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 $E_p = -G\frac{m_1m_2}{r}$ 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 $V_g = -G\frac{M}{r}$.
- The gravitational field strength g as the gravitational potential gradient as given by $g = -\frac{\Delta V_g}{\Delta r}$.
- The work done in moving a mass m in a gravitational field as given by $W = m\Delta V_g$.

- 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

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

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

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

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

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

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

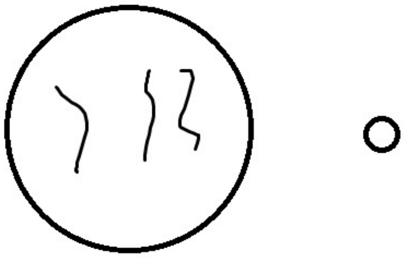
The solutions can be found on the YouTube channel Go Physics Go:

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

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

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

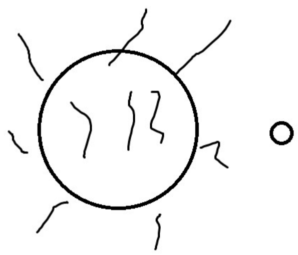
3. C: A satellite in space moves in a circle around the Earth with a constant speed at a radius *r* from the center of the Earth. Label the direction of the velocity, force, and acceleration of the satellite in the diagram below.



4. E: 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.

5. C: 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. E: The mass of the Sun is approximately 1.99×10^{30} kg. The Earth is approximately 1.50×10^{11} m from the Sun. Use this information to determine

   a. the speed of the Earth in m/s and

   b. the period of the Earth in days.

7. E: A satellite, which has a mass of 550. kg and a radius of 2.20 meters, is orbiting the Earth at an altitude of 375 km.

   a. What will be the magnitude of the gravitational force between this satellite and the Earth?

   b. What must the velocity of this satellite be in order for the satellite to remain in a stable orbit?

   c. What will be the magnitude of the centripetal acceleration of this satellite?

   d. How long, in seconds, will it take for this satellite to orbit the Earth once?

8. C: 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?

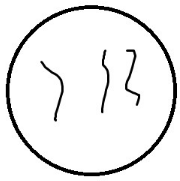
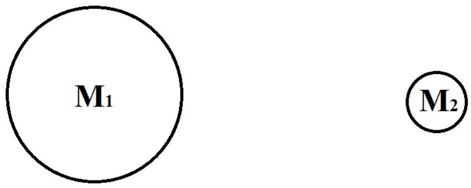
d. What are the mathematical limits of *gravitational field strength*? Can *gravitational field strength* be positive? Negative? Zero?

9. E: The mass of the Earth is approximately 5.97×10^{24} kg and its radius is approximately 6.38×10^{6} m. Use the equation $g = \frac{GM}{r^2}$ to determine the acceleration of gravity near the Earth's surface.

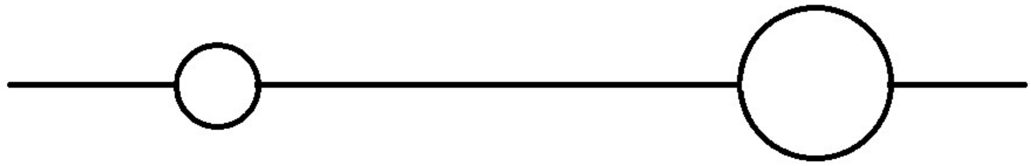
10. C: Draw a *gravitational field strength vs. distance* graph for a planet with a radius *r*.

11. C: List some rules in drawing gravitational field lines.

12.C: **Use a pencil and ruler!** Draw gravitational field lines for each figure.

<table>
<tr><td>A fixed uniform spherical mass
</td><td>Two uniform spherical masses with equal mass and equal radius
</td></tr>
<tr><td colspan="2">Two fixed uniform spherical masses $M_1 \gg M_2$
</td></tr>
</table>

13.E: 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?

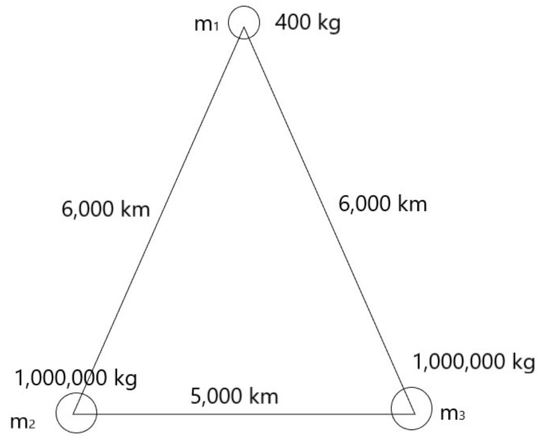
b. $2d$ to the right of mass m_1?

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

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

14. E: Earth has a mass of approximately 5.97×10^{24} kg while Mars has a mass of approximately 6.42×10^{23} kg. Both planets are separated by approximately 2.28×10^{8} km and can be taken to be point particles. How many meters from Mars does a 3.00×10^{3} kg white rhino have to be placed to feel no force?

15.E: A rock in space, which is initially at rest, has a mass $m_1 = 400.$ kg and is 6.00×10^3 km away from two fixed rocks, each with a mass of 1.00×10^6 kg, as shown in the image below. What is the acceleration of m_1 at the moment when it is released from rest?



Additional HL Understandings

16.C: 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?

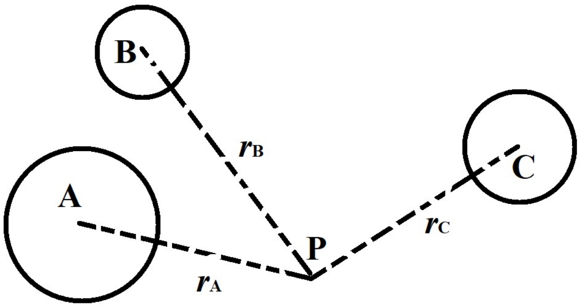
17.E: What will be the gravitational potential energy of a 5.20×10^5 kg rocket orbiting Saturn at an altitude of 1.00×10^4 km? Saturn has a mass of approximately 5.68×10^{26} kg and a radius of approximately 6.00×10^7 m.

18.C: 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*?

19.E: Determine the gravitational potential at point P from three massive objects.



$m_A = 8.67 \times 10^{15}$ kg
$m_B = 5.30 \times 10^{15}$ kg
$m_C = 9.36 \times 10^{15}$ kg
$r_A = 2.70 \times 10^3$ m
$r_B = 1.30 \times 10^3$ m
$r_C = 6.50 \times 10^3$ m

20.C: What is the relationship between the gravitational field strength g and gravitational potential V_g?

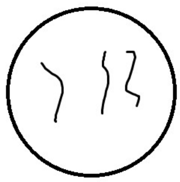
21.C: What is constant in a *gravitational equipotential surface*?

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

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

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

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

<table>
<tr>
<td>A fixed uniform spherical mass
</td>
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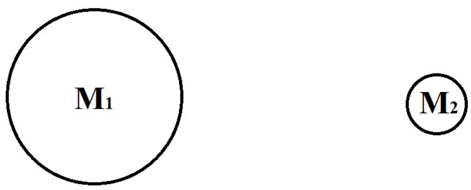
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26.C: The following problem refers to *escape speed*.

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 speed* 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?

27.C: 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 $F_{\mathrm{g}} = m_{\mathrm{planet}} a_{\mathrm{planet}} = \frac{G m_{\mathrm{star}} m_{\mathrm{planet}}}{r^2}$ and the equation for centripetal acceleration $a_{\mathrm{planet}} = \frac{{v_{\mathrm{planet}}}^2}{r}$ to solve for the speed squared ${v_{\mathrm{planet}}}^2$ 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 $\frac{m_{\mathrm{planet}}}{2}$. 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 $E_{\mathrm{total}} = E_{\mathrm{k}} + E_{\mathrm{g}} = \frac{1}{2} m_{\mathrm{planet}} {v_{\mathrm{planet}}}^2 - \frac{G m_{\mathrm{planet}} m_{\mathrm{star}}}{r}$. 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.

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

29.E: A rocket with a mass of 6.40×10^4 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 4.60×10^3 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 4.60×10^3 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 4.60×10^3 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 4.60×10^3 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?

30.E: A rocket, which has a mass of 3.80×10^4 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 $1.40 \times 10^4\ \frac{\text{m}}{\text{s}}$?

