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.

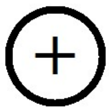
16. Define *electric potential difference*. Units?

17. What are the units of *voltage*?

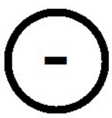
18. Define *electron-volt*.

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?

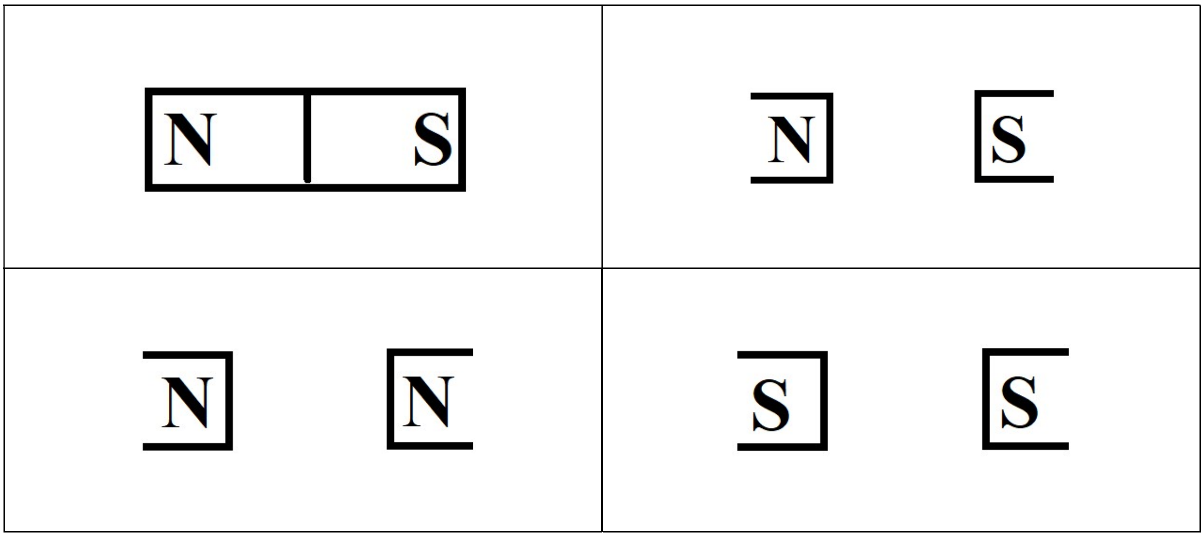
24. List some metals which have magnetic properties.

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.



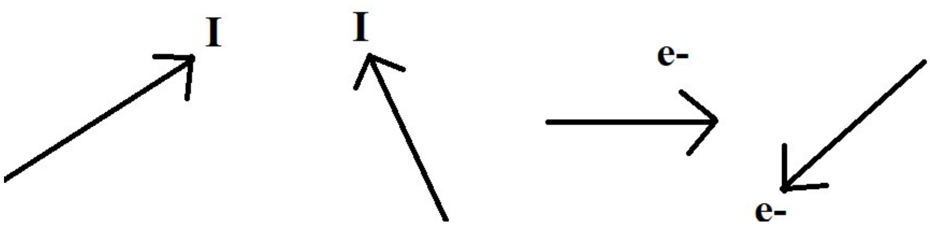
29. Draw and label the Earth's magnetic north pole (MN), magnetic south pole (MS), geographic north pole (GN), and geographic south pole (GS). Draw four magnetic field lines with arrows.

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.

