Name: ______________________

Class: ______________________

Due Date: ______________________

D.1 Gravitational Fields

Understandings

- Kepler's three laws of orbital motion.
- Newton's universal law of gravitation as given by $F = \frac{Gm_1m_2}{r^2}$ for bodies treated as point masses.
- Conditions under which extended bodies can be treated as point masses.
- Gravitational field strength g at a point is the force per unit mass experienced by a small point mass at that point as given by $g = \frac{F}{m} = G\frac{M}{r^2}$.
- Gravitational field lines.

Equations

$$F = \frac{Gm_1m_2}{r^2}$$

$$g = \frac{F}{m} = G\frac{M}{r^2}$$

Additional HL Understandings

- The gravitational potential energy E_p of a system is the work done to assemble the system from infinite separation of the components of the system.
- The gravitational potential energy for a two-body system as given by $E_\mathrm{p} = -G\frac{m_1m_2}{r}$ where r is the separation between the center of mass of the two bodies.
- The gravitational potential V_g at a point is the work done per unit mass in bringing a mass from infinity to that point as given by $V_\mathrm{g} = -G\frac{M}{r}$.
- The gravitational field strength g as the gravitational potential gradient as given by $g = -\frac{\Delta V_\mathrm{g}}{\Delta r}$.
- The work done in moving a mass m in a gravitational field as given by $W = m\Delta V_\mathrm{g}$.

- Equipotential surfaces for gravitational fields.
- The relationship between equipotential surfaces and gravitational field lines.
- The escape speed v_{esc} at any point in a gravitational field as given by $v_{\text{esc}} = \sqrt{\frac{2GM}{r}}$.
- The orbital speed v_{orbital} of a body orbiting a large mass as given by $v_{\text{orbital}} = \sqrt{\frac{GM}{r}}$.
- The qualitative effect of a small viscous drag due to the atmosphere on the height and speed of an orbiting body.

Additional HL Equations

$$E_{\text{p}} = -\frac{Gm_1m_2}{r}$$

$$V_g = -\frac{GM}{r}$$

$$g = -\frac{\Delta V_{\text{g}}}{\Delta r}$$

$$W = m\Delta V_{\text{g}}$$

$$v_{\text{esc}} = \sqrt{\frac{2G}{r}}$$

$$v_{\text{orbital}} = \sqrt{\frac{GM}{r}}$$

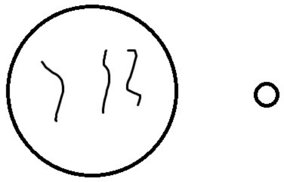
The solutions can be found on the YouTube channel Go Physics Go:

https://www.youtube.com/@gophysicsgo/playlists

1. State the names and describe the laws of Kepler's three laws of orbital motion.

2. Define *Newton's Law of Gravitation* $\vec{F}_g = m_1\vec{g} = \frac{Gm_1m_2}{r^2}$. Units?

3. A satellite in space moves in a circle around the Earth with a constant speed at a radius *r* from the center of the Earth. Label the direction of the velocity, force, and acceleration of the satellite in the diagram below.



4. The force of gravity between a satellite circling the Earth at a distance *r* at a constant speed is F_g. What will happen to the magnitude of the force of gravity between the satellite and the Earth if the satellite moves a distance

   a. 2*r*. b. 3*r*. c. 4*r*. d. *r*/2. e. *r*/3. f. *r*/4.

a.	b.	c.
d.	e.	f.

5. A satellite is moving in a circle with a constant speed around the sun.
   a. Use Newton's second law of motion to obtain an equation for the speed of the satellite in terms of the mass of the sun M_{sun}, the mass of the satellite $M_{\text{satellite}}$, the distance of the satellite to the sun *r*, and the gravitational constant *G*.
   b. Use your solution to obtain an equation for the period *T* of the satellite.

6. The following problem refers to *gravitational field strength*.

   a. Define g*ravitational field strength*. Is it a scalar or a vector?

   b. What is the equation and what are the units for *gravitational field strength*? Define and give the units of each variable.

   c. Where is the *gravitational field strength* zero? Where is the *gravitational field strength* maximum?

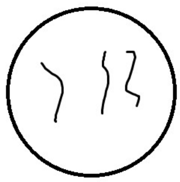
   d. What are the mathematical limits of *gravitational field strength*? Can *gravitational field strength* be positive? Negative? Zero?

7. Draw a *gravitational field strength vs. distance* graph for a planet with a radius *r*.

8. List some rules in drawing gravitational field lines.

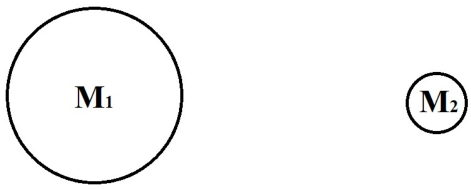
9. **Use a pencil and ruler!** Draw gravitational field lines for each figure.

A fixed uniform spherical mass

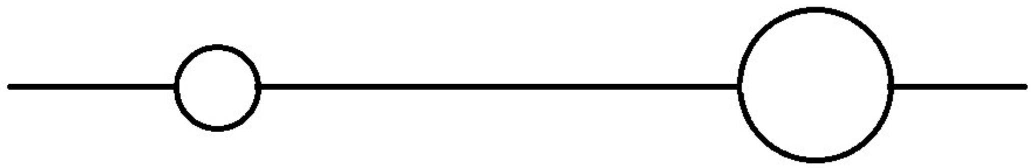


Two uniform spherical masses with equal mass and equal radius

Two fixed uniform spherical masses $M_1 \gg M_2$



10. The center of a planet of mass of $m_1 = 4M$ is a distance of $5d$ from the center of a larger planet of mass $m_2 = 9M$. Assume that the mass of the planets can be concentrated at their centers.



What will be the gravitational field strength (both magnitude and direction) at a point

a. $2d$ to the left of mass m_1?

b. $2d$ to the right of mass m_1?

c. $2d$ to the left of mass m_2?

d. $2d$ to the right of mass m_2?

Additional HL Understandings

11. The following problem refers to *gravitational potential energy* E_P.

    a. Define *gravitational potential energy* E_P. Is it a scalar or a vector?

    b. What is the equation of the *gravitational potential energy* E_P of an object when it is near the surface of a planet? What is the general equation of the *gravitational potential energy* E_P? What is the significance of the negative sign? What are the units of *gravitational potential energy* E_P?