31.E: A rocket, which has a mass of 6.40×10^4 kg, is sitting on the surface of Neptune. Neptune has a mass of approximately 1.03×10^{26} kg and a radius of approximately 2.43×10^7 m. This rocket is to be launched from Neptune's surface with the intention of going into orbit around the planet Neptune at an altitude of 1.00×10^4 km.

a. With what minimum velocity should this rocket be launched from Neptune's surface in order to go into orbit around Neptune at the given altitude?

b. What will be the total energy content of this rocket while orbiting Neptune at the given altitude?

c. How much kinetic energy must be added to this orbiting rocket if it is to escape the gravitational effects of Neptune?

d. What velocity must this orbiting rocket attain in order for it to escape the gravitational effects of Neptune?

e. Suppose that somehow the planet Neptune were to change into a black hole. What would the maximum radius of Neptune have to be in order for it to become a black hole? This is not in the IB physics syllabus.

32.E: A 3.20×10^4 kg rocket is orbiting the planet Jupiter at an altitude of 2.00×10^4 km. Jupiter has a mass of approximately 1.90×10^{27} kg and a radius of approximately 7.14×10^7 m.

a. What is the velocity of this rocket while orbiting Jupiter at this altitude?

b. What is the total energy content of this rocket while orbiting at this altitude?

c. How much additional energy must this rocket acquire in order to leave orbit and escape the gravity of Jupiter?

d. Suppose that this orbiting rocket is given an additional 3.20×10^{13} J of energy. What will be the resulting velocity of this rocket when it is very far from Jupiter?

e. What would the maximum radius of Jupiter have to be if it was to become a black hole? This is not in the IB physics syllabus.

33.E: A rocket, which has a mass of 1.80×10^{4} kg, is moving through space with a velocity of $1.25 \times 10^{4}\ \frac{\text{m}}{\text{s}}$ when it begins its approach to Saturn. This rocket would like to go into orbit around Saturn at an altitude of 8.20×10^{3} km. Saturn has a mass of approximately 5.68×10^{26} kg and a radius of approximately 6.00×10^{7} m.

a. What is the initial total energy of this rocket before it approaches Saturn?

b. What total energy is required in order for the rocket to go into orbit around Saturn at the given altitude?

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. C: What is *charge q*? Units?

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

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

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

    a. Neutron
    b. Proton
    c. Electron

5. C: 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. C: State the *law of conservation of charge.*

7. E: A pith ball has a surplus of 4.20×10^{15} electrons. What will be the net charge on this ball in Coulombs?

8. E: A pith ball has a shortage of 1.85×10^{17} electrons. What is the net charge on this ball in Coulombs?

9. E: How many electrons will be contained in a net charge of 1,250 μC?

10. E: 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.

    a. What will be the final residual charge on each pith ball?

    b. How many extra electrons will be present on each ball after they have been separated?

11. E: 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?

12. E: 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?

13. C: 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*?

14.C: Define relative permittivity ε_{r}.

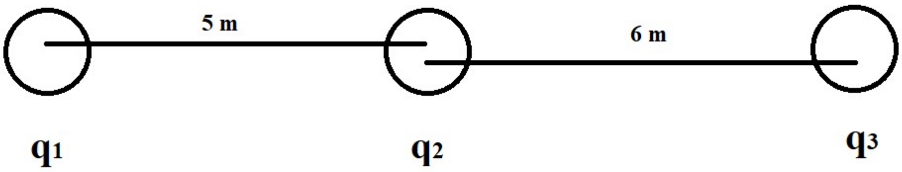
15.E: What will be the magnitude of the electrostatic force between two identical pith balls, each of which has a residual charge of 24.0 μC, which are 15.0 cm apart?

16.E: What will be the magnitude of the electrostatic force between two pith balls 23.0 cm apart if the residual charge on the first ball is -31.0 μC while the residual charge on the second ball is 12.0 μC?

17.E: What will be the electrostatic force between a proton and an electron when they are placed 0.5 Angstroms apart?

18.E: What will be the magnitude of the electrostatic force between two protons in the nucleus of an atom which are approximately 3.00×10^{-15} m apart?

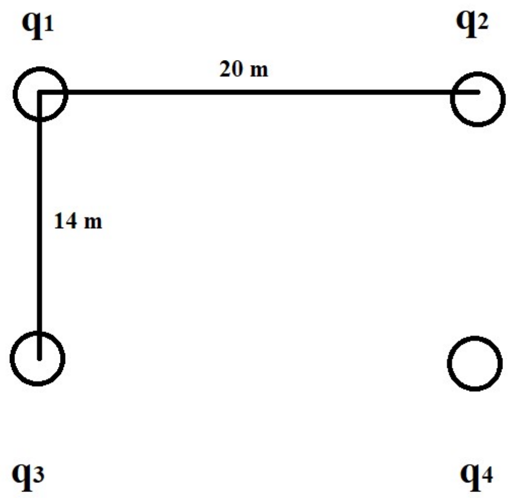
19. E: Use Coulomb's law to determine the electric force on a point charge.



$q_1 = +2 \times 10^{-9}$ 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.

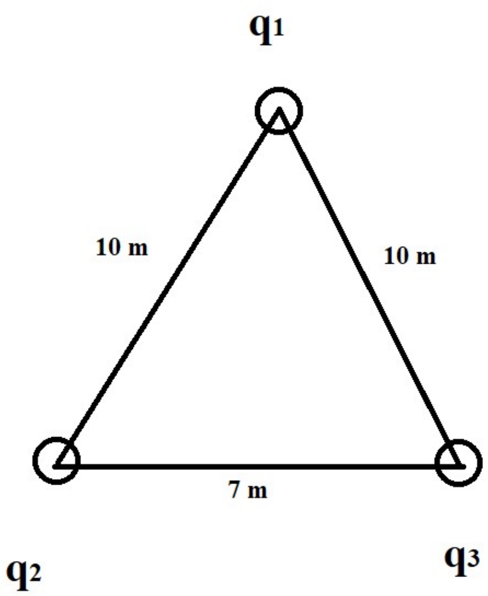
20.C: Use Coulomb's law to calculate the electric force on a point charge.



$q_1 = +2 \times 10^{-9}$ 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.

21.E: 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

Point charges q_2 and q_3 are fixed. Find the force on q_1.

22.C: Explain the meaning of charge being quantized.

23.C: Give an example of how two objects can transfer electric charge by

a. friction

b. electrostatic induction

c. contact

d. grounding/earthing

24.C: 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*?

25.C: Draw a graph of electric field vs. distance of a positively charged solid sphere.

26.E: What will be the strength of the electric field at a point in space where a 5.00 μC charge feels an electrostatic force of $F = 0.0450$ N?

27.E: A charge of 8.50 μC is placed in a uniform electric field which has an intensity of $E = 8.00 \times 10^3\ \frac{\text{N}}{\text{C}}$. What will be the magnitude of the resulting force?

28.E: A proton is placed in a uniform electric field which has an intensity of $6.50 \times 10^5\ \frac{\text{N}}{\text{C}}$.

a. What will be the magnitude of the resulting electrostatic force?

b. What will be the resulting acceleration of the proton as a result of this field?

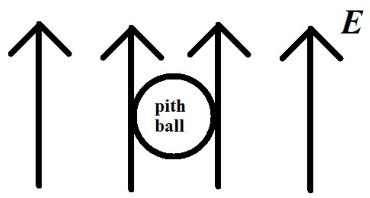
29.E: What will be the electric field strength 45.0 cm from a pith ball which has a residual charge of 5.50 μC?

30.E: What will be the electric field strength a distance 2,450 Angstroms from the nucleus of

a. a helium atom?

b. a carbon atom?

31.E: A small pith ball, which has a mass of 0.056 g and contains a residual charge of 5.00 μC, is sitting in a vertically oriented electric field as shown below. The force of gravity acting downward on this ball is exactly balanced by the electric field directed upward.

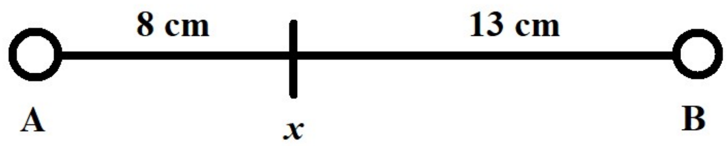


a. What will be the gravitational force acting on the pith ball?

b. What will be the magnitude of the electrostatic force acting on the pith ball?

