UNIVERSITY OF GHANA

BSc. SECOND SEMESTER EXAMINATIONS: 2011/2012

PHYS 144: ELECTRICITY AND MAGNETISM (3 Credits)

ANSWER *ALL* QUESTIONS

TIME ALLOWED: TWO AND HALF (2½) HOURS

Instructions: Answer all questions in Section A, one question in Section B, and one question in Section C.

SECTION A: Answer ALL questions.

Each question is followed by five possible answers A, B, C, D and E. *Write the letter of the answer that you have chosen in the answer booklet.*

Values of Physical Constants

Acceleration due to gravity	$g = 9.81\ \mathrm{m\,s^{-2}}$
Avogadro's number	$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
Coulomb force constant	$k = 9.00 \times 10^{9}\ \mathrm{N\,m^2\,C^{-2}}$
Electronic charge	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
Electron mass	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$
Proton mass	$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$
Permeability of free space	$\mu_o = 4\pi \times 10^{-7}\ \mathrm{T\,m\,A^{-1}}$
Permittivity of free space	$\epsilon_o = 8.55 \times 10^{-12}\ \mathrm{C^2\,N^{-1}\,m^{-2}}$
Pi	$\pi = 3.14$

Examiners: V. K. Kattah, A. A. Yankson, A. Amankwah, J. A. M. Hodasi

1. The magnetic field lines **inside** a bar magnet run in what direction?
   (A) From North Pole to South Pole.
   (B) From South Pole to North Pole.
   (C) From side to side.
   (D) No magnetic field lines inside a bar magnet.
   (E) None of the above.

2. A circular wire has a diameter of 30 cm and contains 20 loops. The current in each loop is 5 A and the coil is placed in an external magnetic field such that a maximum torque of 1.88 Nm is exerted on the coil by the field. Calculate the magnitude of the magnetic field.
   (A) 0.27 T
   (B) 3.76 T
   (C) 0.35 T
   (D) 0.72 T
   (E) 0.35 T

3. An electron moves in the plane of this page toward the top of the page. A magnetic field is also in the plane of the page and directed toward the right. The direction of the magnetic force on the electron is

   (A) toward the bottom of the page,
   (B) toward the left edge of the page,
   (C) toward the right edge of the page.
   (D) upward out of the page,
   (E) downward into the page.

4. A charged particle moves with velocity **v** in a magnetic field **B**. The magnetic force on the particle is a maximum when **v** is

   (A) parallel to **B**
   (B) perpendicular to **B**
   (C) half of **B**
   (D) equal to **B**
   (E) zero

5. A television set uses a magnetic field to deflect its electron beam. This magnetic field is able to steer the electron beam because
   (A) a moving charge can experience a force when it passes through a magnetic field.
   (B) an electron always travels in the direction of the electric field.
   (C) an electron always travels at a right angle to the magnetic field.
   (D) a stationary charge experiences a force in a magnetic field.
   (E) the velocity of the electron is parallel to the field.

6. A copper wire has 2.0×10^{29} free electrons per cubic metre, a cross-sectional area of $2.0\ m^2$ and carries a current of 5.0 A. Calculate the force acting on each electron if the wire is now placed in a magnetic field of magnitude 0.15 T that is perpendicular to the wire.
   (A) 0.9×10^{28} N
   (B) 1.9×10^{-28} N
   (C) 2.1×10^{-29} N
   (D) 1.1×10^{29} N
   (E) 4.1×10^{-28} N

7. The magnetic field due to a very long, straight wire carrying a current I is 0.20 T at a distance r from the wire. Determine the field due to the wire when I is halved and r is doubled.
   (A) 0.1 T
   (B) 0.2 T
   (C) 0.5 T
   (D) 0.6 T
   (E) 0.8 T

8. Which of the following is the correct expression for Gauss's law in magnetism?
   (A) $\oint \boldsymbol{B} \cdot d\boldsymbol{l} = \mu_o I$
   (B) $\oint \boldsymbol{B} \cdot d\boldsymbol{A} = 0$
   (C) $\oint \boldsymbol{E} \cdot d\boldsymbol{A} = {}^{Q}/_{\epsilon_o}$
   (D) $\oint \boldsymbol{B} \cdot d\boldsymbol{A} = {}^{I}/_{\mu_o}$
   (E) $\oint \boldsymbol{E} \cdot d\boldsymbol{A} = 0$

9. A straight wire carries a 12.0 A current. Determine the magnitude of the magnetic field due to a 3.1×10^{-3} m segment of the wire at a point 2.0×10^{-2} m away from it, if the point is on a line at 30^0 to the segment.

(A) 4.7×10^{-6} T
(B) 5.3×10^{-6} T
(C) 6.2×10^{-6} T
(D) 7.8×10^{-6} T
(E) 8.2×10^{-6} T

10. A circular loop lying in a horizontal plane carries current in the clockwise direction. The direction of the magnetic dipole moment is
(A) clockwise
(B) horizontal
(C) into the plane
(D) out of the plane
(E) counterclockwise

11. Given a group of charges close to each other whose net value is nonzero, the equipotential surface at a very great distance is
(A) nearly a plane.
(B) nearly a sphere.
(C) quite indeterminate.
(D) nearly a cylinder.
(E) nearly a pyramid.

12. A 20 pF parallel plate capacitor whose plates are 0.5 mm apart is connected across a 15 V battery. How much energy will it store?
(A) 60 J
(B) 0.416 J
(C) 2.25 nJ
(D) 1.4 nJ
(E) 5.9 nJ

13. The center of a small spherical body of radius r, uniformly charged over its surface with charge Q, coincides with the center of one side of a cube of edge length a (a > 2r). What is the flux of the electric field strength vector through the cube?
(A) $Q/2\varepsilon_0$ Nm^2/C
(B) $3Q/2\varepsilon_0$ Nm^2/C
(C) $4Q/5\varepsilon_0$ Nm^2/C
(D) Q/ε_0 Nm^2/C
(E) $2Q/\varepsilon_0$ Nm^2/C

14. A uniform electric field $(a\hat{i} + b\hat{j})$ intersects a surface of area A. What is the flux through this area if the surface lies in the xy plane?

(A) 0
(B) (a + b)A
(C) bA
(D) aA
(E) (a - b)A

15. What is the drift velocity of electrons in a copper (64.0 g/mol) wire of radius 1.2 mm carrying a current of 2A? (ρ_{copper}=8.93g/cm^3)

(A) 3.28×10^1 m/s
(B) 1.644×10^2 m/s
(C) 6.08×10^{-2} m/s
(D) 3.28×10^{-5} m/s
(E) 4.23×10^2 m/s

16. How many 1.00 μF capacitors must be connected in parallel to store a charge of 1.00 C with a potential of 220 V across the capacitors?

(A) 900
(B) 9090
(C) 11363
(D) 4545
(E) 500

17. The electric field at a point in space is a measure of the

(A) total charge on an object at that point.
(B) electric force on any charged object at that point.
(C) electric force per unit mass on a point charge at that point.
(D electric charge per dipole moment
(E) electric force per unit charge at that point

18. Two charged particles attract each other with a force of magnitude F acting on each. If the charge of one is doubled and the distance separating the particles is also halved, the force acting on each of the two particles has magnitude

(A)F/2
(B) F/4
(C) F
(D) 2F
(E) 8F

19. A charged insulator and an uncharged metal brought near each other

(A) exert no electric force on each other.

(B) repel each other electrically.

(C) attract each other electrically.

(D) attract or repel, depending on whether the charge is positive or negative.

(E) charged insulator loses all its charge.

20. What is the correct unit for electric field?

(A) V/C only

(B) N.m/C only

(C) N/m only

(D) Nm/C or V/m

(E) N/C or V/m

21. A 25.0 Ω bulb is connected across the terminals of a 12.0 V battery having 3.50 Ω of internal resistance. What percentage of the power of the batteries power is dissipated across the internal resistance and hence not available to the bulb?

(A) 12.3 %

(B) 34.8 %

(C) 45.0 %

(D) 68.4 %

(E) 20.3 %

22. The current through a flashlight bulb is 0.720 A. How many electrons flow through the bulb each second?

(A) 9.360×10^{17}

(B) 8.889×10^{-19}

(C) 2.880×10^{-18}

(D) 1.125×10^{18}

(E) 4.500×10^{18}

23. Which of these is equal to the emf of a battery?

(A) the chemical energy stored in the battery.

(B) the maximum voltage across a load.

(C) the maximum current that the battery can supply.

(D) the amount of charge the battery can pump.

(E) the terminal voltage of the battery when no current flows.

24. How does the resistance of a piece of conducting wire change if both its length and diameter are doubled?

(A) remains the same
(B) thrice as much
(C) twice as much
(D) half as much
(E) four times as much

25. Which of the following statements is not correct?

(A) Equivalent resistance in parallel connection is less than any of the individual resistances.
(B) Voltage drop across each resistor connected in parallel is the same.
(C) Resistors in series combine in the same way that capacitors in parallel do.
(D) Same current flows through all resistors connected in series.
(E) Equivalent resistance in parallel connection is greater than any of the individual resistances.

26. Which of the following statements is not correct?

(A) Gauss's law relates electric field to the electric charge.
(B) Ampere's law relates magnetic field to the magnetic source.
(C) Permanent magnet and electric current are sources of magnetic field.
(D) The magnetic field inside an infinite solenoid does not depend on the radius of the solenoid.
(E) Dividing a bar magnet into pieces produces monopoles.