12. The following problem refers to *gravitational potential* V_g.

    a. Define *gravitational potential* V_g. Is it a scalar or a vector?

    b. What is the equation for *gravitational potential* V_g? What are the units of *gravitational potential*?

13. What is the relationship between the gravitational field strength g and gravitational potential V_g?

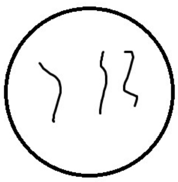
14. What is constant in a *gravitational equipotential surface*?

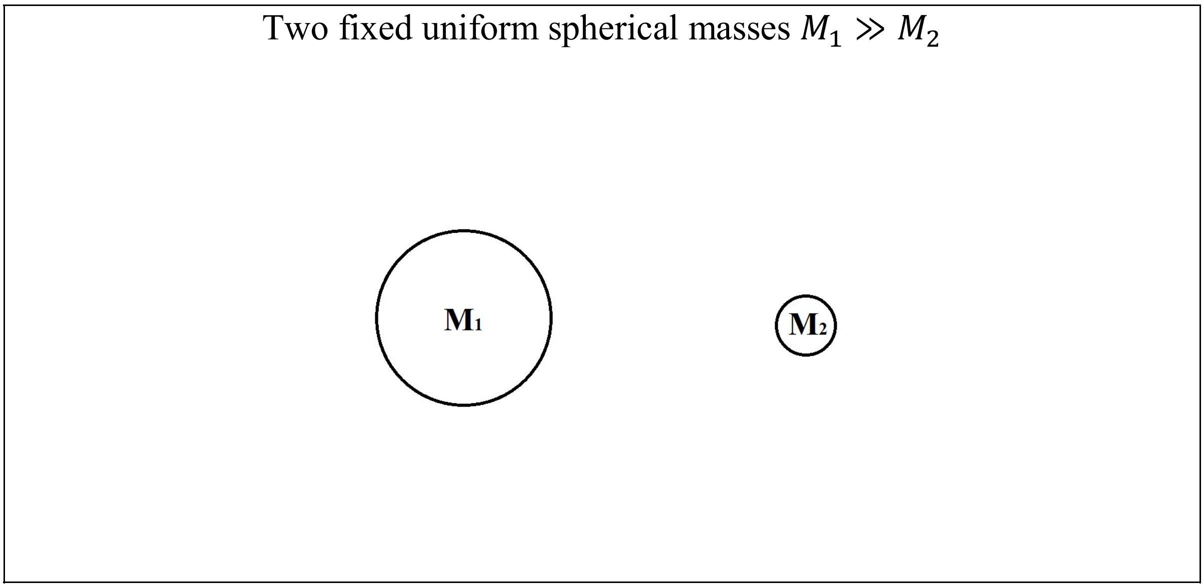
15. How much work is done in moving a mass along the same *equipotential surface*?

16. How much work is done in moving a mass along two different *equipotential surfaces*? State the equation.

17. What is the relationship between an objects *gravitational equipotential surfaces* and *gravitational field lines*?

18. **Use a pencil and ruler!** Draw gravitational field lines and equipotential surfaces for each figure.

A fixed uniform spherical mass	Two uniform spherical masses with equal mass and equal radius
	



19. The following problem refers to *escape speed*.
    a. Define *escape speed*. This is also called *escape velocity*.

    b. What are some assumptions made when defining *escape speed*?

    c. For which objects does *escape speed* apply to?

    d. For which objects does *escape speed* not apply to?

    e. Use the law of conservation of energy $E_{\text{initial}} = E_{\text{final}}$ to solve for the equation of the *escape velocity* of an object leaving the gravitational pull of a planet. What is the minimum speed needed for an object to escape the gravitational pull of the Earth?

20. You might want to derive this equation with your teacher: A planet is orbiting in a circular motion with a constant speed around a star (like the Sun).

a. Use Newton's Law of Gravitation $F_{\text{g}} = m_{\text{planet}} a_{\text{planet}} = \frac{G m_{\text{star}} m_{\text{planet}}}{r^2}$ and the equation for centripetal acceleration $a_{\text{planet}} = \frac{{v_{\text{planet}}}^2}{r}$ to solve for the speed squared ${v_{\text{planet}}}^2$ of a planet moving around a star. Place a box around your answer. In both equations r is the distance from the planet to the star.

b. Take your solution from part a and multiply both sides by $\frac{m_{\text{planet}}}{2}$. This new equation is equal to the kinetic energy of the planet. Place a box around your answer.

c. Substitute your answer from part b to the total energy of the orbiting planet $E_{\text{total}} = KE + GPE = \frac{1}{2} m_{\text{planet}} {v_{\text{planet}}}^2 - \frac{G m_{\text{planet}} m_{\text{star}}}{r}$. Place a box around your answer. Your answer should have only one fraction.

d. Is the total energy positive, negative, or zero? Why?

e. Draw an *energy vs. distance* graph. On this graph draw the kinetic energy vs. distance, potential energy vs. distance, and total energy vs. distance.

21. An object is orbiting a planet. It encounters a small viscous drag due to the atmosphere. Describe the subsequent motion of the object.

22. A rocket with a mass of 64,000 kg is orbiting Jupiter's moon Callisto. Callisto has a radius of 2.40×10^6 m and a mass of 7.35×10^{22} kg.

   a. What would the velocity of the rocket have to be in order for it to orbit Callisto at an altitude of 4,600 km?

   b. What would be the gravitational force between this rocket and Callisto while orbiting at this altitude?

   c. What would be the kinetic energy of this rocket while orbiting Callisto at this altitude?

   d. What would be the gravitational potential energy of this rocket while orbiting Callisto at this altitude?

e. What would be the total energy of this rocket while orbiting Callisto at an altitude of 4,600 km?

f. What would be the total energy of this rocket while sitting at rest on the surface of Callisto?

g. How much kinetic energy would you have to give to this rocket while sitting on the surface of Callisto in order to put the rocket into orbit around Callisto at an altitude of 4,600 km?

h. With what velocity would this rocket have to be launched from the surface of Callisto in order to go into orbit around Callisto at an altitude of 4,600 km?

i. With what velocity would this rocket have to be launched from the surface of Callisto in order for the rocket to escape the gravitational effects of Callisto?