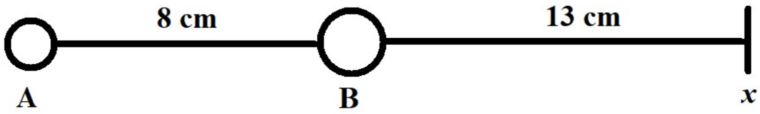
c. What is the magnitude of the electric field that is supporting this ball?

32.E: Determine the magnitude and direction of the electric field at point *x*.



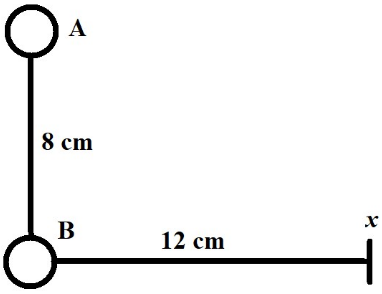
$Q_A = -5.00 \times 10^{-6}$ C
$Q_B = +7.20 \times 10^{-6}$ C

33.E: Determine the magnitude and direction of the electric field at point *x*.



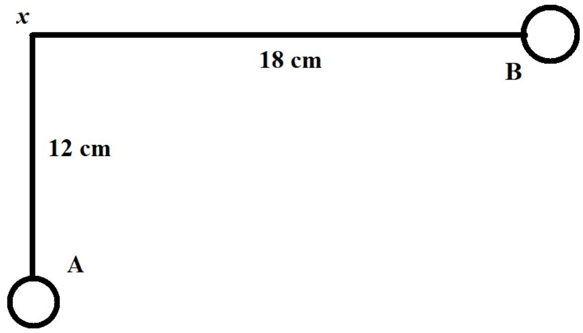
$Q_A = -5.00 \times 10^{-6}$ C
$Q_B = +7.20 \times 10^{-6}$ C

34.E: Determine the magnitude and direction of the electric field at point *x*.



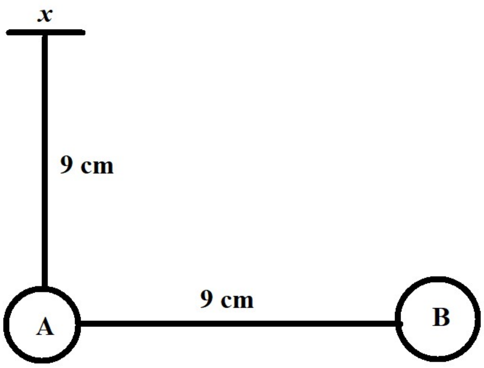
$Q_A = +1.20 \times 10^{-5}$ C
$Q_B = -8.00 \times 10^{-6}$ C

35.E: Determine the magnitude and direction of the electric field at point *x*.



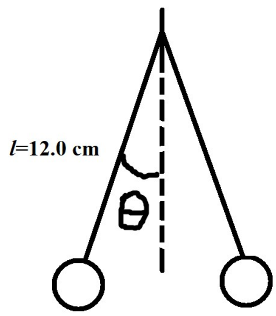
$Q_{\mathrm{A}} = -8.00 \times 10^{-6}\ \mathrm{C}$
$Q_{\mathrm{B}} = +1.20 \times 10^{-5}\ \mathrm{C}$

36.E: Determine the magnitude and direction of the electric field at point *x*.



$Q_A = -8.00 \times 10^{-6}$ C
$Q_B = -5.00 \times 10^{-6}$ C

37.E: Two pith balls, each of which is suspended from the end of a piece of very thin thread, are attached to a common point of suspension. Each pith ball has a mass of 0.130 g and each piece of thread is 12.0 cm long. Each of the two pith balls is given a net charge and as a result the two balls repel one another until the angle between a pith ball and the vertical increases to 16.0°.



a. What will be the magnitude of the electrostatic force between these two balls?

b. Determine the magnitude of the charge on each ball if the charge is distributed evenly between the two balls.

c. Assuming that this charge is negative, how many excess electrons would be found on each ball?

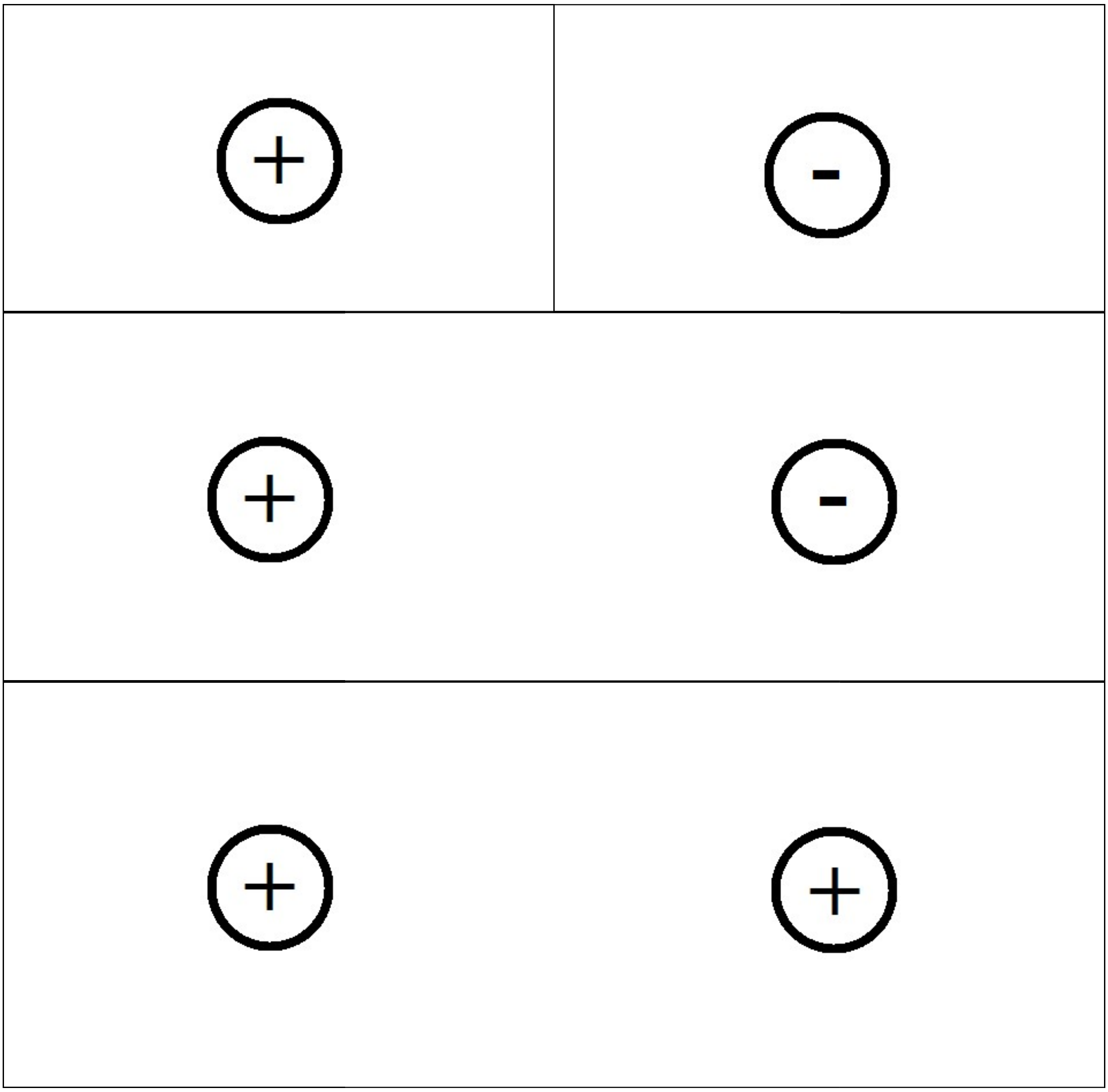
38.C: Define *electric potential difference*. Units?

39.C: What are the units of *voltage*?

40.C: Define *electron-volt*.

41.C: List some rules for drawing electric field lines.

42.C: **Use a pencil and ruler!** Draw electric field lines for each figure.



43.C: **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 $V = Ed$.

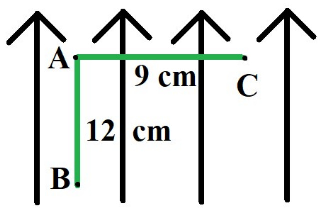
44.E: A charge of 15.0 μC is placed in a uniform electric field which has a field strength of $E = 8.80 \times 10^4\ \frac{\text{N}}{\text{C}}$.

a. What will be the magnitude of the electrostatic force acting on this charge?

b. How much work would be done in moving this charge a distance of 135 cm against the electric field?

c. What will be the potential difference between these two points?