27. Suppose that a current-carrying ohmic metal wire has a cross-sectional area that gradually becomes smaller from one end of the wire to the other. How do the drift velocity and the resistance per unit length vary along the wire as the area becomes smaller?

(A) The drift velocity and resistance remain unchanged.
(B) The drift velocity and resistance both decrease.
(C) The drift velocity increases and the resistance decreases.
(D) The drift velocity decreases and the resistance increases.
(E) The drift velocity and resistance both increase.

28. Three 5Ω resistors are connected in parallel. What emf would drive a current of 0.5 A through the circuit if the battery source has an internal resistance of $0.5\ \Omega$.

(A) 1.45 V
(B) 1.55 V
(C) 18.5 V
(D) 16.5 V
(E) 1.08 V

29. Which of the following equations is not a Kirchhoff's rule?

I. $\emptyset = \int E.dA$
II. $\sum V = 0$
III. $\vec{E} = \rho\vec{J}$

(A) I and II only
(B) II and III only
(C) II only
(D) I only
(E) I and III only

30. A faulty iron cord made of 18 – gauge copper wire is replaced by a 12 – gauge copper wire which has twice the diameter as the 18 – gauge wire. How will the magnitude of the drift velocity be affected if the current remains the same.

(A) Twice as great
(B) Four times as great
(C) Half as great
(D) One – fourth as great
(E) Thrice as great

SECTION B: ANSWER ONE QUESTION IN THIS SECTION IN YOUR ANSWER BOOK

1.

(a) The two wires of a 5.0 m long appliance cord are 2.5 mm apart and carry a d.c current of 12.0 A in opposite direction.

(i) Calculate the force one wire exerts on the other.

(ii) Determine the magnitude and direction of the magnetic field half-way between the wires.

(b) A square 12 –turn coil with sides of length 40 cm carries a current of 3 A. It lies in the xy plane in a uniform magnetic field $B = (0.3\hat{\imath} + 0.4\hat{\jmath})$ T. Find

(i) the magnetic moment of the coil

(ii) the torque exerted on the coil.

[20 marks]

2. (a) A long straight wire of radius a carries a current I that is uniformly distributed over the cross sectional area of the wire. Using the Ampere's law, find the magnetic field inside the wire at a distance r from the centre ($r < a$).

(b) A circular loop of radius 4.0 cm has 12 turns and lies in the xy plane. It carries a current of 4 A in the direction such that the magnetic moment of the loop is along the z-axis. Find the magnetic field on the z-axis at z = 15 cm.

[20 marks]

SECTION C: ANSWER ONE QUESTION IN THIS SECTION IN YOUR ANSWER BOOK

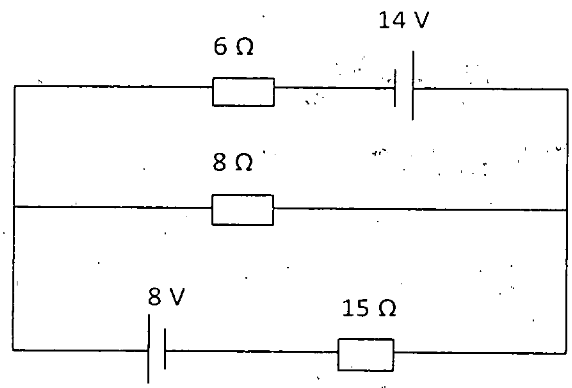
1.

(a) A cylindrical tungsten filament 15.0 cm long with a diameter of 1.00 mm is to be used in a machine for which the temperature will range from room temperature (20°C) up to 120°C. It will carry a current of 12.5 A at all temperatures. [Temperature coefficient of resistivity $\alpha = 0.0045^{o}\ K^{-1}$, and resistivity of tungsten at room temperature, $\rho = 5.25 \times 10^{-8}\ \Omega m$]

(i) What will be the maximum electrical field in the filament?

(ii) What will be the resistance when there is maximum electrical field?

(b) Find the potential difference across the 6 Ω resistor in the circuit below.

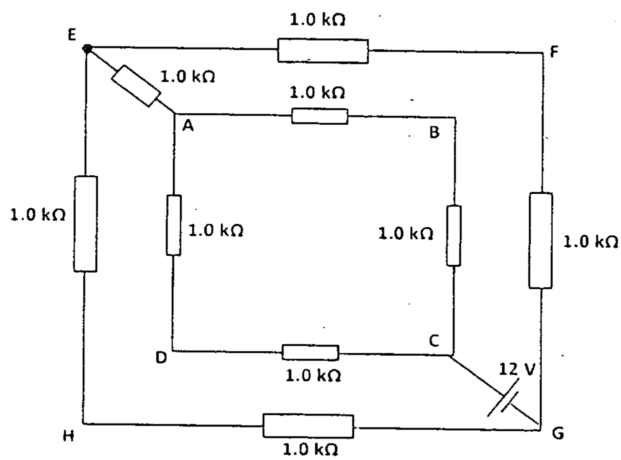


[20 marks]

Examiners: V. K. Kattah, A. A. Yankson, A. Amankwah, J. A. M. Hodasi

2. (a) The circuit below shows a network of resistors with 12 V source between C and G. Determine the

(i) current provided by the source.
(ii) Voltage across points G and



(b) Two parallel plates each having an area of 30 cm^2 and separated by a distance of 0.6 mm are connected to a 120 V battery. The charged plates are immersed in dielectric fluid with the battery still connected.

(i) Calculate the amount of charge on the plates just before the immersion.

(ii) Calculate the capacitance and the amount of charge on the plate after the immersion. (Take dielectric constant of the fluid to be 81.)

[20 marks]

UNIVERSITY OF GHANA

BSc. SECOND SEMESTER EXAMINATIONS: 2011/2012

PHYS 144: ELECTRICITY AND MAGNETISM (3 Credits)

ANSWER *ALL* QUESTIONS

TIME ALLOWED: TWO AND HALF (2½) HOURS

Instructions: Answer all questions in Section A, one question in Section B, and one question in Section C.

SECTION A: Answer ALL questions.

Each question is followed by five possible answers A, B, C, D and E. *Write the letter of the answer that you have chosen in the answer booklet.*

Values of Physical Constants

Acceleration due to gravity	$g = 9.81 \text{ m s}^{-2}$
Avogadro's number	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
Coulomb force constant	$k = 9.00 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$
Electronic charge	$e = 1.60 \times 10^{-19} \text{ C}$
Electron mass	$m_e = 9.11 \times 10^{-31} \text{ kg}$
Proton mass	$m_p = 1.67 \times 10^{-27} \text{ kg}$
Permeability of free space	$\mu_o = 4\pi \times 10^{-7} \text{ T m A}^{-1}$
Permittivity of free space	$\epsilon_o = 8.55 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$
Pi	$\pi = 3.14$

Examiners: V. K. Kattah, A. A. Yankson, A. Amankwah, J. A. M. Hodasi

1. The magnetic field lines **inside** a bar magnet run in what direction?
   (A) From North Pole to South Pole.
   (B) From South Pole to North Pole.
   (C) From side to side.
   (D) No magnetic field lines inside a bar magnet.
   (E) None of the above.

2. A circular wire has a diameter of 30 cm and contains 20 loops. The current in each loop is 5 A and the coil is placed in an external magnetic field such that a maximum torque of 1.88 Nm is exerted on the coil by the field. Calculate the magnitude of the magnetic field.
   (A) 0.27 T
   (B) 3.76 T
   (C) 0.35 T
   (D) 0.72 T
   (E) 0.35 T

3. An electron moves in the plane of this page toward the top of the page. A magnetic field is also in the plane of the page and directed toward the right. The direction of the magnetic force on the electron is

   (A) toward the bottom of the page,
   (B) toward the left edge of the page,
   (C) toward the right edge of the page.
   (D) upward out of the page,
   (E) downward into the page.

4. A charged particle moves with velocity **v** in a magnetic field **B**. The magnetic force on the particle is a maximum when **v** is

   (A) parallel to **B**
   (B) perpendicular to **B**
   (C) half of **B**
   (D) equal to **B**
   (E) zero

5. A television set uses a magnetic field to deflect its electron beam. This magnetic field is able to steer the electron beam because
   (A) a moving charge can experience a force when it passes through a magnetic field.
   (B) an electron always travels in the direction of the electric field.
   (C) an electron always travels at a right angle to the magnetic field.
   (D) a stationary charge experiences a force in a magnetic field.
   (E) the velocity of the electron is parallel to the field.

6. A copper wire has 2.0×10^{29} free electrons per cubic metre, a cross-sectional area of $2.0\ m^2$ and carries a current of 5.0 A. Calculate the force acting on each electron if the wire is now placed in a magnetic field of magnitude 0.15 T that is perpendicular to the wire.
   (A) 0.9×10^{28} N
   (B) 1.9×10^{-28} N
   (C) 2.1×10^{-29} N
   (D) 1.1×10^{29} N
   (E) 4.1×10^{-28} N

7. The magnetic field due to a very long, straight wire carrying a current I is 0.20 T at a distance r from the wire. Determine the field due to the wire when I is halved and r is doubled.
   (A) 0.1 T
   (B) 0.2 T
   (C) 0.5 T
   (D) 0.6 T
   (E) 0.8 T

8. Which of the following is the correct expression for Gauss's law in magnetism?
   (A) $\oint \boldsymbol{B} \cdot d\boldsymbol{l} = \mu_0 I$
   (B) $\oint \boldsymbol{B} \cdot d\boldsymbol{A} = 0$
   (C) $\oint \boldsymbol{E} \cdot d\boldsymbol{A} = Q/\epsilon_0$
   (D) $\oint \boldsymbol{B} \cdot d\boldsymbol{A} = I/\mu_0$
   (E) $\oint \boldsymbol{E} \cdot d\boldsymbol{A} = 0$

9. A straight wire carries a 12.0 A current. Determine the magnitude of the magnetic field due to a 3.1×10^{-3} m segment of the wire at a point 2.0×10^{-2} m away from it, if the point is on a line at 30^0 to the segment.