23. A rocket, which has a mass of 38,000 kg, is initially sitting at rest on the surface of the planet Venus. Venus has a radius of 6.05×10^6 m and a mass of 4.87×10^{24} kg.

a. What is the total energy content of this rocket while sitting at rest on the surface of Venus?

b. What velocity would be required for this rocket to orbit Venus at an altitude of 550 km?

c. What total energy is required if this rocket is to orbit Venus at an altitude of 550 km?

d. With what velocity should this rocket be launched from the surface of Venus in order to go into orbit around Venus at an altitude of 550 km?

e. With what minimum velocity should this rocket be launched from the surface of Venus in order to escape the gravitational effects of Venus?

f. What will be the velocity of this rocket when it is very far from Venus if the rocket is launched from the surface of Venus with a velocity of $1.4 \times 10^4\ \frac{\text{m}}{\text{s}}$?

Name: ______________________

Class: ______________________

Due Date: ______________________

D.2 Electric and Magnetic Fields

Understandings

- The direction of forces between the two types of electric charge.
- Coulomb's law as given by $F = k\frac{q_1 q_2}{r^2}$ for charged bodies treated as point charges where $k = \frac{1}{4\pi\varepsilon_0}$.
- The conservation of electric charge.
- Millikan's experiment as evidence for quantization of electric charge.
- The electric charge can be transferred between bodies using friction, electrostatic induction, and by contact, including the role of grounding (earthing).
- The electric field strength as given by $E = \frac{F}{q}$.
- Electric field lines.
- The relationship between field line density and field strength.
- The uniform electric field strength between parallel plates as given by $E = \frac{V}{d}$.
- Magnetic field lines.

Equations

$F = k\frac{q_1 q_2}{r^2}$ where $k = \frac{1}{4\pi\varepsilon_0}$

$E = \frac{F}{q}$

$E = \frac{V}{d}$

Additional HL Understandings
- The electric potential energy E_p in terms of work done to assemble the system from infinite separation.
- The electric potential energy for a system of two charged bodies as given by $E_\mathrm{p} = k\frac{q_1 q_2}{r}$.
- The electric potential is a scalar quantity with zero defined at infinity.
- The electric potential V_e at a point is the work done per unit charge to bring a test charge from infinity to that point as given by $V_\mathrm{e} = \frac{kQ}{r}$.
- The electric field strength E as the electric potential gradient as given by $E = -\frac{\Delta V_\mathrm{e}}{\Delta r}$.
- The work done in moving a charge q in an electric field as given by $W = q\Delta V_\mathrm{e}$.
- Equipotential surfaces for electric fields.
- The relationship between equipotential surfaces and electric field lines.

Additional HL Equations

$$E_\mathrm{p} = k\frac{q_1 q_2}{r}$$

$$V_\mathrm{e} = \frac{kQ}{r}$$

$$E = -\frac{\Delta V_\mathrm{e}}{\Delta r}$$

$$W = q\Delta V_\mathrm{e}$$

If you are interested in learning more about electricity and magnetism then please read the book *Electricity and Magnetism* by Edward M. Purcell and David J. Morin.

Important! ***Electric potential*** **and** ***electric potential energy*** **are not the same! Compare the definitions, equations, and units!**

The solutions can be found on the YouTube channel Go Physics Go:

https://www.youtube.com/@gophysicsgo/playlists

Part 1: Use your favorite sources to answer the following questions

1. What is *charge q*? Units?

2. What is the difference between an *electrical conductor* and an *electrical insulator*? Give two examples of each.

3. Two charged objects with the same charge will ______ each other while two charged objects with the opposite charge will ______ each other.

4. State the charge, in Coulombs, of each particle:

   a. Neutron

   b. Proton

   c. Electron

5. There is a metal sphere which has a net positive charge.
   a. Is there any negative charge in it?

   b. Where does the extra positive charge go?

6. Define and give the units of each variable in *Coulomb's Law* $\vec{F}_{\text{electric}} = k\frac{q_1 q_2}{r^2}$. What is the minimum number of objects required to use *Coulomb's law*?

7. Define relative permittivity ε_{r}.

8. State the law of *conservation of charge*.

9. A pith ball, which has a residual charge of -36 μC, is brought into contact with a second, identical pith ball which is initially neutral, allowing charge to flow between them. These two balls are then separated. What will be the final residual charge on each pith ball?

10. A pith ball, which has a residual charge of +54 μC, is brought in contact with a second identical pith ball which has an initial residual charge of -38 μC. What will be the final residual charge on each pith ball after they have been separated?

11. A pith ball, which has a residual charge of +66 μC, is brought in contact with a second pith ball which has an initial residual charge of -33 μC and which has twice the surface area of the first pith ball. What will be the final residual charge on each pith ball after they have been separated?

12. Explain the meaning of charge being quantized.

13. Give an example of how two objects can transfer electric charge by
    a. friction:

    b. electrostatic induction:

    c. contact:

    d. grounding/earthing:

14. Define *electric field strength* $\vec{E} = \frac{\vec{F}}{q} = k\frac{q_1}{r^2}$. What is the minimum number of objects required to use the equation for *electric field strength*?

15. Draw a graph of electric field vs. distance of a positively charged solid sphere.

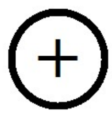
16. Define *electric potential difference*. Units?

17. What are the units of *voltage*?

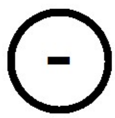
18. Define *electron-volt*.

19. List some rules for drawing electric field lines.

20. **Use a pencil and ruler!** Draw electric field lines for each figure.
    a. An isolated positive charge.



    b. An isolated negative charge.



c. A positive charge and a negative charge with equal magnitudes of charge.

d. Two positive charges with the same magnitude.

21. **Use a pencil and ruler!**

a. Draw charged *parallel plates*.

b. Draw (and label) six electric field lines between the parallel plates.

c. If a positive charge is placed between the plates then in which direction will it accelerate?

d. If a negative charge is placed between the plates then in which direction will it accelerate?

e. Which variable is constant between charged parallel plates?

f. Define each variable for the equation for parallel plates $V = Ed$.