45.E: A proton is placed at point A in a uniform electric field which has a field strength of $E = 4.50 \times 10^3\ \frac{\text{N}}{\text{C}}$ and which is directed toward the top of the page as shown in the diagram below:



a. What will be the direction of the electrostatic force acting on this proton while at point A?

b. What will be the magnitude of the electrostatic force acting on this proton while at point A?

c. How much work will be done in moving this charge a distance of 12.0 cm against this electric field to point B?

d. How will the electrostatic potential at point B in this field compare with the electrostatic potential at point A?

e. What will be the potential difference between points A and B?

Suppose that this proton is then released and is allowed to accelerate back to point A.

f. What will be the velocity of this proton when it returns to point A?

Suppose that the proton is again at rest at point A.

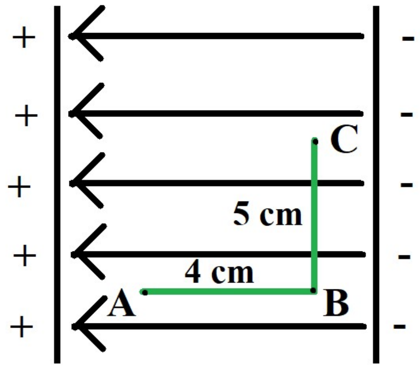
g. How much work would be done in moving this proton from point A to point C?

h. How will the electrostatic potential at point C compare to the electrostatic potential at point A?

i. What will be the potential difference between point C and point B?

j. How much work will have to be done on a proton to move it from point C to point B?

46.E: Two parallel plates are arranged as shown below. The electric field between the plates is uniform and is directed from the positive plate to the negative plate. The electric field strength is $E = 6.00 \times 10^4 \ \frac{\text{N}}{\text{C}}$ and the two plates are $d = 6.00$ cm apart. A particle, which has a charge of $q = -0.0150$ μC, is initially placed at point A.



a. How much work would have to be done to move this particle from point A to point B?

b. What is the potential difference between point A and point B?

c. How much work would have to be done in moving this particle from point A to point C?

d. What is the potential difference between points B and C?

Suppose that another particle, which has a charge of 2.00 μC, is placed, initially, on the negative plate. This particle is then moved from the negative plate to the positive plate.

e. How much work would be done in moving this particle from the negative plate to the positive plate?

f. What will be the potential difference between these two plates?

47.C: List some differences between the electric force and the magnetic force.

48.C: What are two situations in which magnetic fields are observed?

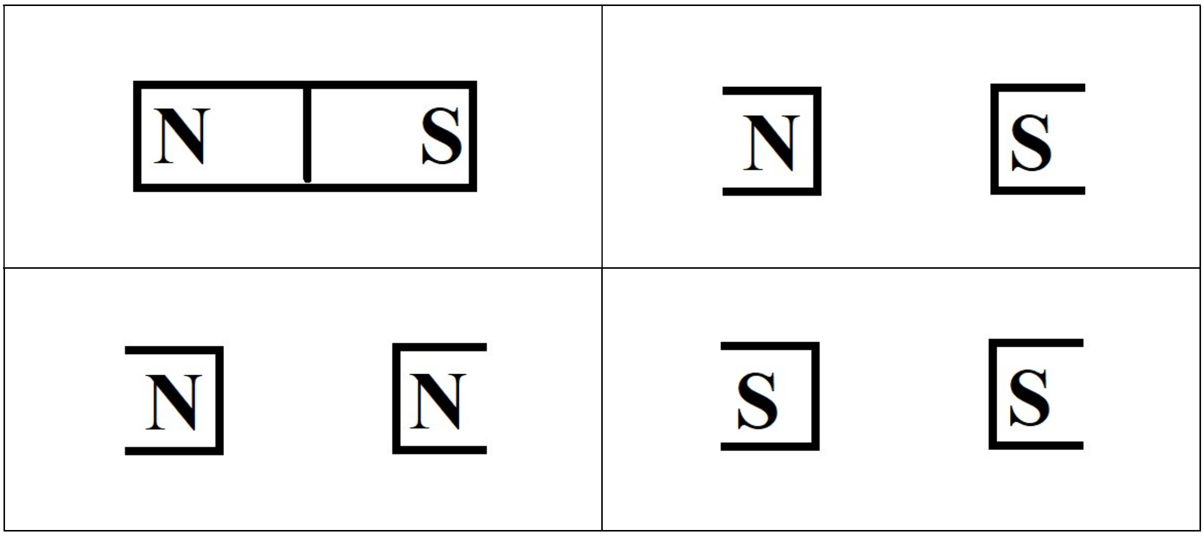
49.C: List some metals which have magnetic properties.

50.C: Define *hard magnet*. Define *soft magnet*.

51.C: How can you demagnetize a magnet?

52.C: Give some rules for drawing magnetic field lines.

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



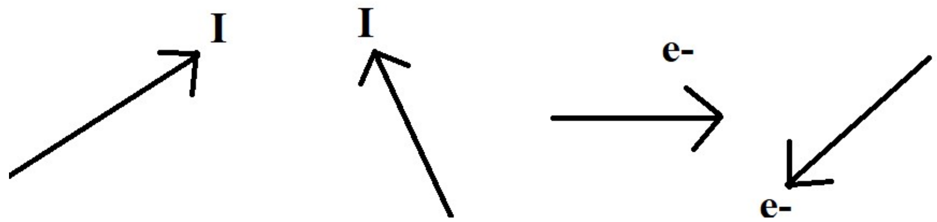
54.C: Draw and label the Earth's magnetic north pole (MN), magnetic south pole (MS), geographic north pole (GN), and geographic south pole (GS). Draw four magnetic field lines with arrows.

55.C: What are some differences between magnetic field lines and electric field lines?

56.C: What is a *magnetic monopole*? Where in the universe can we find a *magnetic monopole*?

57.C: Draw the symbols for an axis going into the page and out of the page.

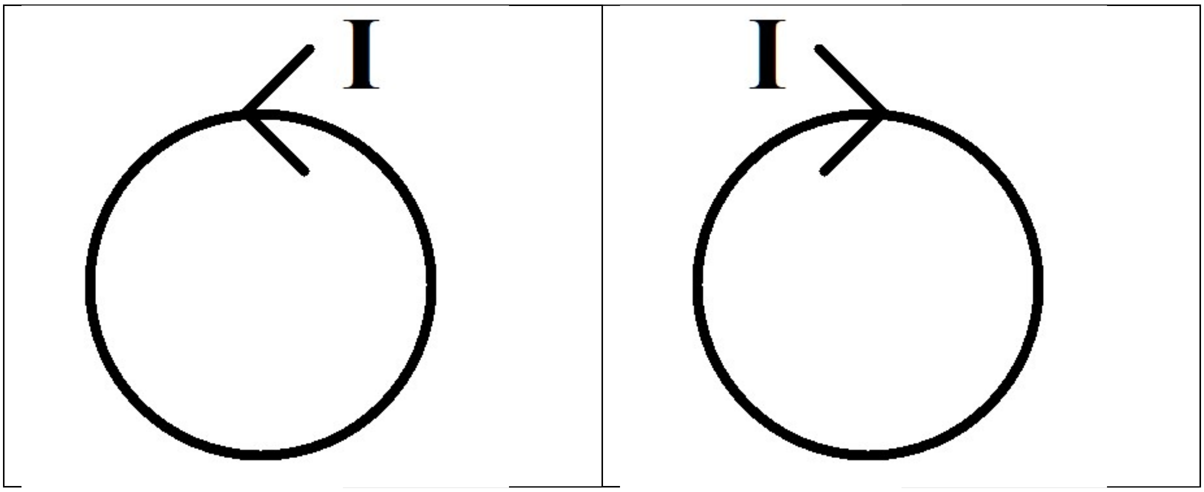
58.C: **Use a pencil!** Draw magnetic field lines for each current carrying wire.



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

60.C: State three ways we can we increase the magnetic field inside a solenoid.

61.C: Draw magnetic field lines in a circular current carrying loop.



Additional HL Content

62.C: 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?

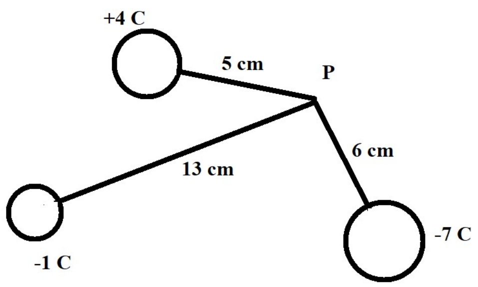
b. What is the equation for *electric potential energy* E_P? Units?