(A) 4.7×10^{-6} T
(B) 5.3×10^{-6} T
(C) 6.2×10^{-6} T
(D) 7.8×10^{-6} T
(E) 8.2×10^{-6} T

10. A circular loop lying in a horizontal plane carries current in the clockwise direction. The direction of the magnetic dipole moment is
(A) clockwise
(B) horizontal
(C) into the plane
(D) out of the plane
(E) counterclockwise

11. Given a group of charges close to each other whose net value is nonzero, the equipotential surface at a very great distance is
(A) nearly a plane.
(B) nearly a sphere.
(C) quite indeterminate.
(D) nearly a cylinder.
(E) nearly a pyramid.

12. A 20 pF parallel plate capacitor whose plates are 0.5 mm apart is connected across a 15 V battery. How much energy will it store?
(A) 60 J
(B) 0.416 J
(C) 2.25 nJ
(D) 1.4 nJ
(E) 5.9 nJ

13. The center of a small spherical body of radius r, uniformly charged over its surface with charge Q, coincides with the center of one side of a cube of edge length a (a > 2r). What is the flux of the electric field strength vector through the cube?
(A) $Q/2\varepsilon_0$ Nm^2/C
(B) $3Q/2\varepsilon_0$ Nm^2/C
(C) $4Q/5\varepsilon_0$ Nm^2/C
(D) Q/ε_0 Nm^2/C
(E) $2Q/\varepsilon_0$ Nm^2/C

14. A uniform electric field $(a\hat{i} + b\hat{j})$ intersects a surface of area A. What is the flux through this area if the surface lies in the xy plane?

(A) 0
(B) (a + b)A
(C) bA
(D) aA
(E) (a - b)A

15. What is the drift velocity of electrons in a copper (64.0 g/mol) wire of radius 1.2 mm carrying a current of 2A? (ρ_{copper}=8.93g/cm^3)

(A) 3.28×10^1 m/s
(B) 1.644×10^2 m/s
(C) 6.08×10^{-2} m/s
(D) 3.28×10^{-5} m/s
(E) 4.23×10^2 m/s

16. How many 1.00 μF capacitors must be connected in parallel to store a charge of 1.00 C with a potential of 220 V across the capacitors?

(A) 900
(B) 9090
(C) 11363
(D) 4545
(E) 500

17. The electric field at a point in space is a measure of the

(A) total charge on an object at that point.
(B) electric force on any charged object at that point.
(C) electric force per unit mass on a point charge at that point.
(D electric charge per dipole moment
(E) electric force per unit charge at that point

18. Two charged particles attract each other with a force of magnitude F acting on each. If the charge of one is doubled and the distance separating the particles is also halved, the force acting on each of the two particles has magnitude

(A)F/2
(B) F/4
(C) F
(D) 2F
(E) 8F

19. A charged insulator and an uncharged metal brought near each other

(A) exert no electric force on each other.

(B) repel each other electrically.

(C) attract each other electrically.

(D) attract or repel, depending on whether the charge is positive or negative.

(E) charged insulator loses all its charge.

20. What is the correct unit for electric field?

(A) V/C only

(B) N.m/C only

(C) N/m only

(D) Nm/C or V/m

(E) N/C or V/m

21. A 25.0 Ω bulb is connected across the terminals of a 12.0 V battery having 3.50 Ω of internal resistance. What percentage of the power of the batteries power is dissipated across the internal resistance and hence not available to the bulb?

(A) 12.3 %

(B) 34.8 %

(C) 45.0 %

(D) 68.4 %

(E) 20.3 %

22. The current through a flashlight bulb is 0.720 A. How many electrons flow through the bulb each second?

(A) 9.360×10^{17}

(B) 8.889×10^{-19}

(C) 2.880×10^{-18}

(D) 1.125×10^{18}

(E) 4.500×10^{18}

23. Which of these is equal to the emf of a battery?

(A) the chemical energy stored in the battery.

(B) the maximum voltage across a load.

(C) the maximum current that the battery can supply.

(D) the amount of charge the battery can pump.

(E) the terminal voltage of the battery when no current flows.

24. How does the resistance of a piece of conducting wire change if both its length and diameter are doubled?

(A) remains the same
(B) thrice as much

(C) twice as much

(D) half as much

(E) four times as much

25. Which of the following statements is not correct?

(A) Equivalent resistance in parallel connection is less than any of the individual resistances.
(B) Voltage drop across each resistor connected in parallel is the same.
(C) Resistors in series combine in the same way that capacitors in parallel do.
(D) Same current flows through all resistors connected in series.
(E) Equivalent resistance in parallel connection is greater than any of the individual resistances.

26. Which of the following statements is not correct?
(A) Gauss's law relates electric field to the electric charge.
(B) Ampere's law relates magnetic field to the magnetic source.
(C) Permanent magnet and electric current are sources of magnetic field.
(D) The magnetic field inside an infinite solenoid does not depend on the radius of the solenoid.
(E) Dividing a bar magnet into pieces produces monopoles.

27. Suppose that a current-carrying ohmic metal wire has a cross-sectional area that gradually becomes smaller from one end of the wire to the other. How do the drift velocity and the resistance per unit length vary along the wire as the area becomes smaller?
(A) The drift velocity and resistance remain unchanged.
(B) The drift velocity and resistance both decrease.
(C) The drift velocity increases and the resistance decreases.
(D) The drift velocity decreases and the resistance increases.
(E) The drift velocity and resistance both increase.

28. Three 5Ω resistors are connected in parallel. What emf would drive a current of 0.5 A through the circuit if the battery source has an internal resistance of $0.5\ \Omega$.

(A) 1.45 V
(B) 1.55 V
(C) 18.5 V
(D) 16.5 V
(E) 1.08 V

29. Which of the following equations is not a Kirchhoff's rule?

I. $\emptyset = \int E.dA$
II. $\sum V = 0$
III. $\vec{E} = \rho\vec{J}$

(A) I and II only
(B) II and III only
(C) II only
(D) I only
(E) I and III only

30. A faulty iron cord made of 18 – gauge copper wire is replaced by a 12 – gauge copper wire which has twice the diameter as the 18 – gauge wire. How will the magnitude of the drift velocity be affected if the current remains the same.

(A) Twice as great
(B) Four times as great
(C) Half as great
(D) One – fourth as great
(E) Thrice as great

SECTION B: ANSWER ONE QUESTION IN THIS SECTION IN YOUR ANSWER BOOK

1.

(a) The two wires of a 5.0 m long appliance cord are 2.5 mm apart and carry a d.c current of 12.0 A in opposite direction.

(i) Calculate the force one wire exerts on the other.

(ii) Determine the magnitude and direction of the magnetic field half-way between the wires.

(b) A square 12 –turn coil with sides of length 40 cm carries a current of 3 A. It lies in the xy plane in a uniform magnetic field $B = (0.3\hat{\imath} + 0.4\hat{\jmath})$ T. Find

(i) the magnetic moment of the coil

(ii) the torque exerted on the coil.

[20 marks]

2. (a) A long straight wire of radius a carries a current I that is uniformly distributed over the cross sectional area of the wire. Using the Ampere's law, find the magnetic field inside the wire at a distance r from the centre ($r < a$).

(b) A circular loop of radius 4.0 cm has 12 turns and lies in the xy plane. It carries a current of 4 A in the direction such that the magnetic moment of the loop is along the z-axis. Find the magnetic field on the z-axis at z = 15 cm.

[20 marks]

SECTION C: ANSWER ONE QUESTION IN THIS SECTION IN YOUR ANSWER BOOK

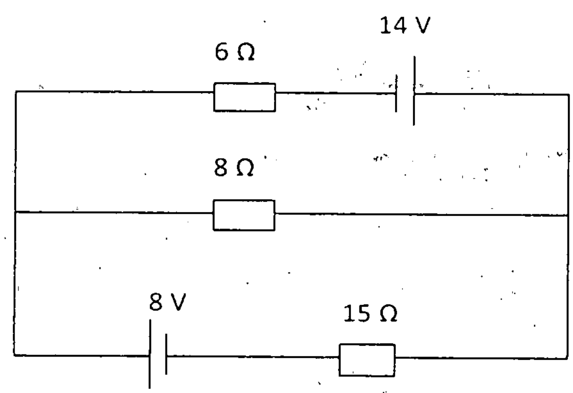
1.

(a) A cylindrical tungsten filament 15.0 cm long with a diameter of 1.00 mm is to be used in a machine for which the temperature will range from room temperature (20°C) up to 120°C. It will carry a current of 12.5 A at all temperatures. [Temperature coefficient of resistivity $\alpha = 0.0045^{o}\ K^{-1}$, and resistivity of tungsten at room temperature, $\rho = 5.25 \times 10^{-8}\ \Omega m$]

(i) What will be the maximum electrical field in the filament?

(ii) What will be the resistance when there is maximum electrical field?