22. List some differences between the electric force and the magnetic force.

23. What are two situations in which magnetic fields are observed?

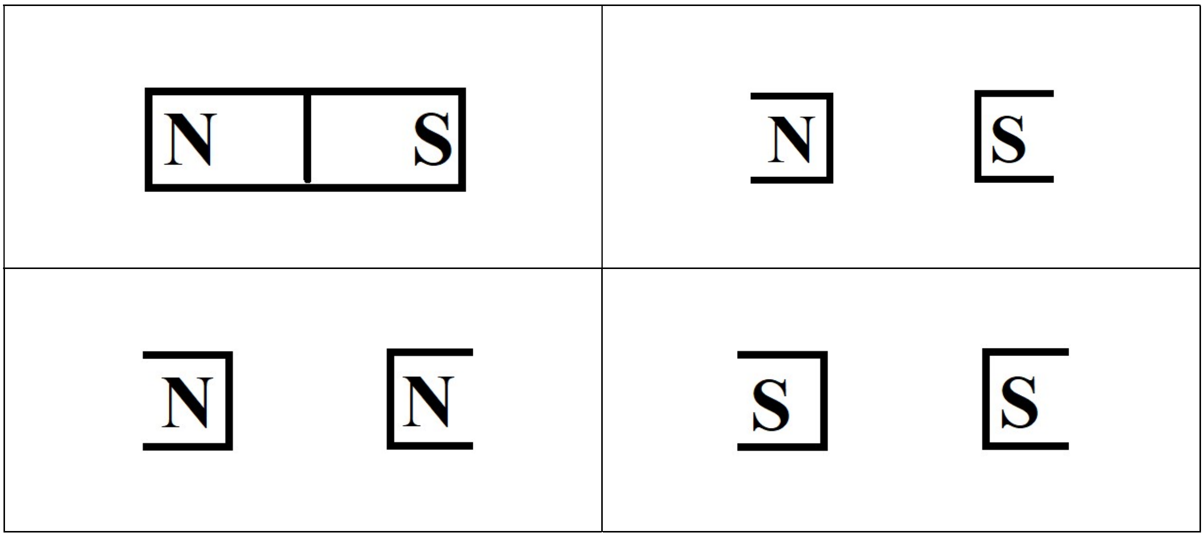
24. List some metals which have magnetic properties.

25. Define *hard magnet*. Define *soft magnet*.

26. How can you demagnetize a magnet?

27. Give some rules for drawing magnetic field lines.

28. **Use a pencil and ruler!** For each figure draw six magnetic field lines with arrows.



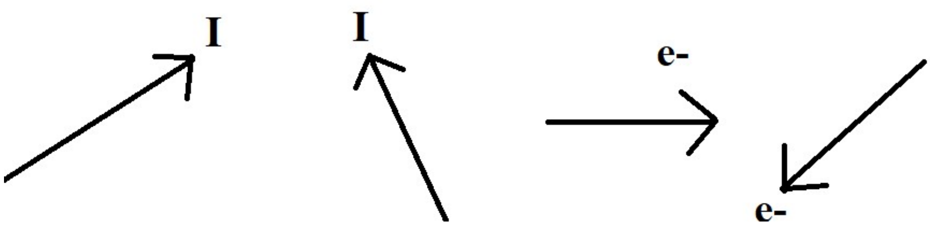
29. Draw and label the Earth's magnetic north pole (MN), magnetic south pole (MS), geographic north pole (GN), and geographic south pole (GS). Draw four magnetic field lines with arrows.

30. What are some differences between magnetic field lines and electric field lines?

31. What is a *magnetic monopole*? Where in the universe can we find a *magnetic monopole*?

32. Draw the symbols for an axis going into the page and out of the page.

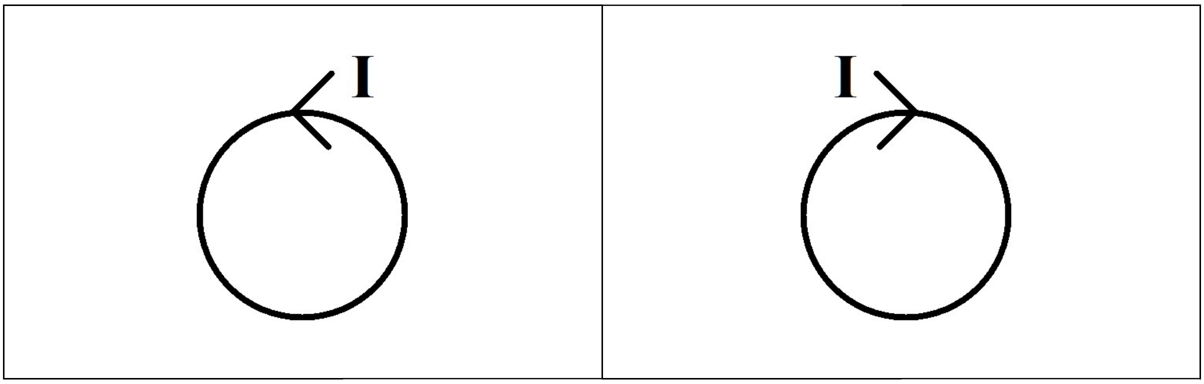
33. **Use a pencil!** Draw magnetic field lines for each current carrying wire.



34. **Use a pencil!** Describe and draw a *solenoid*. Use the right hand rule to draw magnetic field lines and the poles.

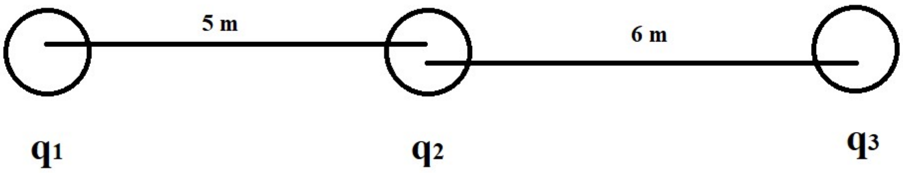
35. State three ways we can we increase the magnetic field inside a solenoid.

36. Draw magnetic field lines in a circular current carrying loop.



37. Use Coulomb's law to calculate the electric force on a point charge.

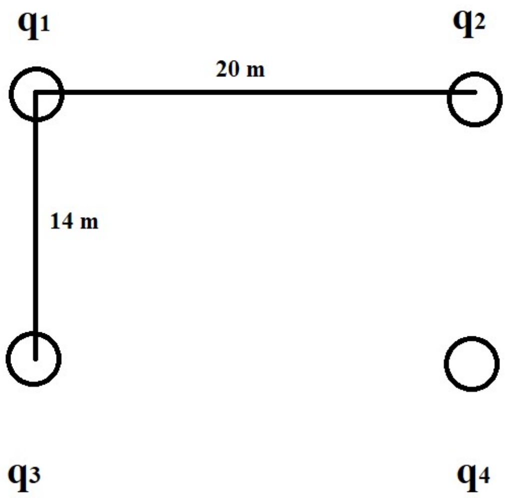
$q_1 = +2 \times 10^{-9}$ C	$q_2 = -3 \times 10^{-9}$ C	$q_3 = +4 \times 10^{-9}$ C



a. q_1 and q_2 are fixed. Find the force on q_3.
b. q_1 and q_3 are fixed. Find the force on q_2.
c. q_2 and q_3 are fixed. Find the force on q_1.