63.C: 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?

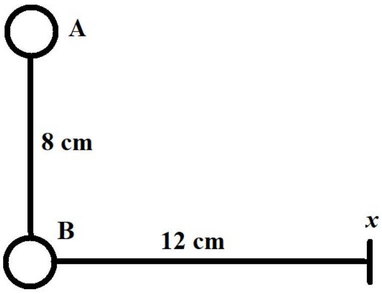
b. What is the equation for *electric potential*? Units?

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



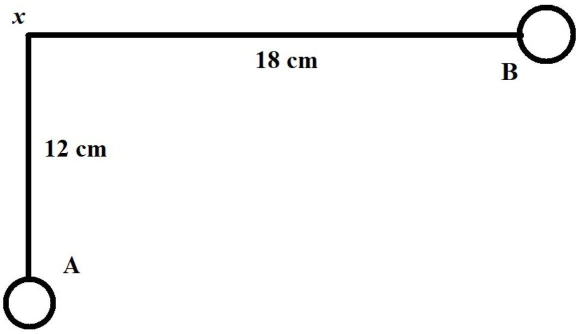
65.E: What will be the electrostatic potential of a point P which is both 12.0 cm from a 25.0 μC charge and 6.00 cm from a 50.0 μC charge?

66.E: Determine the electrostatic potential at point *x*.



$Q_{\mathrm{A}} = +1.20 \times 10^{-5}\ \mathrm{C}$
$Q_{\mathrm{B}} = -8.00 \times 10^{-6}\ \mathrm{C}$

67.E: Determine the electrostatic potential at point x.



$Q_{\mathrm{A}} = -8.00 \times 10^{-6}\ \mathrm{C}$
$Q_{\mathrm{B}} = +1.20 \times 10^{-5}\ \mathrm{C}$

68.C: Draw a graph of *electric potential vs. distance* of a positively charged solid sphere.

69.C: 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?

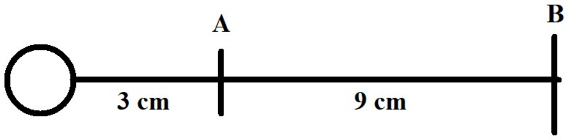
b. What is the equation and what are the units for *electric field strength*? Define each variable.

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*?

70.E: A small sphere contains a charge of $+5.00 \times 10^{-6}$ C.



a. What will be the direction and magnitude of the electric field at point A?

b. What will be the direction and magnitude of the electrostatic force acting on a proton placed at point A?

c. What will be the electrostatic potential at point A?

d. What will be the direction and magnitude of the electric field at point B?

e. What will be the direction and magnitude of the electrostatic force acting on a proton placed at point B?

f. What will be the electrostatic potential at point B?

g. What will be the potential difference between points A and B?

h. How much work would be required to move a proton from point B to point A?

i. How much work would be required to move a proton from point A to point B?

j. Which point is at the higher potential, A or B?

k. What will be the electrostatic potential at infinity?

l. What would be the potential difference between infinity and point B?

m. How much work would be required to move a proton from infinity to point B?

n. How much work would be required to bring an electron from infinity to point B?

71.E: An atom of C-12 contains six protons in its nucleus.

a. What will be the total charge of the nucleus of a C-12 atom?

b. What will be the strength of the electric field a distance of 0.5 angstroms from this C-12 nucleus?

c. What will be the electrostatic potential a distance of 0.5 angstroms from this C-12 nucleus?

d. What will be the electrostatic potential infinitely far from this C-12 nucleus?

e. What will be the potential difference between a point 0.5 angstroms from the C-12 nucleus and infinity?

f. How much work will be done in moving an electron from infinity to a point 0.5 angstroms from the nucleus of the C-12 nucleus?

g. What will be the potential difference between a point 0.5 angstroms from the nucleus of a C-12 atom and a point 1.5 angstroms from that same nucleus?

h. How much work will be done in moving an electron from a point 0.5 angstroms from the nucleus of a C-12 atom to a point 1.5 angstroms from the same C-12 nucleus?

72.E: Protons in the nucleus of an atom are on average a distance of 3.00 Fermi apart.

a. What will be the electrostatic potential 3.00 Fermi from a proton?

b. What will be the electrostatic potential infinitely far away from a proton?

c. What will be the potential difference between a point infinitely far away from a proton and a point 3.00 Fermi from a proton?

d. How much work will be required to move a proton from infinity to a point 3.00 Fermi from a second proton?

Suppose that you hold onto one of these protons and allow the other to accelerate to infinity.

e. What will be the velocity of this proton when it is very far away?

73.C: 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.

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

75.C: 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*.

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

77.C: 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. E: A proton, which has a mass of 1.67×10^{-27} kg and a charge of 1.60×10^{-1} C, is moving with a velocity of $5.60 \times 10^{6}\ \frac{\text{m}}{\text{s}}$ from left to right into a uniform electric field as shown in the figure below. The electric field has a magnitude of $5.60 \times 10^{5}\ \frac{\text{N}}{\text{C}}$ 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?

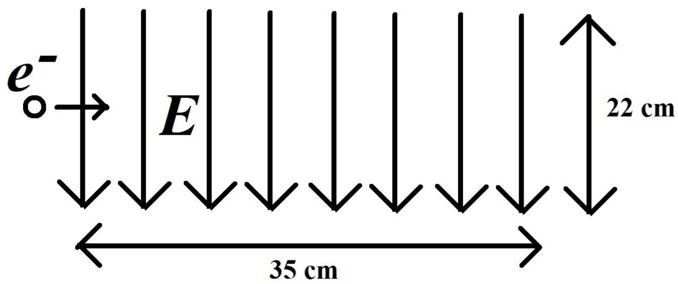
c. What will be the direction and magnitude of the net force acting on the proton?

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. E: An electron, which has a mass of 9.11×10^{-31} kg and a charge of -1.60×10^{-19} C, enters a uniform electric field with a velocity of $5.80 \times 10^{7}\ \frac{\text{m}}{\text{s}}$. The electric field has a magnitude of $2.90 \times 10^{4}\ \frac{\text{N}}{\text{C}}$, is pointing vertically downward and is contained within a limited area. The dimensional limits of the electric field is 35.0 cm horizontally and 22.0 cm vertically. The electron enters the uniform electric field from the middle of the vertical.



a. **Use a pencil!** Sketch the path of this particle through the electric field in the image above.

b. What will be the net force acting on this electron?

c. How long will it take for this electron to pass through this field?

d. Where, exactly, will the electron exit the field?

e. What will be the velocity of the electron as it exits the field?

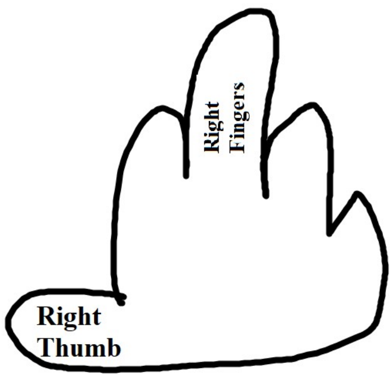
3. C: Compare the following equations of force: Newton's Law of Gravitation, Coulomb's Law, and the magnetic force.

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

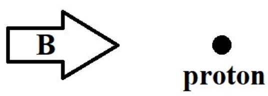
4. C: List some differences between the electric force and the magnetic force.

5. C: What are the units and fundamental units for the magnetic field $\vec{B}$?

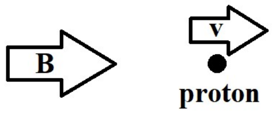
6. C: Use the equation $\vec{F}_{\mathrm{B}} = q\vec{v} \times \vec{B}_{\mathrm{external}}$ with the right hand rule to find the direction of the magnetic force of the charged object.

 $\vec{F}_{\mathrm{B}} = q\vec{v} \times \vec{B}_{\mathrm{external}}$	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!