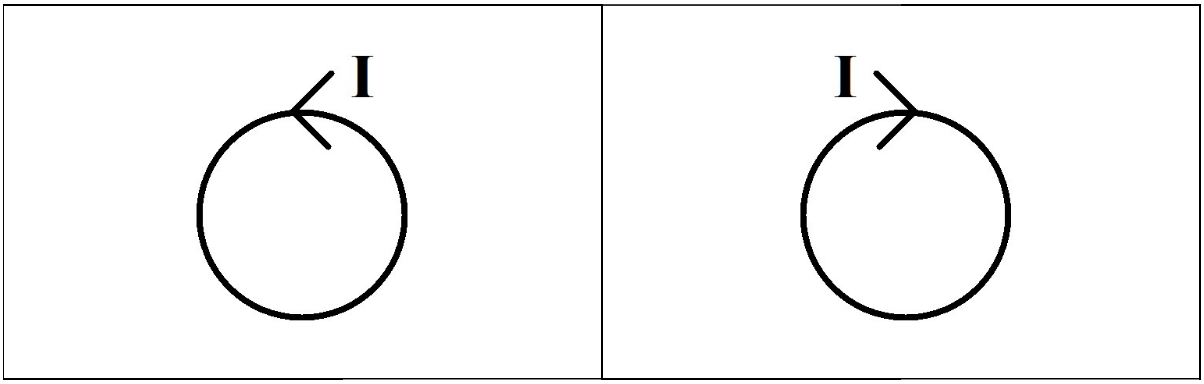
33. **Use a pencil!** Draw magnetic field lines for each current carrying wire.



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

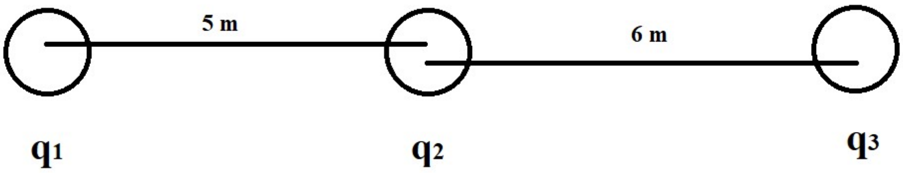
35. State three ways we can we increase the magnetic field inside a solenoid.

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.

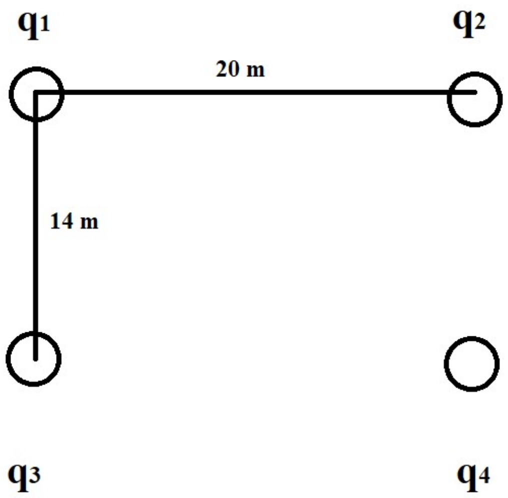
$q_1 = +2 \times 10^{-9}$ C	$q_2 = -3 \times 10^{-9}$ C	$q_3 = +4 \times 10^{-9}$ C



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.

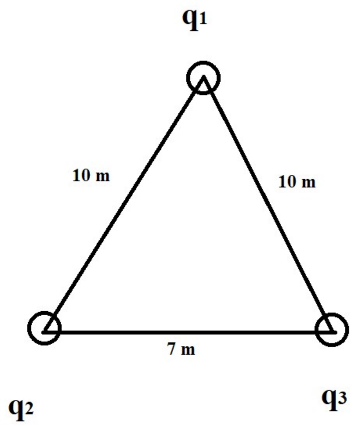
$q_1 = +2 \times 10^{-9}$ C	$q_2 = -3 \times 10^{-9}$ C
$q_3 = -4 \times 10^{-9}$ C	$q_4 = +5 \times 10^{-9}$ C



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?

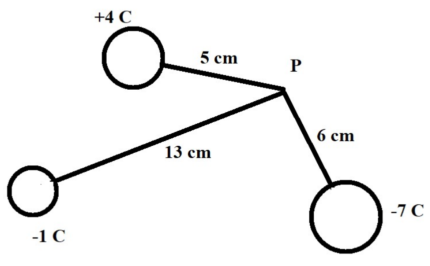
    b. What is the equation for *electric potential energy* E_P? Units?

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 $V = Ed$.