38.Use Coulomb's law to calculate the electric force on a point charge.

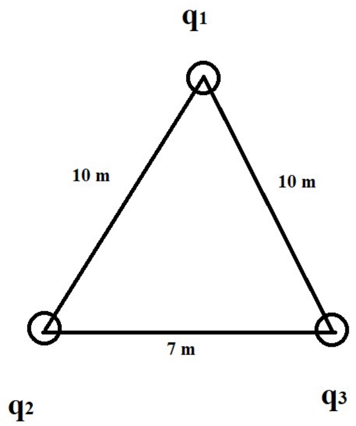
$q_1 = +2 \times 10^{-9}$ C	$q_2 = -3 \times 10^{-9}$ C
$q_3 = -4 \times 10^{-9}$ C	$q_4 = +5 \times 10^{-9}$ C



a. q_1, q_2, and q_3 are fixed. Find the force on q_4.
b. q_1, q_2, and q_4 are fixed. Find the force on q_3.
c. q_1, q_3, and q_4 are fixed. Find the force on q_2.
d. q_2, q_3, and q_4 are fixed. Find the force on q_1.

39.Use Coulomb's law to calculate the electric force on a point charge.

$q_1 = +2 \times 10^{-9}$ C	$q_2 = -3 \times 10^{-9}$ C	$q_3 = -3 \times 10^{-9}$ C



Additional HL Content

40. The following problem refers to *electric potential energy* E_P. This is also called *electrostatic potential energy* E_P.

    a. Define *electric potential energy* E_P. Is it a scalar or a vector?

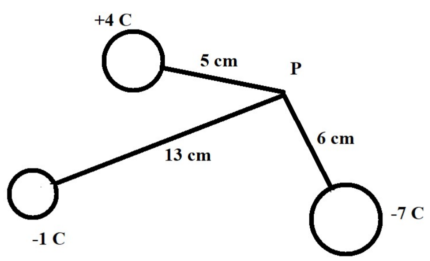
    b. What is the equation for *electric potential energy* E_P? Units?

41. The following problem refers to *electric potential* V_e. This is also called *electrostatic potential.*

    a. Define *electric potential* V_e. Is it a scalar or a vector?

    b. What is the equation for *electric potential*? Units?

    c. Determine the electric potential at point P in the figure below:



42. Draw a graph of *electric potential vs. distance* of a positively charged solid sphere.

43. The following problem refers to *electric field strength E*. This is also called *electrostatic field strength*.

   a. Define *electric field strength E*. Is it a scalar or a vector?

   b. What is the equation and what are the units for *electric field strength*? Define each variable.

   c. Where is the *electric field strength* zero? Where is the *electric field strength* maximum?

   d. What are the mathematical limits of *electric field strength*? Can *electric field strength* be positive? Negative? Zero?

   e. What is the relationship between the *electric field strength* and *electric potential*?

44. The following problem refers to *equipotential surfaces*.

    a. What is an *equipotential surface*?

    b. How much work is done in moving a charge along the same *equipotential surface*?

    c. How much work is done in moving a charge along a different *equipotential surface*? State the equation.

45. What is the relationship between an objects *equipotential surfaces* and *electric field lines*?

46. Draw a spherical negative charge and a spherical positive charge, both with equal magnitudes of charge and volume, with *electric field lines* and *equipotential surfaces*.

47. Draw two spherical negative charges, both with equal magnitudes of charge and volume, with *electric field lines* and *equipotential surfaces*.

48. Draw *electric field lines* and *equipotential surfaces* between parallel plates with an equal and opposite charge. For parallel plates remember the equations $W = Fd = q\Delta V$ and $V = Ed$.

Name: ______________________

Class: ______________________

Due Date: ______________________

D.3 Motion in Electromagnetic Fields

Understandings

- The motion of a charged particle in a uniform electric field.
- The motion of a charged particle in a uniform magnetic field.
- The motion of a charged particle in perpendicularly oriented uniform electric and magnetic fields.
- The magnitude and direction of the force on a charge moving in a magnetic field as given by $F = qvB\sin\theta$.
- The magnitude and direction of the force on a current-carrying conductor in a magnetic field as given by $F = BIL\sin\theta$.
- The force per unit length between parallel wires as given by $\frac{F}{L} = \mu_0 \frac{I_1 I_2}{2\pi r}$.

Equations

$F = qvB\sin\theta$

$F = BIL\sin\theta$

$\frac{F}{L} = \mu_0 \frac{I_1 I_2}{2\pi r}$

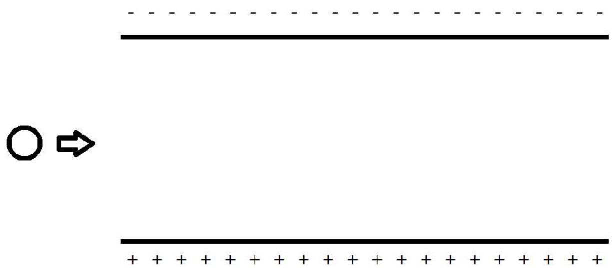
If you are interested in learning more about electricity and magnetism then please read the book *Electricity and Magnetism* by Edward M. Purcell and David J. Morin.

The solutions can be found on the YouTube channel Go Physics Go:

https://www.youtube.com/@gophysicsgo/playlists

Part 1: Use your favorite sources to answer the following questions

1. A proton, which has a mass of 1.67×10^{-27} kg and a charge of 1.6×10^{-1} C, is moving with a velocity of $5.6 \times 10^{6}\ \frac{\mathrm{m}}{\mathrm{s}}$ from left to right into a uniform electric field as shown in the figure below. The electric field has a magnitude of 560,000 N/C and is directed upward.



a. What will be the direction and magnitude of the gravitational force acting on this proton?

b. What will be the direction and magnitude of the electrostatic force acting on this proton?

c. What will be the direction and magnitude of the net force acting on the proton?

d. What will be the direction and magnitude of the acceleration of this proton?

e. What will be the velocity of this proton 1.25 microseconds after entering the electric field?

f. What will be the displacement of this proton 1.25 microseconds after entering the electric field?