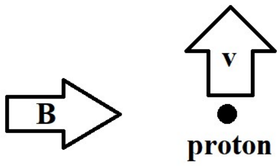
a. A proton is at rest. A magnetic field with constant magnitude points to the right. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



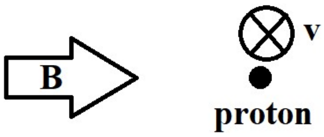
b. A proton moves to the right with a constant speed. A magnetic field with constant magnitude points to the right. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



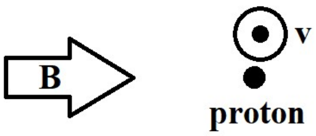
c. A proton moves up with a constant speed v. A magnetic field with constant magnitude points to the right. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



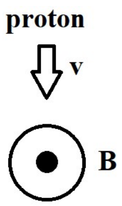
d. A proton moves into the page with a constant speed v. A magnetic field with constant magnitude points to the right. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



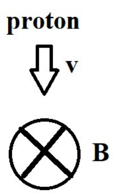
e. A proton moves out of the page with a constant speed v. A magnetic field with constant magnitude points to the right. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



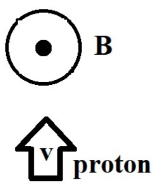
f. A proton moves down with a constant speed v. A magnetic field with constant magnitude points out of the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



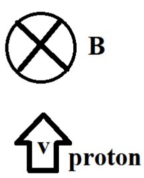
g. A proton moves down with a constant speed v. A magnetic field with constant magnitude points into the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



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?)

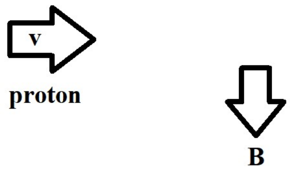


i. A proton moves up with a constant speed v. A magnetic field with constant magnitude points into the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)

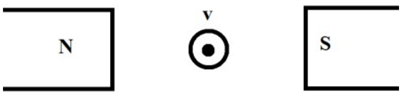


j. A proton moves to the right with a constant speed v. A magnetic field with constant magnitude points up. (What would be the direction of the magnetic force if the proton is replaced by an electron?)

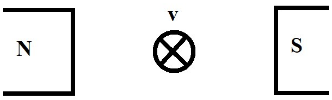
k. A proton moves to the right with a constant speed v. A magnetic field with constant magnitude points down. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



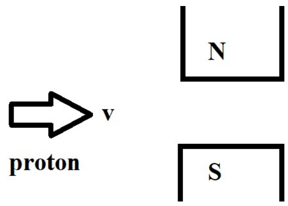
l. A proton moves out of the page with a constant speed v. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



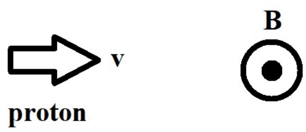
m. A proton moves into the page with a constant speed v. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



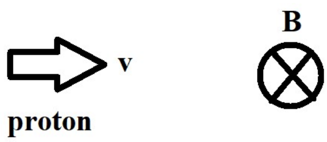
n. A proton moves to the right with a constant speed v. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



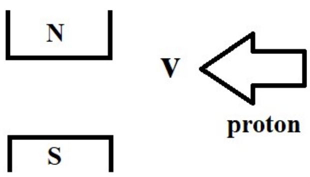
o. A proton moves to the right with a constant speed v. A magnetic field with constant magnitude points out of the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



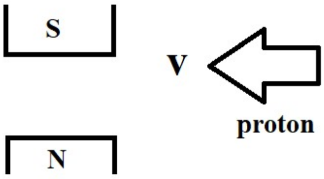
p. A proton moves to the right with a constant speed v. A magnetic field with constant magnitude points into the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



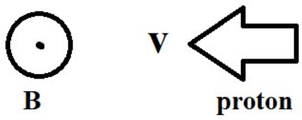
q. A proton is moving to the left with a constant speed v. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



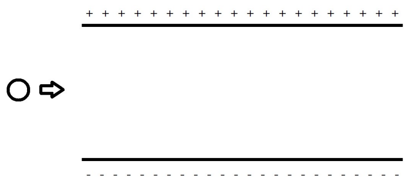
r. A proton is moving to the left with a constant speed v. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



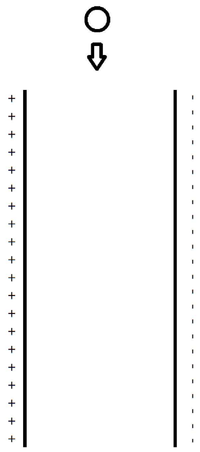
s. A proton is moving to the left with a constant speed v. A magnetic field with constant magnitude points out of the page. (What would be the direction of the magnetic force if the proton is replaced by an electron?)



7. E: 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?

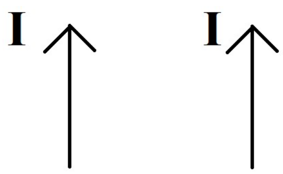


8. E: A proton is moving vertically downwards. It enters a region between a uniform external electric field as shown below. Which direction should the external magnetic field point if the proton is to move down without deflection?

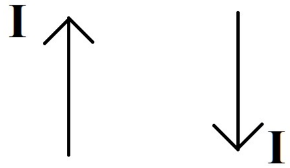


9. C: Determine an equation for the charge to mass ratio for a charged particle entering a uniform magnetic field. The velocity of the charged particle is perpendicular to the external magnetic field.

10. C: 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*.



11. C: 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*.



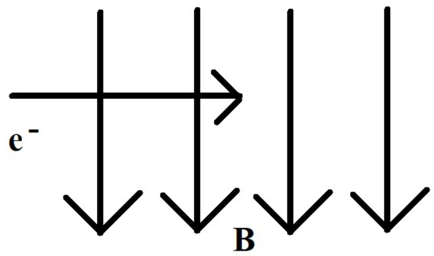
12.C: Describe the equation $F = BIL \sin\theta$ for a current carrying wire.

13.E: A proton is moving with a velocity of 820. m/s through a magnetic field which has a field intensity 1.20 Tesla. Assume that this proton is moving at right angles to the field.

a. What will be the magnitude of the resultant magnetic force?

b. What will be the force on the proton if the direction of motion of the proton is parallel to the direction of the magnetic field lines?

14.E: A magnetic field, which has an intensity of 0.950 Tesla, is directed vertically downward. An electron is moving horizontally through the field from left to right with a speed of $1.20 \times 10^4 \ \frac{\text{m}}{\text{s}}$.



a. What will be the direction of the magnetic force acting on this electron?

b. Describe the path of motion of this electron as it moves through the magnetic field.

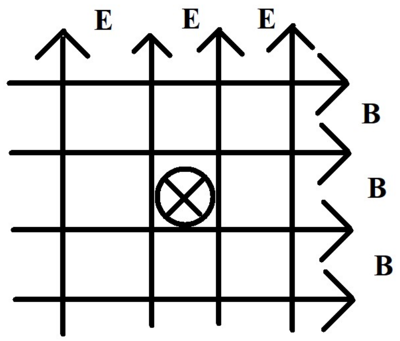
c. What will be the magnitude of the magnetic force acting on this electron?

d. What will be the radius of the circle in which this electron will move?

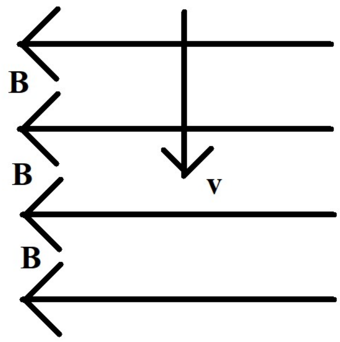
15. A proton is moving with a velocity of $2.1 \times 10^4 \ \frac{\text{m}}{\text{s}}$ through a uniform magnetic field such that the proton moves in a circular path which has a radius of 4.50 cm. What is the strength of the magnetic field B_{ext}?

16. E: An alpha particle is moving with a velocity of $2.00 \times 10^4 \ \frac{\text{m}}{\text{s}}$ through a uniform magnetic field which has a strength of 2.20 T at right angles to the field. What will be the magnitude of the resulting magnetic force?

17.E: A positively charged particle moves through an area of space where both an electric field, which has an intensity of $E = 1.20 \times 10^4\ \frac{\mathrm{N}}{\mathrm{C}}$, and a magnetic field, which has an intensity of $B = 2.40$ T, are present. The two fields are mutually perpendicular and the velocity of the positively charged particle is moving perpendicularly into the page such that the charged particle passes through the fields undeflected. What is the velocity of the positively charged particle?



18.E: A magnetic field has a strength of 0.780 T. A positive charge particle of 1.20 μC enters the field from the top of the page with a velocity of 550. m/s.



