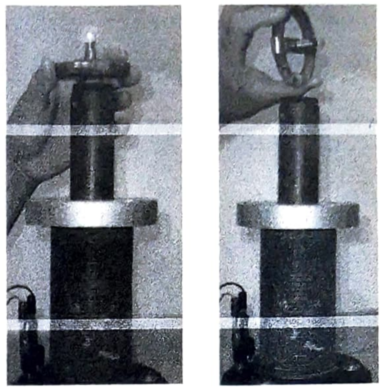
      ii. Which experiment(s) will not work? Why?

      the slow turnup b/c the field is not changing quickly enough with respect to time.

   d. The experiment is repeated with a ring with a gap in it. Which experiment, if any, will work. Which will not? Why?

   None Because there can be no current throught the ring.

e. A light bulb is connected to a wire loop and placed over the top of the iron core in the two orientations shown. Explain why the light bulb lights up in the first orientation but not in the second. See Light Bulb Near AC Solenoid for a video clip.



because there is no induced magnetic field since $\frac{d\phi}{dt} = 0$

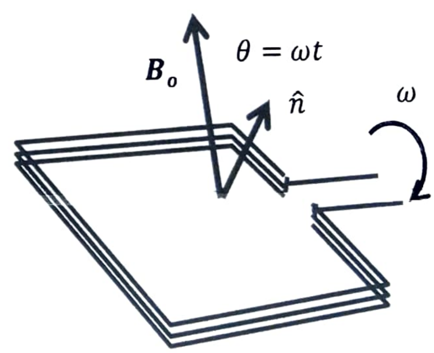
3. **Electric Generator** – An AC electric generator can be either a rotating coil near a stationary magnet or a magnet rotating near a stationary coil. Generators can range in size from the hand generator in this class demo to the electric generators at the Hoover Dam. See https://www.youtube.com/watch?v=6lmds-0XnMU for a video.

   a. Observe the voltage on the oscilloscope as you vary the rate at which you crank the manual AC generator. What happens to the amplitude of the voltage as you crank the generator faster?

   It incruses

   A $L \times L$ square coil of wire has N turns. The coil sits in a uniform magnetic field of B_o. The coil turns at a constant angular frequency ω so the angle between the coil's unit normal and the magnetic field is $\theta = \omega t$.

   b. What is the magnetic flux through the coil of N turns as a function of time?

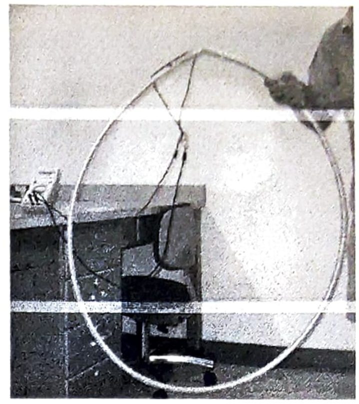


   c. What is EMF as a function of time? Please include sign. Show work.

   d. Does the dependence on angular frequency ω agree with what you found when you increase the speed at which you crank the hand held generator?

Note that electric generators naturally produce an alternating current (AC) EMF. This is one of the reasons why AC rather than DC power is used in the electric grid.

4. **Earth Generator** -- A large circular wire loop is made by enclosing the wire in a hula hoop. The ends of the wire are attached to an ammeter and the hula hoop is rotated vertically about its diameter. Where is the magnetic field coming from? Why is there a change in flux through the loop when the loop is rotated? For a video of the experiment see https://psu.mediaspace.kaltura.com/media/1_b9y8a75i



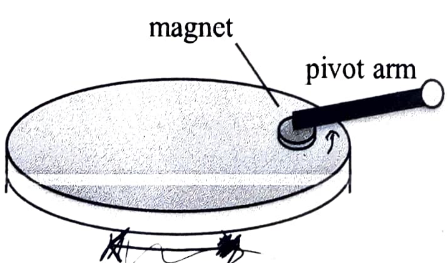
The magnetic field comes from the earths magnetic field.

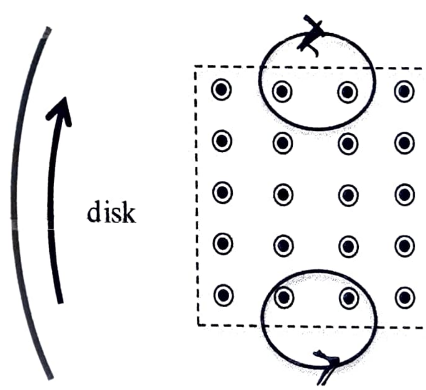
There is flux because the angle between the loop and the magnetic field lines was changing.

5. **Magnet Turntable:** -- A permanent magnet is placed on a pivot arm above a aluminum disk. When the aluminum disk is spun rapidly the magnet levitates. See https://psu.mediaspace.kaltura.com/media/1_8h25hgv4

Eddy currents occur where the disk enters and leaves the magnetic field region. Draw arrows showing the direction (cw or ccw) of the top and bottom eddy currents.