2. Compare the following equations of force: Newton's Law of Gravitation, Coulomb's Law, and the magnetic force.

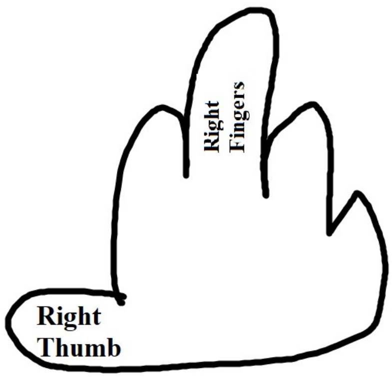
$\vec{F}_{\text{gravity}} = m_1\vec{g} = \frac{Gm_1m_2}{r^2}$ $\vec{F}_{\text{electric}} = q_1\vec{E} = \frac{kq_1q_2}{r^2}$ $\vec{F}_{\text{magnetic}} = q\vec{v} \times \vec{B}_{\text{external}}$ $= q\vec{v}\vec{B}_{\text{external}} \sin\theta$	a. Which force equations look similar to each other? What do they have in common? b. Which force equations look different from each other? What do they not have in common?

3. List some differences between the electric force and the magnetic force.

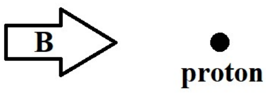
4. What are the units for the magnetic field $\vec{B}$?

5. Use the equation $\vec{F}_{\text{B}} = q\vec{v} \times \vec{B}_{\text{external}}$ with the right hand rule to find the direction of the magnetic force of the charged object.

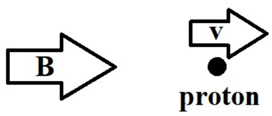
http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/magfor.html

 $\vec{F}_{\text{B}} = q\vec{v} \times \vec{B}_{\text{external}}$	Step 1: Put your fingers from your right hand in the direction of qv. Step 2: Bend your fingers in the direction of the external magnetic field. Step 3: Your thumb points in the direction of the magnetic force. Note: If the charged object has a negative charge then just switch the direction of the answer. Please see the examples below!

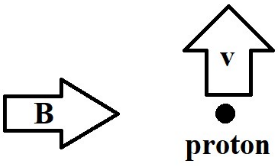
a. A proton is at rest. A magnetic field with constant magnitude points to the right. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



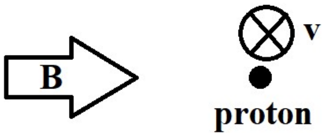
b. A proton moves to the right with a constant speed. A magnetic field with constant magnitude points to the right. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



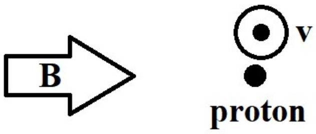
c. A proton moves up with a constant speed v. A magnetic field with constant magnitude points to the right. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



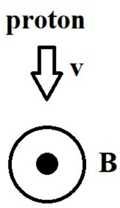
d. A proton moves into the page with a constant speed v. A magnetic field with constant magnitude points to the right. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



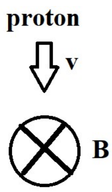
e. A proton moves out of the page with a constant speed v. A magnetic field with constant magnitude points to the right. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



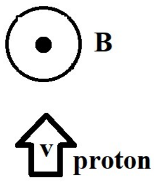
f. A proton moves down with a constant speed v. A magnetic field with constant magnitude points out of the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



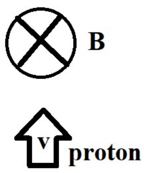
g. A proton moves down with a constant speed v. A magnetic field with constant magnitude points into the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



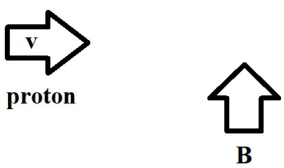
h. A proton moves up with a constant speed v. A magnetic field with constant magnitude points out of the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



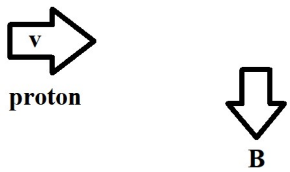
i. A proton moves up with a constant speed v. A magnetic field with constant magnitude points into the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



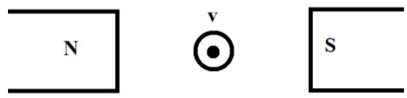
j. A proton moves to the right with a constant speed v. A magnetic field with constant magnitude points up. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



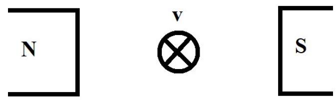
k. A proton moves to the right with a constant speed v. A magnetic field with constant magnitude points down. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



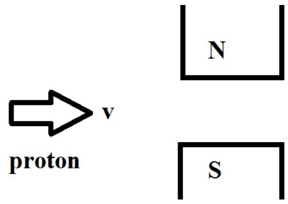
l. A proton moves out of the page with a constant speed v. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



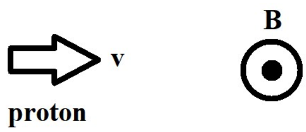
m. A proton moves into the page with a constant speed v. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



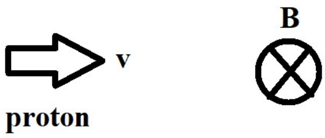
n. A proton moves to the right with a constant speed v. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



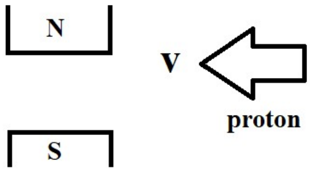
o. A proton moves to the right with a constant speed v. A magnetic field with constant magnitude points out of the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



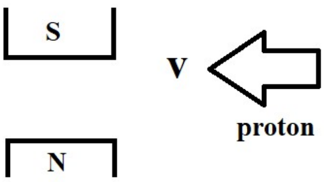
p. A proton moves to the right with a constant speed v. A magnetic field with constant magnitude points into the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



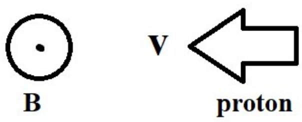
q. A proton is moving to the left with a constant speed v. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



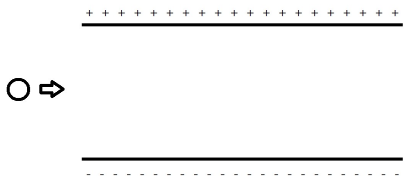
r. A proton is moving to the left with a constant speed v. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



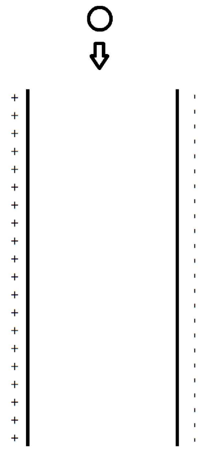
s. A proton is moving to the left with a constant speed v. A magnetic field with constant magnitude points out of the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



6. A proton is moving horizontally to the right. It enters a region between a uniform external electric field as shown below. Which direction should the external magnetic field point if the proton is to move to the right without deflection?