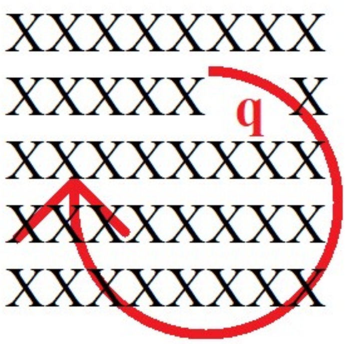
a. What will be the direction of the resultant magnetic force?

b. What will be the magnitude of the magnetic force acting on this positive particle?

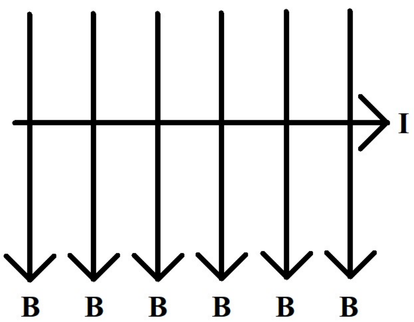
c. What will be the direction of the force if the particle is negative?

d. What will be the direction of the force if the negative particle is moving from left to right?

19.E: A doubly ionized gold atom is moving in a circular path in a uniform magnetic field. The radius of the path is 12.8 cm and the gold atom is moving with a velocity of $6.50 \times 10^5\ \frac{\text{m}}{\text{s}}$. What is the strength of the required magnetic field B? $q = -3.2 \times 10^{-19}$ C and $m = 3.29 \times 10^{-25}$ kg



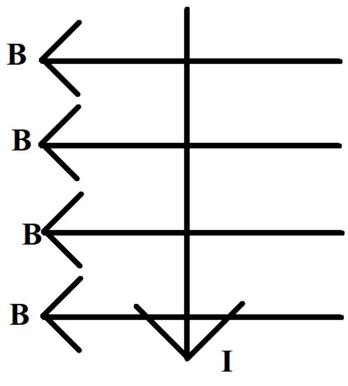
20.E: A piece of wire 15.0 cm long has a current of 3.10 A flowing through it and is sitting in a uniform magnetic field which has an intensity of 0.450 T. The wire is oriented perpendicularly to the magnetic field.



a. What will be the magnitude of the resulting magnetic force?

b. What will be the direction of the resulting magnetic force?

21.E: A conventional current of $I = 5.30$ A is flowing through a wire oriented perpendicularly to a magnetic field. The strength of the magnetic field is $B = 0.600$ T and the length of the wire sitting in the magnetic field is 40.0 cm.

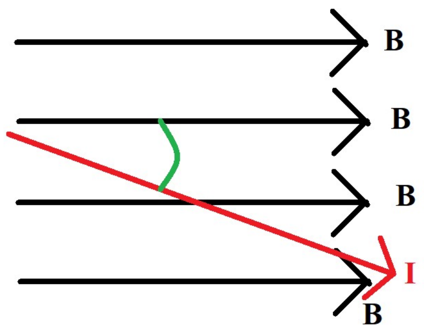


a. What will be the magnitude of the resulting magnetic force?

b. What will be the direction of the resulting magnetic force?

c. How could this wire be oriented so that it will feel no magnetic force?

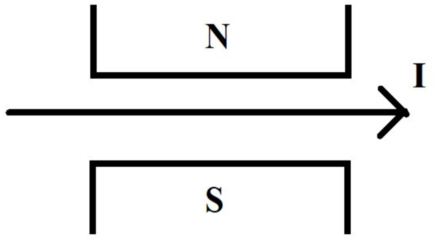
22.E: A wire 30.0 cm long is sitting in a uniform magnetic field. The strength of the magnetic field is $B = 0.220$ T and a current of $I = 3.25$ A is flowing through the wire. The wire is oriented at an angle of 38.0° relative to the magnetic field.



a. What will be the magnitude of the resulting magnetic force?

b. What will be the direction of the resulting magnetic force?

23.E: A wire is sitting in a uniform magnetic field between the poles of a permanent magnet. The magnet is 3.00 cm wide. When a conventional current of 6.25 A flows through this wire it feels a magnetic force of 0.0160 N.

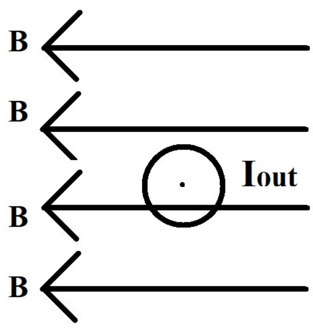


a. What is the strength of the magnetic field generated by the permanent magnet?

b. What will be the direction of the magnetic force acting on the wire?

c. What will be the direction of the magnetic force if the direction of the current is reversed?

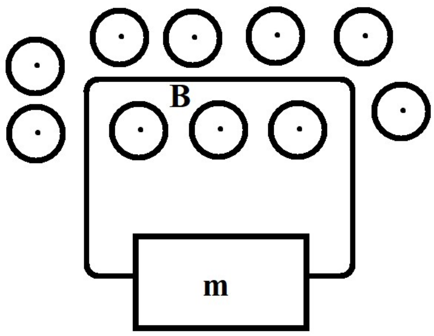
24.E: A conventional current of 7.50 A is flowing out of the page where the magnetic field strength is 2.20 T.



a. What is the magnitude of the resulting magnetic force for each meter of length of this wire?

b. What is the direction of the resulting magnetic force?

25.E: A loop of wire is attached to a mass of 50.0 g. One end of the loop is sitting in a magnetic field directed out of the page which has a magnitude of 3.00 T. The length of the wire sitting in the magnetic field is 35.0 cm.



a. What is the magnitude of the conventional current in the wire if the loop is to support the weight of the hanging mass?

b. What will be the direction of the required conventional current to support the hanging mass?

26.C: 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. C: Define *induction* and *induce*.

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

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

4. C: Define *flux*. Draw a picture.

5. C: *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. E: Consider a single loop of wire which is 25.0 cm by 25.0 cm. Passing through this loop is a magnetic field which has a magnitude of 0.220 T.

   a. Assuming that the magnetic field is parallel to the normal of the loop, what will be the total magnetic flux passing through the loop?

   b. Assuming that the magnetic field meets the normal to the loop at an angle of 35.0°, what will be the total magnetic flux passing through the loop?

   c. Assuming that the magnetic field is perpendicular to the normal to the loop, what will be the total magnetic flux passing through the loop?

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

8. E: Consider a single loop of wire which encloses an area of $50.0\ \text{cm}^2$. A magnetic field, which is parallel to the normal of this loop, initially has an intensity of 0.220 T. Over a time period of 0.200 s the magnetic field strength drops to zero.

   a. What will be the resulting emf in the loop?

   b. What will be the emf in this circuit if the loop consists of 1,000 turns rather than a single turn?

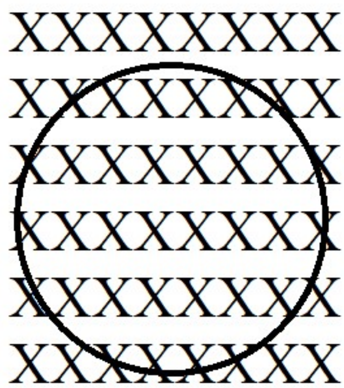
9. E: Consider a coil of wire which has 1,200 turns, encloses an area of 18.0 cm^2, and contains a magnetic field of 3.50 T oriented parallel to the normal to the loop. What will be the induced emf in this coil if the magnetic field drops to zero in 0.0167 s?