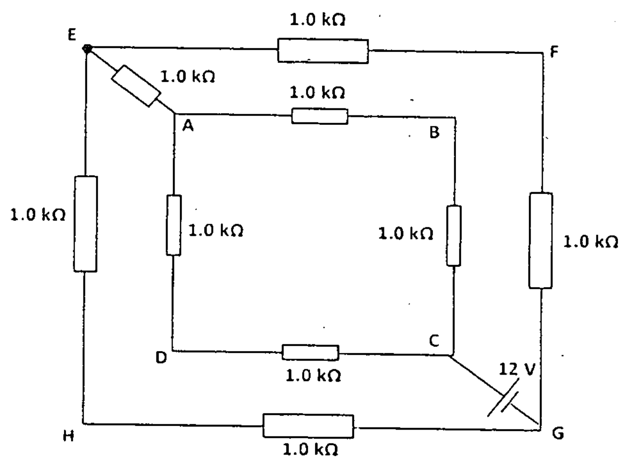
(b) Find the potential difference across the 6 Ω resistor in the circuit below.



[20 marks]

2. (a) The circuit below shows a network of resistors with 12 V source between C and G. Determine the

(i) current provided by the source.
(ii) Voltage across points G and



(b) Two parallel plates each having an area of 30 cm^2 and separated by a distance of 0.6 mm are connected to a 120 V battery. The charged plates are immersed in dielectric fluid with the battery still connected.

(i) Calculate the amount of charge on the plates just before the immersion.

(ii) Calculate the capacitance and the amount of charge on the plate after the immersion. (Take dielectric constant of the fluid to be 81.)

[20 marks]

UNIVERSITY OF GHANA

BSc. SECOND SEMESTER EXAMINATIONS: 2011/2012

PHYS 144: ELECTRICITY AND MAGNETISM (3 Credits)

ANSWER *ALL* QUESTIONS

TIME ALLOWED: TWO AND HALF (2½) HOURS

Instructions: Answer all questions in Section A, one question in Section B, and one question in Section C.

SECTION A: Answer ALL questions.

Each question is followed by five possible answers A, B, C, D and E. *Write the letter of the answer that you have chosen in the answer booklet.*

<u>Values of Physical Constants</u>

Acceleration due to gravity	$g = 9.81\ \text{m s}^{-2}$
Avogadro's number	$N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$
Coulomb force constant	$k = 9.00 \times 10^{9}\ \text{N m}^2\ \text{C}^{-2}$
Electronic charge	$e = 1.60 \times 10^{-19}\ \text{C}$
Electron mass	$m_e = 9.11 \times 10^{-31}\ \text{kg}$
Proton mass	$m_p = 1.67 \times 10^{-27}\ \text{kg}$
Permeability of free space	$\mu_o = 4\pi \times 10^{-7}\ \text{T m A}^{-1}$
Permittivity of free space	$\epsilon_o = 8.55 \times 10^{-12}\ \text{C}^2\ \text{N}^{-1}\ \text{m}^{-2}$
Pi	$\pi = 3.14$

Examiners: V. K. Kattah, A. A. Yankson, A. Amankwah, J. A. M. Hodasi

1. The magnetic field lines **inside** a bar magnet run in what direction?
   (A) From North Pole to South Pole.
   (B) From South Pole to North Pole.
   (C) From side to side.
   (D) No magnetic field lines inside a bar magnet.
   (E) None of the above.

2. A circular wire has a diameter of 30 cm and contains 20 loops. The current in each loop is 5 A and the coil is placed in an external magnetic field such that a maximum torque of 1.88 Nm is exerted on the coil by the field. Calculate the magnitude of the magnetic field.
   (A) 0.27 T
   (B) 3.76 T
   (C) 0.35 T
   (D) 0.72 T
   (E) 0.35 T

3. An electron moves in the plane of this page toward the top of the page. A magnetic field is also in the plane of the page and directed toward the right. The direction of the magnetic force on the electron is

   (A) toward the bottom of the page,
   (B) toward the left edge of the page,
   (C) toward the right edge of the page.
   (D) upward out of the page,
   (E) downward into the page.

4. A charged particle moves with velocity **v** in a magnetic field **B**. The magnetic force on the particle is a maximum when **v** is

   (A) parallel to **B**
   (B) perpendicular to **B**
   (C) half of **B**
   (D) equal to **B**
   (E) zero

5. A television set uses a magnetic field to deflect its electron beam. This magnetic field is able to steer the electron beam because
   (A) a moving charge can experience a force when it passes through a magnetic field.
   (B) an electron always travels in the direction of the electric field.
   (C) an electron always travels at a right angle to the magnetic field.
   (D) a stationary charge experiences a force in a magnetic field.
   (E) the velocity of the electron is parallel to the field.

6. A copper wire has 2.0×10^{29} free electrons per cubic metre, a cross-sectional area of $2.0\ m^2$ and carries a current of 5.0 A. Calculate the force acting on each electron if the wire is now placed in a magnetic field of magnitude 0.15 T that is perpendicular to the wire.
   (A) 0.9×10^{28} N
   (B) 1.9×10^{-28} N
   (C) 2.1×10^{-29} N
   (D) 1.1×10^{29} N
   (E) 4.1×10^{-28} N

7. The magnetic field due to a very long, straight wire carrying a current I is 0.20 T at a distance r from the wire. Determine the field due to the wire when I is halved and r is doubled.
   (A) 0.1 T
   (B) 0.2 T
   (C) 0.5 T
   (D) 0.6 T
   (E) 0.8 T

8. Which of the following is the correct expression for Gauss's law in magnetism?
   (A) $\oint \boldsymbol{B} \cdot d\boldsymbol{l} = \mu_o I$
   (B) $\oint \boldsymbol{B} \cdot d\boldsymbol{A} = 0$
   (C) $\oint \boldsymbol{E} \cdot d\boldsymbol{A} = {Q}/{\epsilon_o}$
   (D) $\oint \boldsymbol{B} \cdot d\boldsymbol{A} = {I}/{\mu_o}$
   (E) $\oint \boldsymbol{E} \cdot d\boldsymbol{A} = 0$

9. A straight wire carries a 12.0 A current. Determine the magnitude of the magnetic field due to a 3.1×10^{-3} m segment of the wire at a point 2.0×10^{-2} m away from it, if the point is on a line at 30^0 to the segment.

(A) 4.7×10^{-6} T
(B) 5.3×10^{-6} T
(C) 6.2×10^{-6} T
(D) 7.8×10^{-6} T
(E) 8.2×10^{-6} T

10. A circular loop lying in a horizontal plane carries current in the clockwise direction. The direction of the magnetic dipole moment is
(A) clockwise
(B) horizontal
(C) into the plane
(D) out of the plane
(E) counterclockwise

11. Given a group of charges close to each other whose net value is nonzero, the equipotential surface at a very great distance is
(A) nearly a plane.
(B) nearly a sphere.
(C) quite indeterminate.
(D) nearly a cylinder.
(E) nearly a pyramid.

12. A 20 pF parallel plate capacitor whose plates are 0.5 mm apart is connected across a 15 V battery. How much energy will it store?
(A) 60 J
(B) 0.416 J
(C) 2.25 nJ
(D) 1.4 nJ
(E) 5.9 nJ

13. The center of a small spherical body of radius r, uniformly charged over its surface with charge Q, coincides with the center of one side of a cube of edge length a (a > 2r). What is the flux of the electric field strength vector through the cube?
(A) $Q/2\varepsilon_0$ Nm^2/C
(B) $3Q/2\varepsilon_0$ Nm^2/C
(C) $4Q/5\varepsilon_0$ Nm^2/C
(D) Q/ε_0 Nm^2/C
(E) $2Q/\varepsilon_0$ Nm^2/C

14. A uniform electric field $(a\hat{\imath} + b\hat{\jmath})$ intersects a surface of area A. What is the flux through this area if the surface lies in the xy plane?

(A) 0
(B) (a + b)A
(C) bA
(D) aA
(E) (a - b)A

15. What is the drift velocity of electrons in a copper (64.0 g/mol) wire of radius 1.2 mm carrying a current of 2A? (ρ_{copper}=8.93g/cm^3)

(A) 3.28×10^{1} m/s
(B) 1.644×10^{2} m/s
(C) 6.08×10^{-2} m/s
(D) 3.28×10^{-5} m/s
(E) 4.23×10^{2} m/s

16. How many 1.00 μF capacitors must be connected in parallel to store a charge of 1.00 C with a potential of 220 V across the capacitors?

(A) 900
(B) 9090
(C) 11363
(D) 4545
(E) 500

17. The electric field at a point in space is a measure of the

(A) total charge on an object at that point.
(B) electric force on any charged object at that point.
(C) electric force per unit mass on a point charge at that point.
(D electric charge per dipole moment
(E) electric force per unit charge at that point

18. Two charged particles attract each other with a force of magnitude F acting on each. If the charge of one is doubled and the distance separating the particles is also halved, the force acting on each of the two particles has magnitude

(A)F/2
(B) F/4
(C) F
(D) 2F
(E) 8F

19. A charged insulator and an uncharged metal brought near each other

(A) exert no electric force on each other.

(B) repel each other electrically.

(C) attract each other electrically.

(D) attract or repel, depending on whether the charge is positive or negative.

(E) charged insulator loses all its charge.

20. What is the correct unit for electric field?

(A) V/C only

(B) N.m/C only

(C) N/m only

(D) Nm/C or V/m

(E) N/C or V/m

21. A 25.0 Ω bulb is connected across the terminals of a 12.0 V battery having 3.50 Ω of internal resistance. What percentage of the power of the batteries power is dissipated across the internal resistance and hence not available to the bulb?