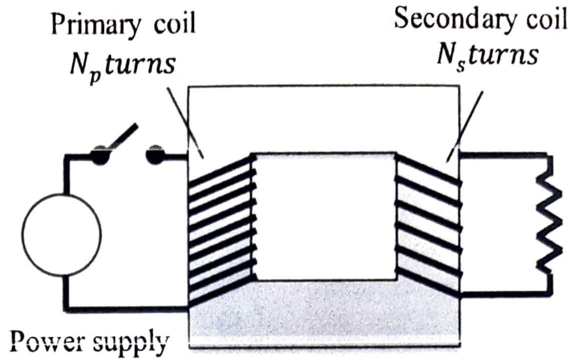
The induced currents in the magnetic turntable acts like magnets which effectively repel the magnet above it. The exact reason why the net force is repulsive is somewhat complicated.





6. **Electric Transformers:** A simple transformer consists of two coils wrapped around an iron core. The left coil is called the primary and is connected to a power supply. The right coil is called the secondary and connected to the load.

The iron core amplifies and bends the magnetic field so that the magnetic flux, Φ_1, through one turn of the primary, is the same as the magnetic flux through one turn of the secondary. See the YouTube video clip https://www.youtube.com/watch?v=fBJbjFVOIsM.



a. **Demo:** The ammeter is connected to the secondary coil while the primary is connected to a DC power supply and switch. Tap and release the switch to complete and open the circuit to the primary. When is there a current in the secondary coil?

The instants the current is/isn't allowed to flow

(when the $\frac{d\Phi}{dt} \neq 0$)

b. Usually the primary is attached to an AC power supply, $\mathcal{E}_p = V_p \cos(\omega t)$. In this case, the flux depends on time and the voltage in the primary and secondary coils are given by Faraday's Law:

$$\mathcal{E}_p(t) = -\frac{d\Phi_m^p}{dt} = -N_p\frac{d\Phi_1}{dt}, \quad \mathcal{E}_s(t) = -\frac{d\Phi_m^s}{dt} = -N_s\frac{d\Phi_1}{dt}$$

The ratio of the voltage in the secondary to the voltage in the primary is

$$\frac{\mathcal{E}_s}{\mathcal{E}_p} = \frac{V_s}{V_p} = \frac{N_s}{N_p}$$

where V_s and V_p are the amplitudes of the voltages of the secondary and primary coils.

A high voltage transmission line delivers power at 700,000 Volts. A transformer reduces this to 2,000 Volts at a substation. The secondary coil has 5 turns. How many turns are there in the primary coil?

$\frac{700000}{2000} = \frac{x}{5}$ $\qquad$ $x = 1750$ turns

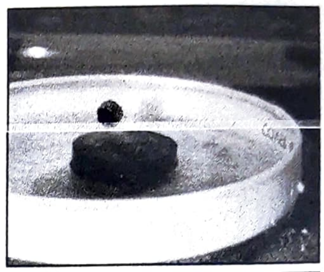
350.5

c. Thomas Edison's original power system used DC current but the AC system promoted by Nickolai Tesla and George Weshinghouse eventually won out. One of the main reasons for the failure of DC was that it is difficult to convert DC power from one voltage to another without extensive losses. Explain why the transformer won't work for DC power supplies.

They rely on magnetic flux to change voltage but DC is a constant voltage/current so it won't change with time.

i.e. $\frac{d\Phi}{dt} \approx 0$

7. **Superconductor:** Many materials become superconducting when the temperature is sufficiently low. That is, the resistance vanishes below a critical temperature T_c and, once a current is established, it can continue indefinitely.



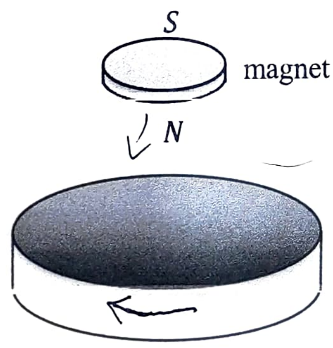
Most metals become superconducting below 4 to 10 Kelvin making them impractical for must applications. However, in the 1980's, materials were discovered with superconducting temperatures above 80 Kelvin which means they can be cooled by relativly inexpensive liquid nitrogen.

Presently most cell phone towers have a high selectivity frequency filter using high T_c superconductors. There are also pilot projects with superconducting transmission lines. The primary difficulty with using high T_c superconductors in more large scale applications is that the materials are ceramics, making it difficult to make long flexible wires.

A magnet is placed above a disk of high-T_c material. After liquid nitrogen is poured on the disk, the disk becomes superconducting and the magnet floats above the high-T_c superconducting disk. See the YouTube link: https://www.youtube.com/watch?v=l0jEbWfFAXU for video clip. This technique has been used to float Sumo wrestlers. We want to explain why a magnet floats on top of superconductors.

a. Assume a permanent magnet oriented as shown. What is the direction of magnetic field due to the permanent magnet through the superconductor?

Down



b. A superconductor actively excludes magnetic fields from its interior (Meissner effect). Therefore there must be a current induced in the superconductor to create a magnetic field to cancel out any external magnetic field. What is the direction of the induced current in the superconductor (out at the left, in at the right or in at the left, out at the right) required to cancel out the magnetic field due to the magnet?

in left out right

c. Since we have an induced current loop in the superconductor, the superconductor will act like a magnet. Which end is the north pole of the superconductor?

top

Since the resistance is zero, there is no energy lost and this current will continue until something is changed (magnet is moved or the superconductor is heated above superconducting temperature.)

d. Why does the magnet float on top of the superconductor?

They both have fields in opposite directions so they repel each other.