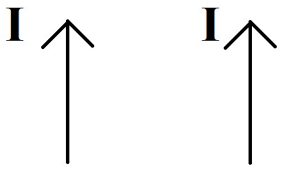


7. A proton is moving vertically downwards. It enters a region between a uniform external electric field as shown below. Which direction should the external magnetic field point if the proton is to move down without deflection?

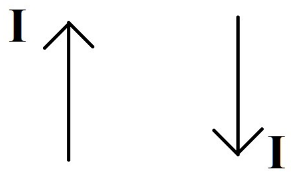


8. Determine an equation for the charge to mass ratio for a charged particle entering a uniform magnetic field.

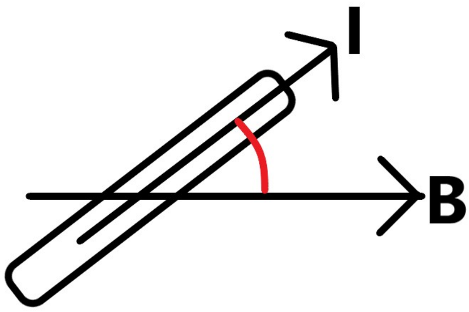
9. Use the equation $\vec{F}_{\mathrm{B}} = I\vec{l} \times \vec{B}_{\mathrm{ext}}$ and the right hand rule to determine if parallel wires with current moving in the same direction will *attract* or *repel*.



10. Use the equation $\vec{F}_B = I\vec{l} \times \vec{B}_{\mathrm{ext}}$ and the right hand rule to determine if parallel wires with current moving in opposite directions will *attract* or *repel*.



11.Describe the equation $F = BIL\sin\theta$ for a current carrying wire.



12.Describe the equation $\frac{F}{L} = \mu_0 \frac{I_1 I_2}{2\pi r}$ for two parallel current carrying wires.

Name: ______________________

Class: ______________________

Due Date: ______________________

D.4 Induction

Additional HL Understandings

- Magnetic flux Φ as given by $\Phi = BA\cos\theta$.
- A time-changing magnetic flux induces an emf ε as given by Faraday's law of induction $\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$.
- A uniform magnetic field induces an emf in a straight conductor moving perpendicularly to it as given by $\varepsilon = Bvl$.
- The direction of induced emf is determined by Lenz's law and is a consequence of energy conservation.
- A uniform magnetic field induces a sinusoidal varying emf in a coil rotating within it.
- The effect on induced emf caused by changing the frequency of rotation.

Additional HL Equations

$\Phi = BA\cos\theta$

$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$

$\varepsilon = BvL$

The solutions can be found on the YouTube channel Go Physics Go:

https://www.youtube.com/@gophysicsgo/playlists

Part 1: Use your favorite sources to answer the following questions

1. Define *induction* and *induce*.

2. What are the units of *electromotive force* ε?

3. True or false: *Electromotive force* ε is a force.

4. Define *flux*. Draw a picture.

5. *Magnetic flux* is defined as $\Phi = BA\cos\theta$. Define and give the units of each variable. Draw an image showing *magnetic flux* and label theta θ in the image. Also draw an image of magnetic flux when $\theta = 0°$ and when $\theta = 90°$.

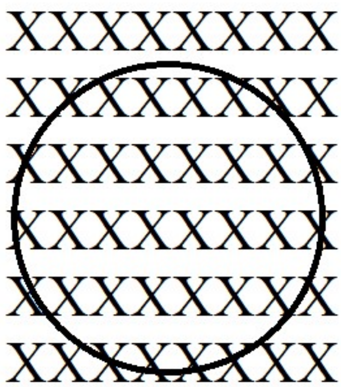
6. Use words to define and describe *Faraday's Law* $\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$. Draw a picture if you have to.

7. The negative sign in *Faraday's Law* is known as *Lenz's Law*. What does it mean?

8. Use *Lenz's law* and the right hand rule to determine the direction of the induced current on the metal conducting wire.

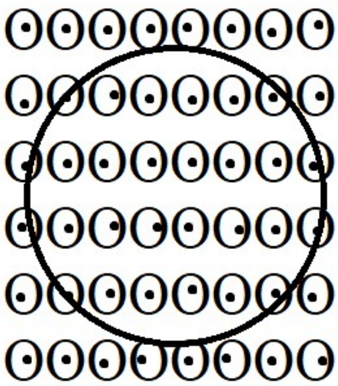
a. There is a magnetic field which points into the page. The magnitude of the magnetic field is

i. decreasing.
ii. constant.
iii. increasing.



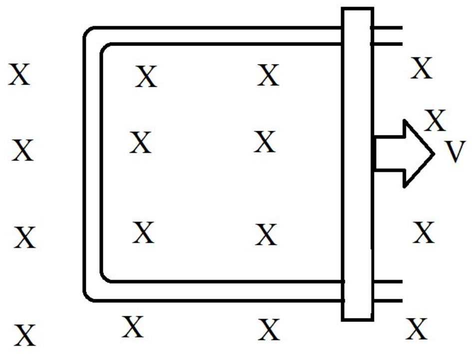
b. There is a magnetic field which points out the page. The magnitude of the magnetic field is

i. decreasing.
ii. constant.
iii. increasing.

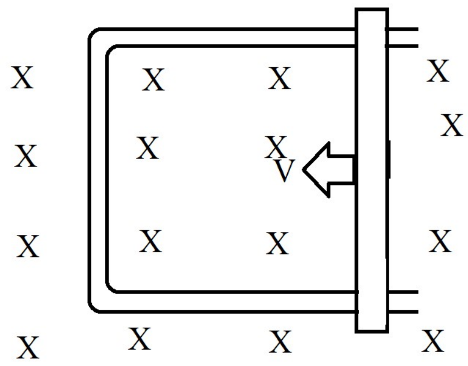


c. There is a constant magnetic field into the page. Which direction is the induced current?

i. The area of the loop is increasing.