(A) 12.3 %

(B) 34.8 %

(C) 45.0 %

(D) 68.4 %

(E) 20.3 %

22. The current through a flashlight bulb is 0.720 A. How many electrons flow through the bulb each second?

(A) 9.360×10^{17}

(B) 8.889×10^{-19}

(C) 2.880×10^{-18}

(D) 1.125×10^{18}

(E) 4.500×10^{18}

23. Which of these is equal to the emf of a battery?

(A) the chemical energy stored in the battery.

(B) the maximum voltage across a load.

(C) the maximum current that the battery can supply.

(D) the amount of charge the battery can pump.

(E) the terminal voltage of the battery when no current flows.

24. How does the resistance of a piece of conducting wire change if both its length and diameter are doubled?

(A) remains the same
(B) thrice as much
(C) twice as much
(D) half as much
(E) four times as much

25. Which of the following statements is not correct?

(A) Equivalent resistance in parallel connection is less than any of the individual resistances.
(B) Voltage drop across each resistor connected in parallel is the same.
(C) Resistors in series combine in the same way that capacitors in parallel do.
(D) Same current flows through all resistors connected in series.
(E) Equivalent resistance in parallel connection is greater than any of the individual resistances.

26. Which of the following statements is not correct?
(A) Gauss's law relates electric field to the electric charge.
(B) Ampere's law relates magnetic field to the magnetic source.
(C) Permanent magnet and electric current are sources of magnetic field.
(D) The magnetic field inside an infinite solenoid does not depend on the radius of the solenoid.
(E) Dividing a bar magnet into pieces produces monopoles.

27. Suppose that a current-carrying ohmic metal wire has a cross-sectional area that gradually becomes smaller from one end of the wire to the other. How do the drift velocity and the resistance per unit length vary along the wire as the area becomes smaller?
(A) The drift velocity and resistance remain unchanged.
(B) The drift velocity and resistance both decrease.
(C) The drift velocity increases and the resistance decreases.
(D) The drift velocity decreases and the resistance increases.
(E) The drift velocity and resistance both increase.

28. Three 5Ω resistors are connected in parallel. What emf would drive a current of 0.5 A through the circuit if the battery source has an internal resistance of $0.5\ \Omega$.

(A) 1.45 V
(B) 1.55 V
(C) 18.5 V
(D) 16.5 V
(E) 1.08 V

29. Which of the following equations is not a Kirchhoff's rule?

I. $\emptyset = \int E.dA$
II. $\sum V = 0$
III. $\vec{E} = \rho \vec{J}$

(A) I and II only
(B) II and III only
(C) II only
(D) I only
(E) I and III only

30. A faulty iron cord made of 18 – gauge copper wire is replaced by a 12 – gauge copper wire which has twice the diameter as the 18 – gauge wire. How will the magnitude of the drift velocity be affected if the current remains the same.

(A) Twice as great
(B) Four times as great
(C) Half as great
(D) One – fourth as great
(E) Thrice as great

SECTION B: ANSWER ONE QUESTION IN THIS SECTION IN YOUR ANSWER BOOK

1.

(a) The two wires of a 5.0 m long appliance cord are 2.5 mm apart and carry a d.c current of 12.0 A in opposite direction.

(i) Calculate the force one wire exerts on the other.

(ii) Determine the magnitude and direction of the magnetic field half-way between the wires.

(b) A square 12 –turn coil with sides of length 40 cm carries a current of 3 A. It lies in the xy plane in a uniform magnetic field $B = (0.3\hat{\imath} + 0.4\hat{\jmath})$ T. Find

(i) the magnetic moment of the coil

(ii) the torque exerted on the coil.

[20 marks]

2. (a) A long straight wire of radius a carries a current I that is uniformly distributed over the cross sectional area of the wire. Using the Ampere's law, find the magnetic field inside the wire at a distance r from the centre ($r < a$).

(b) A circular loop of radius 4.0 cm has 12 turns and lies in the xy plane. It carries a current of 4 A in the direction such that the magnetic moment of the loop is along the z-axis. Find the magnetic field on the z-axis at z = 15 cm.

[20 marks]

SECTION C: ANSWER ONE QUESTION IN THIS SECTION IN YOUR ANSWER BOOK

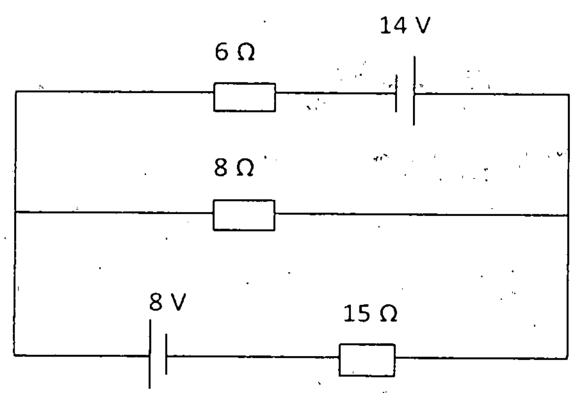
1.

(a) A cylindrical tungsten filament 15.0 cm long with a diameter of 1.00 mm is to be used in a machine for which the temperature will range from room temperature (20°C) up to 120°C. It will carry a current of 12.5 A at all temperatures. [Temperature coefficient of resistivity $\alpha = 0.0045^{o}\ K^{-1}$, and resistivity of tungsten at room temperature, $\rho = 5.25 \times 10^{-8}\ \Omega m$]

(i) What will be the maximum electrical field in the filament?

(ii) What will be the resistance when there is maximum electrical field?

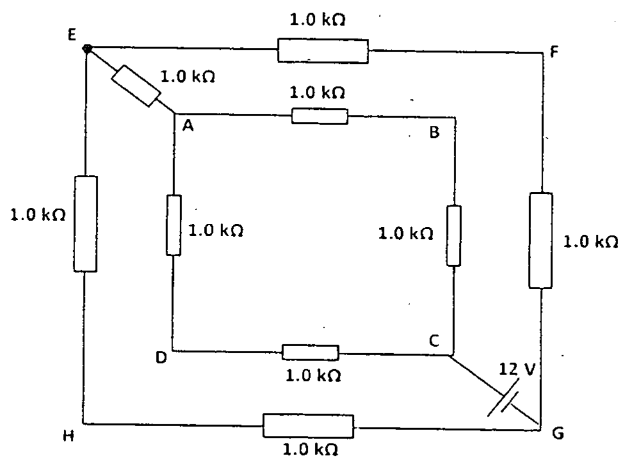
(b) Find the potential difference across the 6 Ω resistor in the circuit below.



[20 marks]

2. (a) The circuit below shows a network of resistors with 12 V source between C and G. Determine the

(i) current provided by the source.
(ii) Voltage across points G and



(b) Two parallel plates each having an area of 30 cm^2 and separated by a distance of 0.6 mm are connected to a 120 V battery. The charged plates are immersed in dielectric fluid with the battery still connected.

(i) Calculate the amount of charge on the plates just before the immersion.

(ii) Calculate the capacitance and the amount of charge on the plate after the immersion. (Take dielectric constant of the fluid to be 81.)

[20 marks]

Electric Field

Refs.: Young and Freeman, University Physics, Chapter 21, © 2020

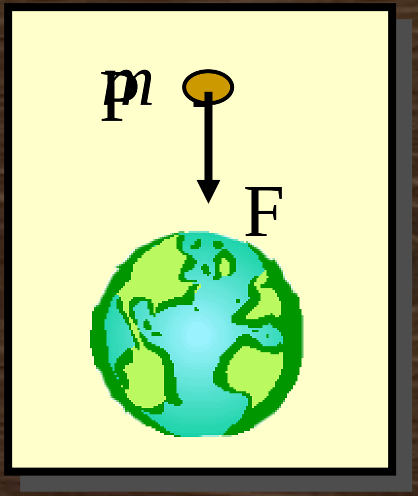
Paul E. Tippens, Southern Polytechnic State University, © 2007

Objectives: After finishing this unit you should be able to:

- Define the electric field and explain what determines its magnitude and direction.
- Write and apply formulas for the electric field intensity at known distances from point charges.
- Discuss electric field lines and the meaning of permittivity of space.

The Concept of a Field

A field is defined as a property of space in which a material object experiences a force.



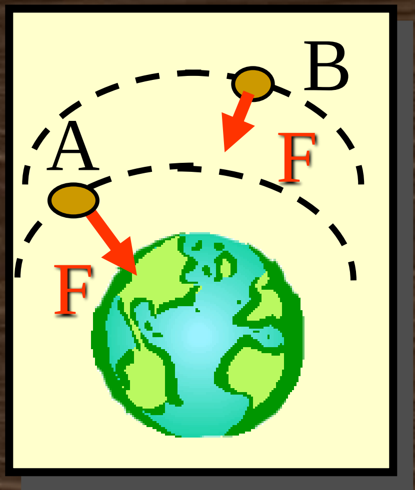
Above earth, we say there is a gravitational field at P.

Because a mass *m* experiences a downward force at that point.

No force, no field; No field, no force!

The direction of the field is determined by the force.

The Gravitational Field



Consider points A and B above the surface of the earth—just points in space.

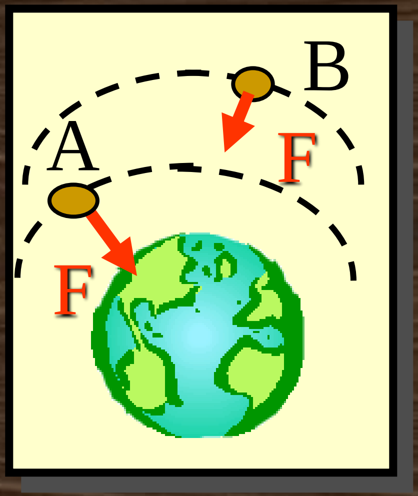
The field at points A or B might be found from:

$$g = \frac{F}{m}$$

If g is known at every point above the earth then the force F on a given mass can be found.