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

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

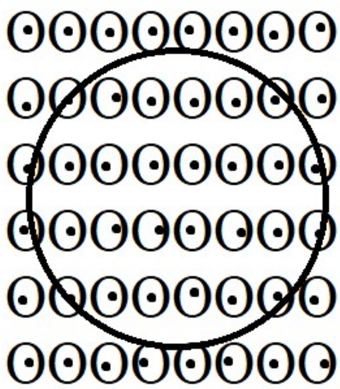
    a. There is a magnetic field which points into the page. The magnitude of the magnetic field is

        i. decreasing
        ii. constant
        iii. increasing

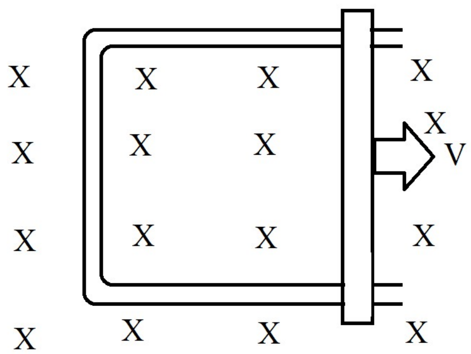
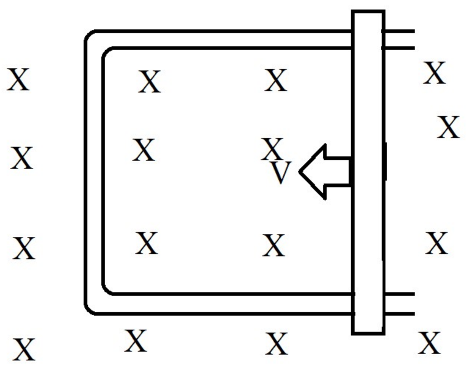


b. There is a magnetic field which points out the page. The magnitude of the magnetic field is

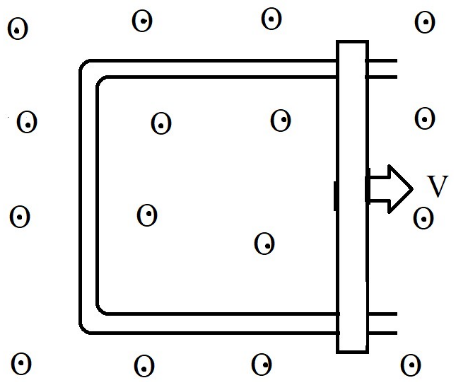
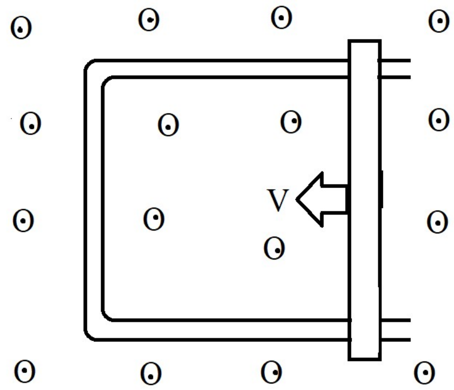
i. decreasing
ii. constant
iii. increasing



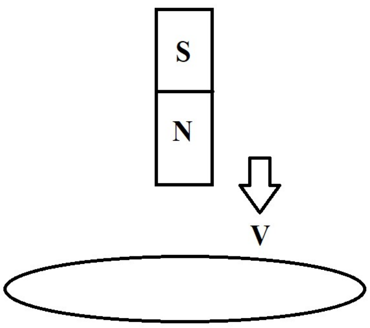
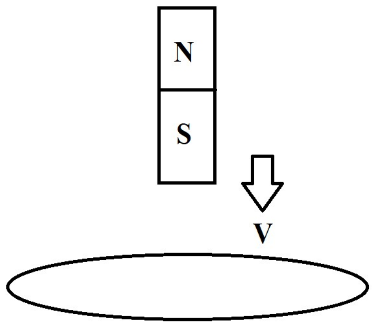
c. There is a constant magnetic field into the page. Which direction is the induced current?

i. The area of the loop is increasing.	ii. The area of the loop is decreasing.
	

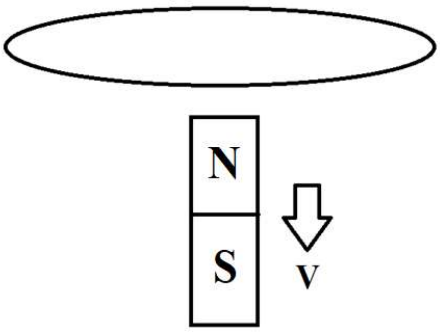
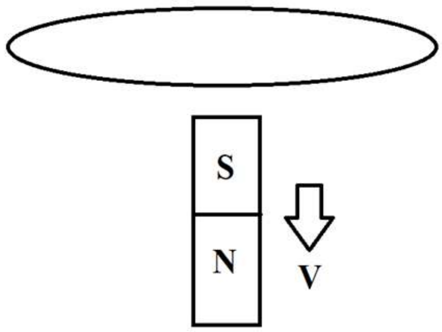
d. There is a constant magnetic field out of the page.

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?

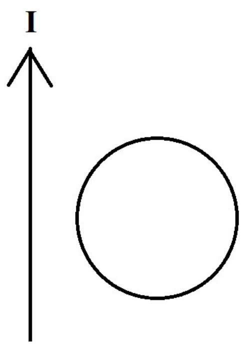
i. The north pole is facing downwards.  	ii. The south pole is facing downwards. 

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

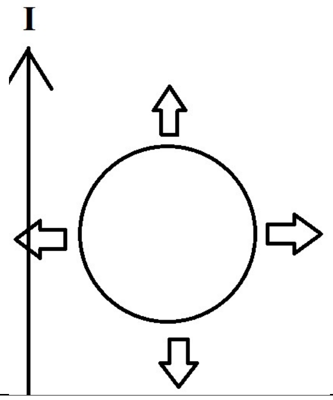
i. The north pole is facing upwards. 	ii. The south pole is facing upwards. 

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

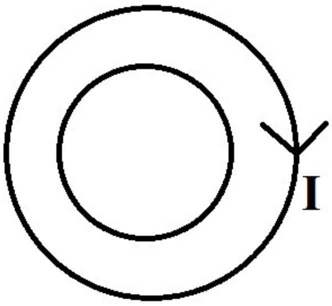
i. decreasing
ii. constant
iii. increasing



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	

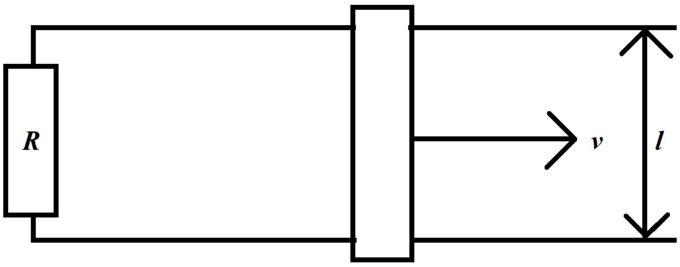
i. A small loop of wire is inside a larger loop of wire. The larger loop of wire has a constant current clockwise. What is the direction of the induced current of the smaller loop if the current of the larger loop is

i. decreasing ii. constant iii. increasing	

12.C: What happens to a magnet if it falls down a hollow metal cylinder? Why?
https://www.youtube.com/watch?v=N7tIi71-AjA

13.C: Describe the equation $\varepsilon = BvL$.

14.E: Two parallel rails are connected together at one end by a resistance of 20.0 Ω. Across these two rails, which are 45.0 cm apart, there lies a conducting metal bar. The magnetic field is uniform, has a strength of 2.20 T, and is directed into the page. A force is applied to the metal bar so as to push the bar to the right with a velocity of 8.40 m/s.



a. What will be the resulting emf in this circuit?

b. What will be the direction of the resulting conventional current flowing through this circuit?

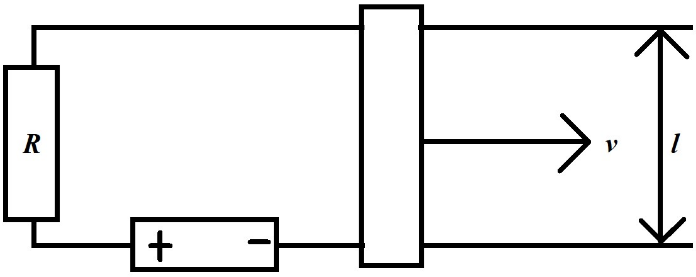
c. What will be the magnitude of the resulting current?

d. At what rate is electrical energy being generated?

e. How much force is being applied to this bar?

f. At what rate is mechanical energy being consumed?

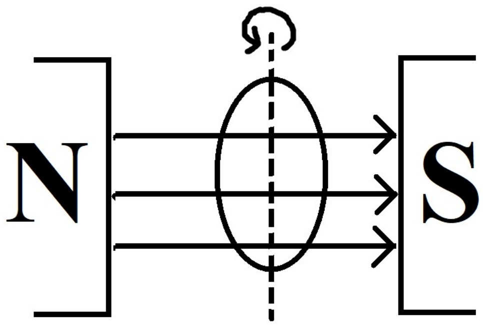
15.E: A battery, which has an emf of 6.00 V, is inserted into a circuit. The magnetic field has an intensity of 2.20 T and is directed into the paper. The resistance has a value of 20.0 Ω and the two parallel horizontal rails are separated by a distance of 45.0 cm. A current of 0.200 A is measured to be flowing through the circuit.



a. What will be the resulting velocity of the bar?

b. How much force is being applied to the bar by the magnetic field as it moves through the field?

16.C: 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 $2f$.



17.C: Define *self-induction*.