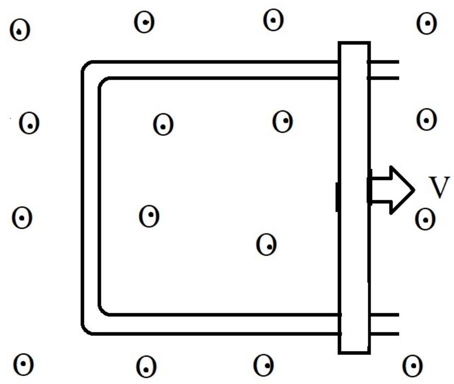


ii. The area of the loop is decreasing.

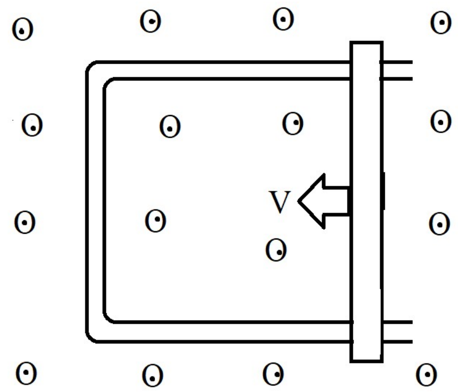


d. There is a constant magnetic field out of the page.

i. The area of the loop is increasing.

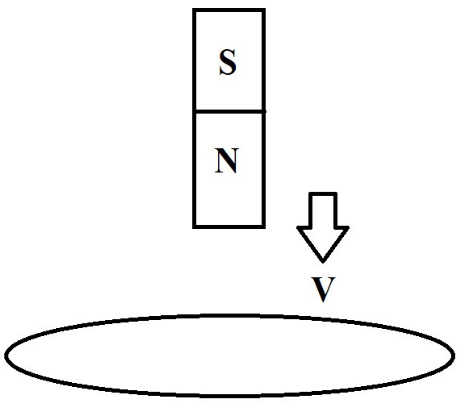


ii. The area of the loop is decreasing.

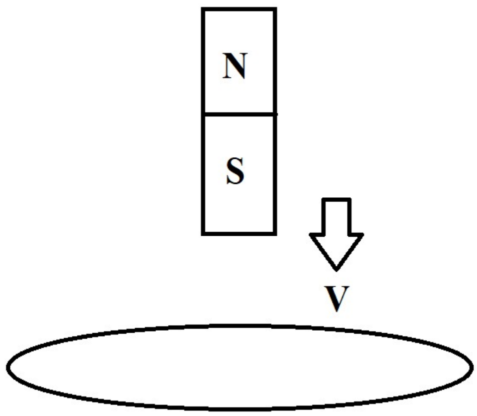


e. A magnet is falling down and entering a loop. Which direction is the induced current if we are looking downwards?

i. The north pole is facing downwards.

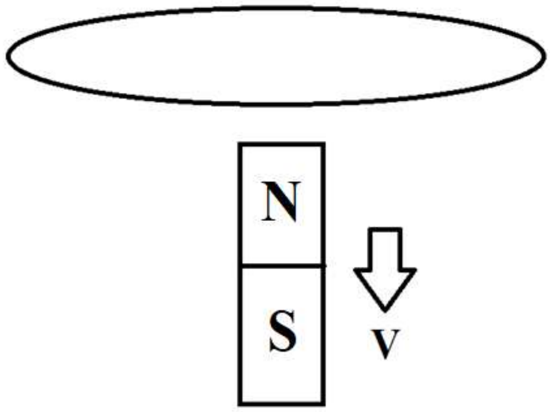


ii. The south pole is facing downwards.

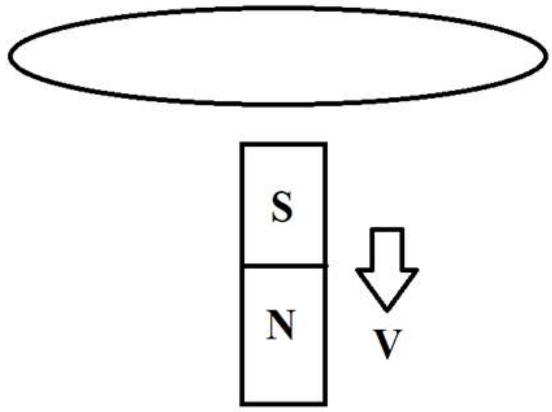


f. A magnet is falling down and leaving a loop. Which direction is the induced current if we are looking downwards?

i. The north pole is facing upwards.

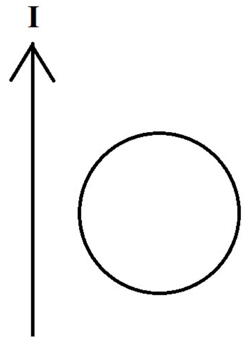


ii. The south pole is facing upwards.



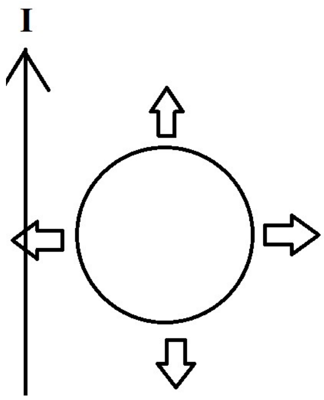
g. There is a current carrying straight wire. There is a circular wire next to it. The current in the straight wire is

i. decreasing.
ii. constant.
iii. increasing.



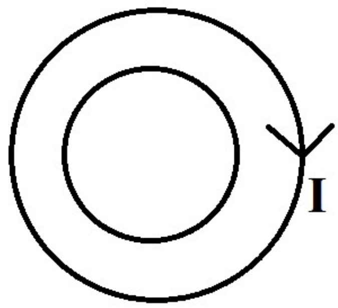
h. There is a current carrying straight wire. There is a circular wire next to it. The circular wire

i. moves up parallel to the wire.
ii. moves down parallel to the wire.
iii. moves to the left perpendicular to the wire.
iv. moves to the right perpendicular to the wire.



i. A small loop of wire is inside a larger loop of wire. The larger loop of wire has a constant current clockwise. What is the direction of the induced current of the smaller loop if the current of the larger loop is

i. decreasing.
ii. constant.
iii. increasing.



9. What happens to a magnet if it falls down a hollow metal cylinder? Why?

10. Describe the equation $\varepsilon = BvL$.

11. Draw an *emf vs. time* graph of a conducting loop rotating in the presence of an external magnetic field with a frequency of f and $2f$.

12. Define *self-induction*.