The magnitude and direction of the field g depends on the weight, which is the force F.

The Gravitational Field



Note that the force F is real, but the field is just a convenient way of describing space.

The field at points A or B might be found from:

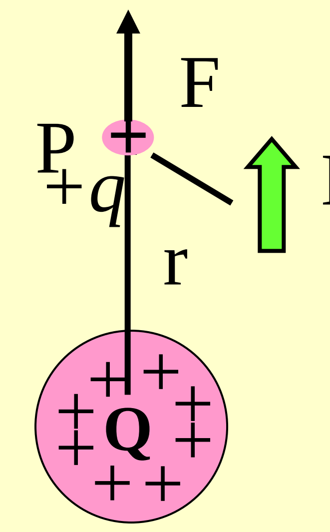
$$g = \frac{F}{m}$$

If g is known at every point above the earth then the force F on a given mass can be found.

The magnitude and direction of the field g depends on the weight, which is the force F.

The Electric Field

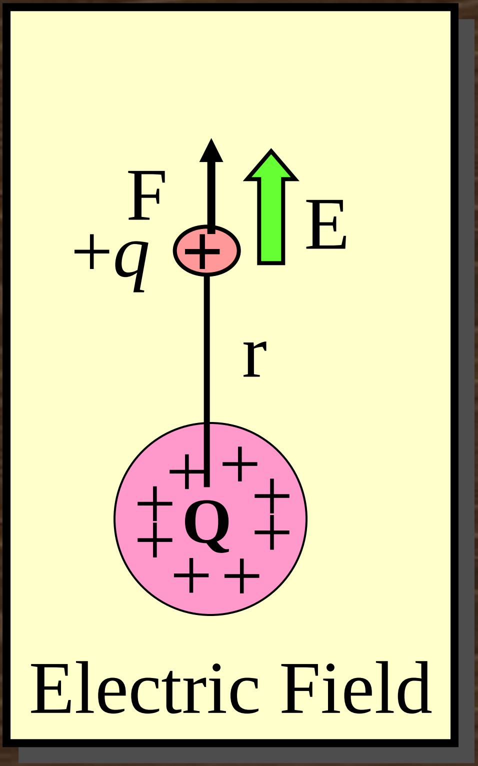
1. Now, consider point P a distance *r* from +Q.
2. An electric field E exists at P if a test charge +q has a force F at that point.
3. The direction of the E is the same as the direction of a force on + (pos) charge.
4. The magnitude of E is given by the formula:



Electric Field

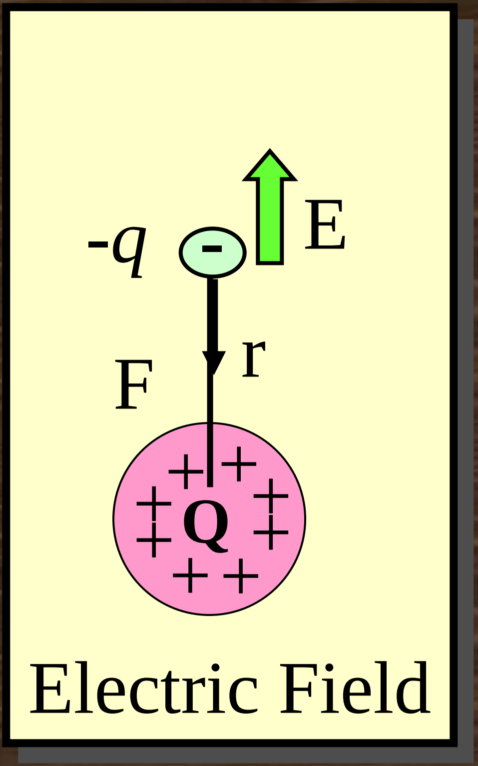
$$E = \frac{F}{q}; \text{ Units } \frac{\text{N}}{\text{C}}$$

Field is Property of Space



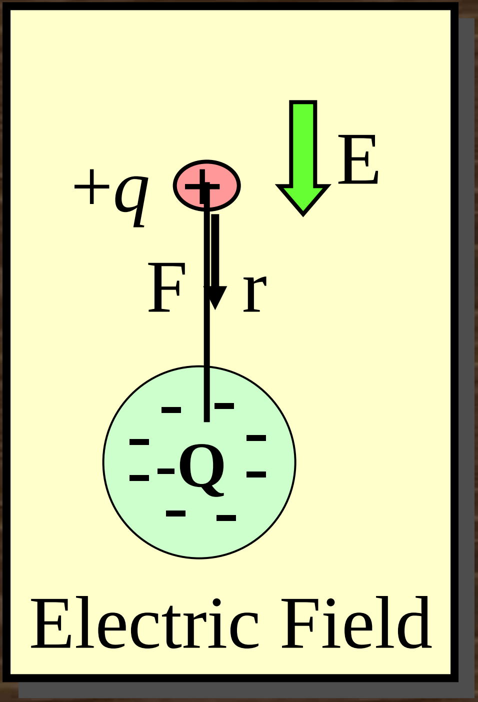
Force on +q is with field direction.

Force on -q is against field direction.



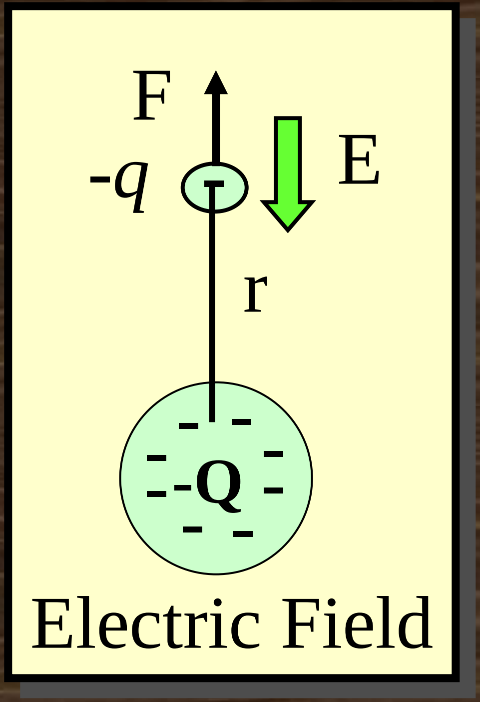
The field E at a point exists whether there is a charge at that point or not. The direction of the field is away from the +Q charge.

Field Near a Negative Charge



Force on +q is with field direction.

Force on -q is against field direction.



Note that the field E in the vicinity of a negative charge –Q is toward the charge—the direction that a +q test charge would move.

The Magnitude of E-Field

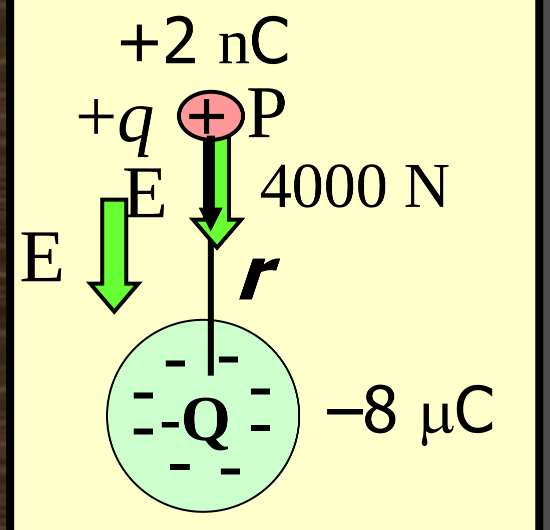
The magnitude of the electric field intensity at a point in space is defined as the force per unit charge (N/C) that would be experienced by any test charge placed at that point.

Electric Field Intensity E

$$E = \frac{F}{q}; \text{ Units } \left(\frac{\text{N}}{\text{C}}\right)$$

The direction of E at a point is the same as the direction that a positive charge would move IF placed at that point.

Example 1. A +2 nC charge is placed at a distance r from a –8 μC charge. If the charge experiences a force of 4000 N, what is the electric field intensity E at point P?



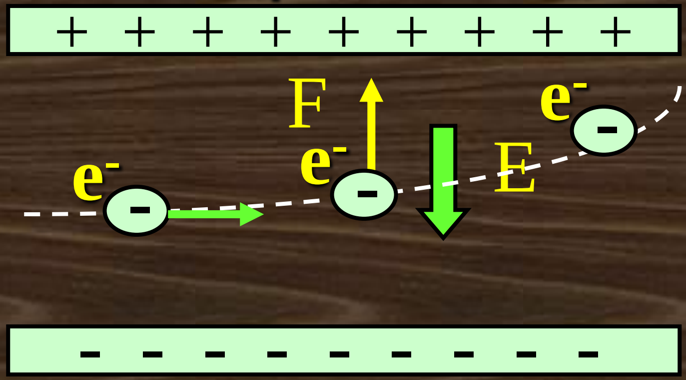
First, we note that the direction of E is toward –Q (down).

$$E = \frac{F}{q} = \frac{4000\ \text{N}}{2 \times 10^{-9}\text{C}}$$

E = 2 x 10^{12} N/C
Downward

Note: The field E would be the same for any charge placed at point P. It is a property of that space.

Example 2. A constant E field of 40,000 N/C is maintained between the two parallel plates. What are the magnitude and direction of the force on an electron that passes horizontally between the plates.



The E-field is downward, and the force on e^- is up.

$$E = \frac{F}{q}; \quad F = qE$$

$$F = qE = (1.6 \text{ x } 10^{-19}\text{C})(4 \text{ x } 10^{4} \tfrac{N}{C})$$

$$\boxed{F = 6.40 \text{ x } 10^{-15} \text{ N, Upward}}$$

The E-Field at a distance r from a single charge Q

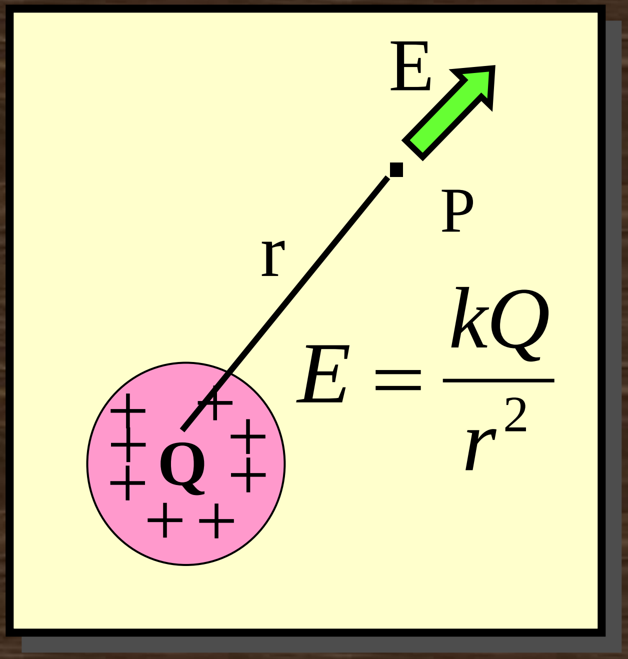
Consider a test charge +q placed at P a distance r from Q.

The outward force on +q is:

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

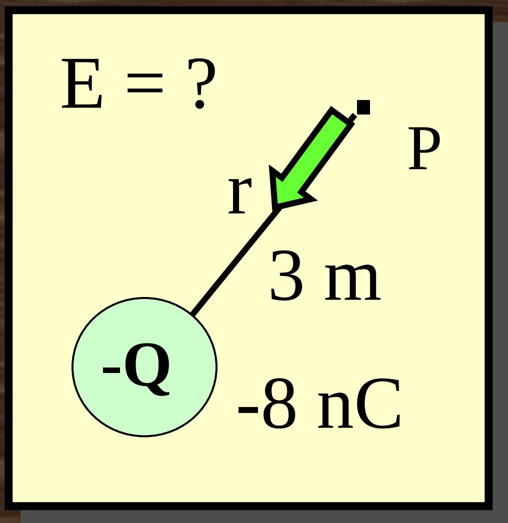
The electric field E is therefore:

$$E = \frac{F}{q} = \frac{kQ\cancel{q}/r^2}{\cancel{q}}$$



$$\boxed{E = \frac{kQ}{r^2}}$$

Example 3. What is the electric field intensity E at point P, a distance of 3 m from a negative charge of –8 nC?



First, find the magnitude:

$$E = \frac{kQ}{r^2} = \frac{(9 \text{ x } 10^9 \frac{\text{Nm}^2}{\text{C}^2})(8 \text{ x } 10^{-9}\text{C})}{(3 \text{ m})^2}$$

E = 8.00 N/C

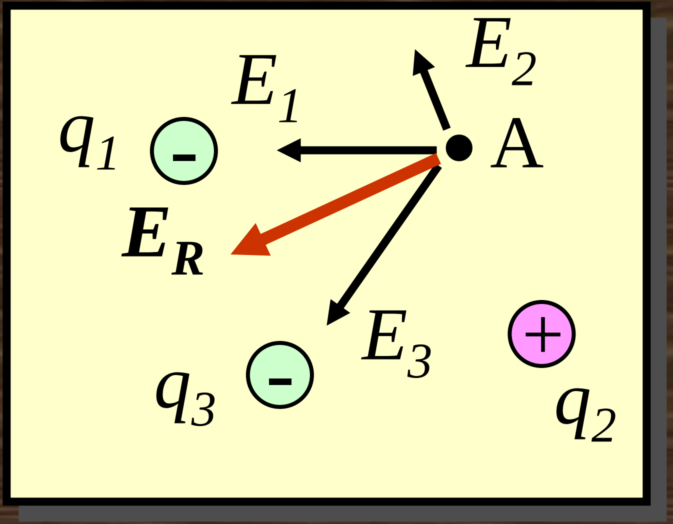
The direction is the same as the force on a positive charge if it were placed at the point P: toward –Q.

E = 8.00 N, toward -Q

The Resultant Electric Field.

The resultant field E in the vicinity of a number of point charges is equal to the vector sum of the fields due to each charge taken individually.

Consider E for each charge.



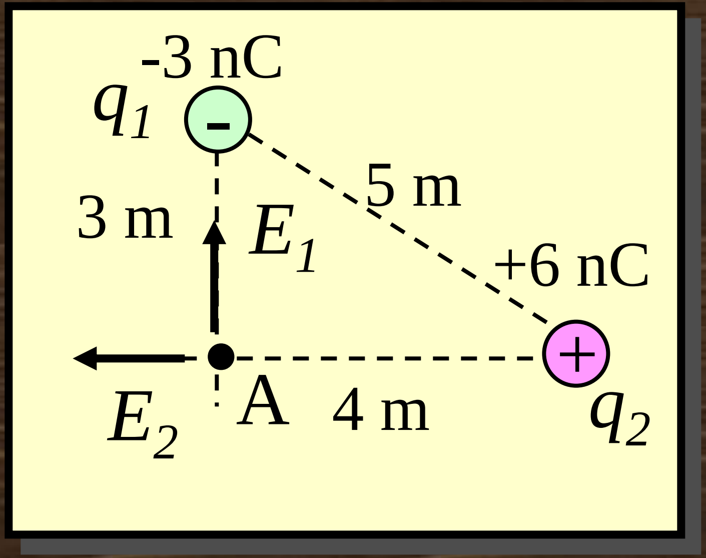
Vector Sum:
$\boldsymbol{E} = \boldsymbol{E_1} + \boldsymbol{E_2} + \boldsymbol{E_3}$

Magnitudes are from:

$$E = \frac{kQ}{r^2}$$

Directions are based on positive test charge.

Example 4. Find the resultant field at point A due to the –3 nC charge and the +6 nC charge arranged as shown.

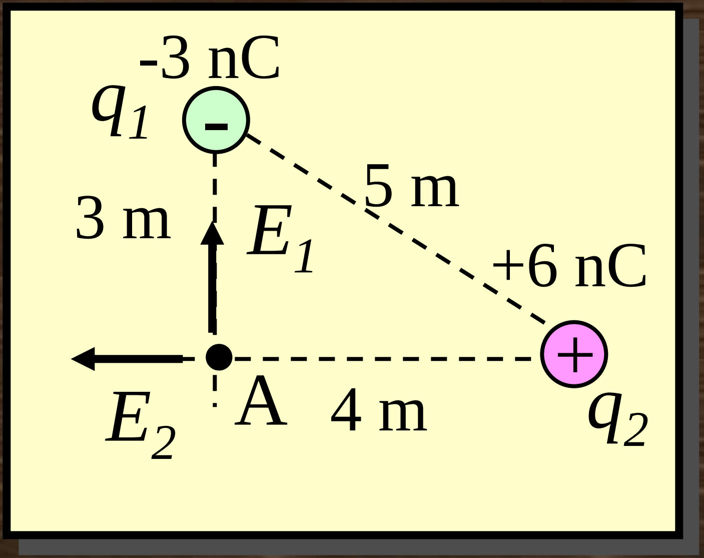


E for each q is shown with direction given.

$$E_1 = \frac{kq_1}{r_1^2}; \quad E_2 = \frac{kq_2}{r_2^2}$$

$$E_1 = \frac{(9 \text{ x } 10^9 \frac{\text{Nm}^2}{\text{C}^2})(3 \text{ x } 10^{-9}\text{C})}{(3 \text{ m})^2} \qquad E_2 = \frac{(9 \text{ x } 10^9 \frac{\text{Nm}^2}{\text{C}^2})(6 \text{ x } 10^{-9}\text{C})}{(4 \text{ m})^2}$$

Example 4. (Cont.) Find the resultant field at point A. The magnitudes are:



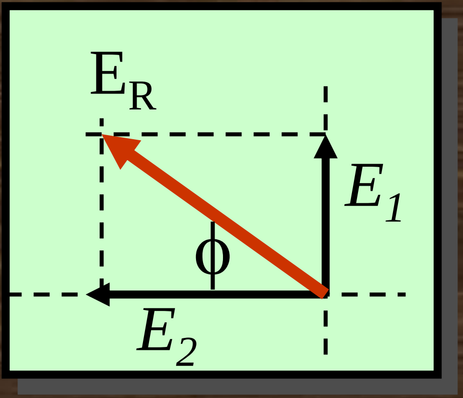
$$E_1 = \frac{(9 \text{ x } 10^9 \frac{\text{Nm}^2}{\text{C}^2})(3 \text{ x } 10^{-9}\text{C})}{(3 \text{ m})^2}$$

$$E_2 = \frac{(9 \text{ x } 10^9 \frac{\text{Nm}^2}{\text{C}^2})(6 \text{ x } 10^{-9}\text{C})}{(4 \text{ m})^2}$$

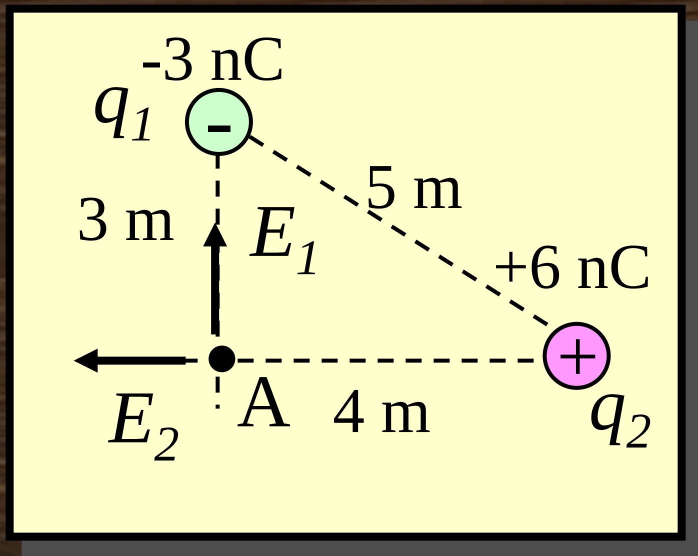
E_1 = 3.00 N, West E_2 = 3.38 N, North

Next, we find vector resultant E_R

$$E_R = \sqrt{E_2^2 + E_1^2}; \ \tan\varphi = \frac{E_1}{E_2}$$



Example 4. (Cont.) Find the resultant field at point A. The magnitudes are:



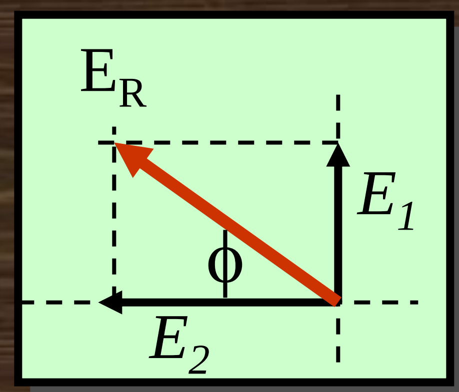
$$E_{1x} = 3.00 \cos 90 = 0$$
$$E_{1y} = 3.00 \sin 90 = 3.00$$

$$E_{2x} = 3.38 \cos 180 = -3.38$$
$$E_{2y} = 3.38 \sin 180 = 0$$

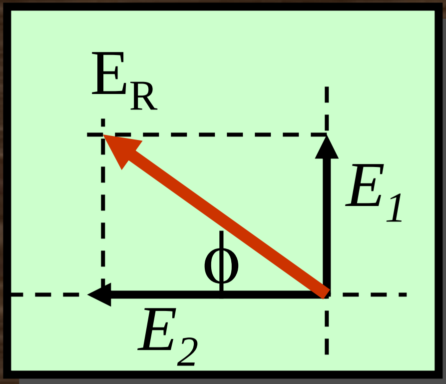
$E_1 = E_{1y} = 3.00$ N, West $\quad E_2 = E_{2x} = 3.38$ N, North

Next, we find vector resultant E_R

$$E_R = \sqrt{E_2^2 + E_1^2};\ \tan\varphi = \frac{E_1}{E_2}$$



Example 4. (Cont.) Find the resultant field at point A using vector mathematics.



$E_1 = E_{1y} = 3.00$ N, West $= 3\hat{j}$

$E_2 = E_{2x} = 3.38$ N, North $= -3.38\hat{\imath}$

Find vector resultant E_R

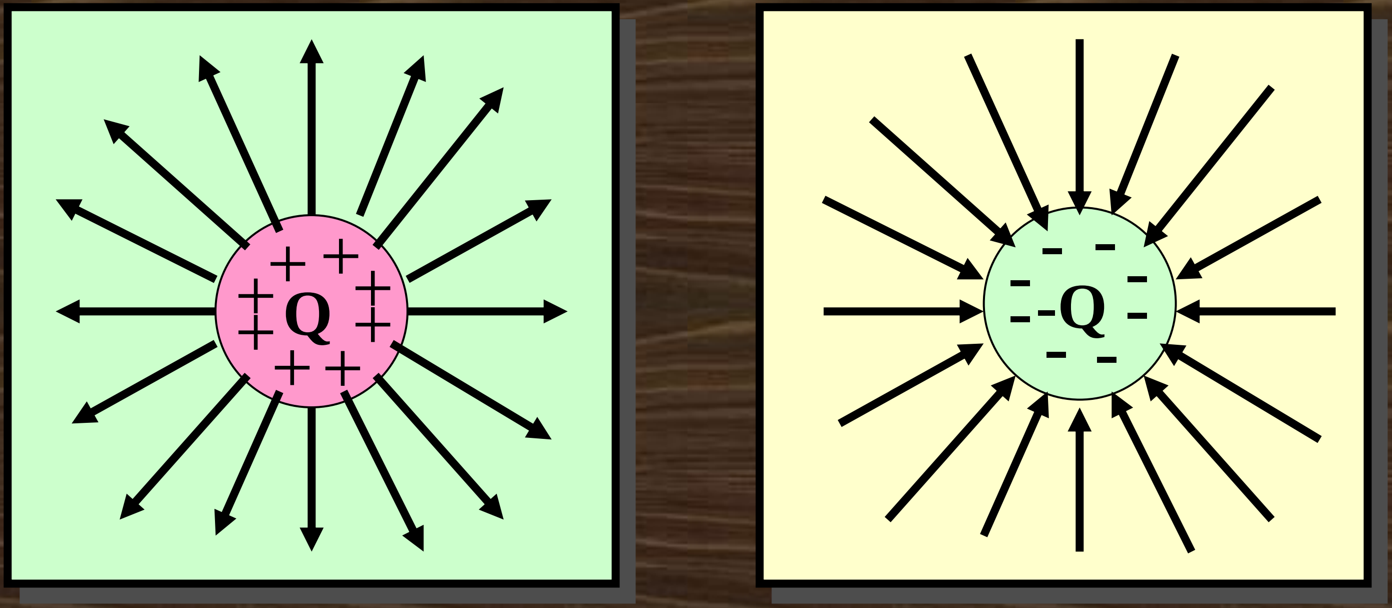
$$E = \sqrt{(-3.38\text{ N})^2 + (3.00\text{ N})^2} = 4.52\text{ N}; \quad \tan\varphi = \frac{3.00\text{ N}}{3.83\text{ N}}$$

$\phi = 41.6^0$ N of W; or $\theta = 138^0$

Resultant Field: $E_R = 4.52$ N; 138^0

Electric Field Lines

Electric Field Lines are imaginary lines drawn in such a way that their direction at any point is the same as the direction of the field at that point.

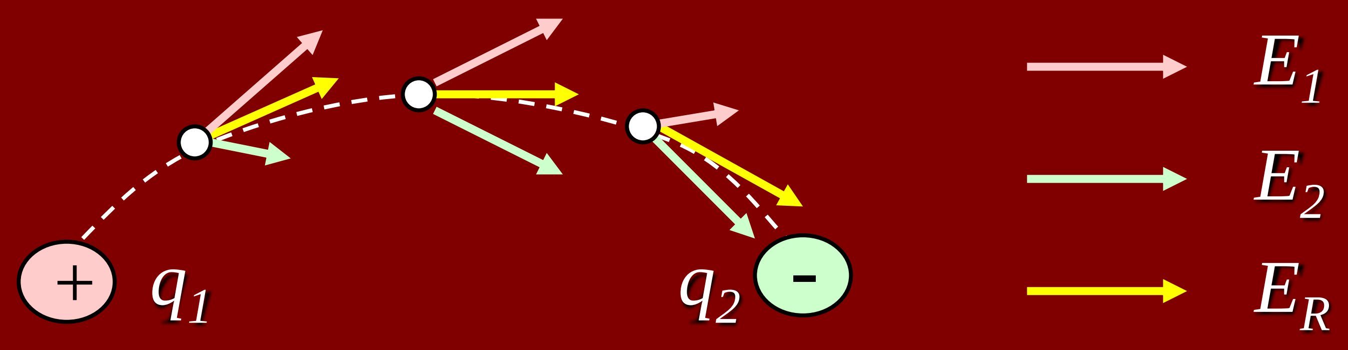


Field lines go away from positive charges and toward negative charges.

Rules for Drawing Field Lines

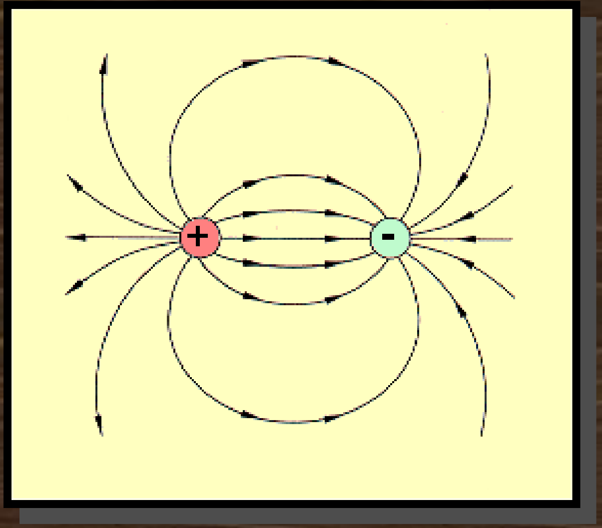
1. The direction of the field line at any point is the same as motion of +q at that point.

2. The spacing of the lines must be such that they are close together where the field is strong and far apart where the field is weak.

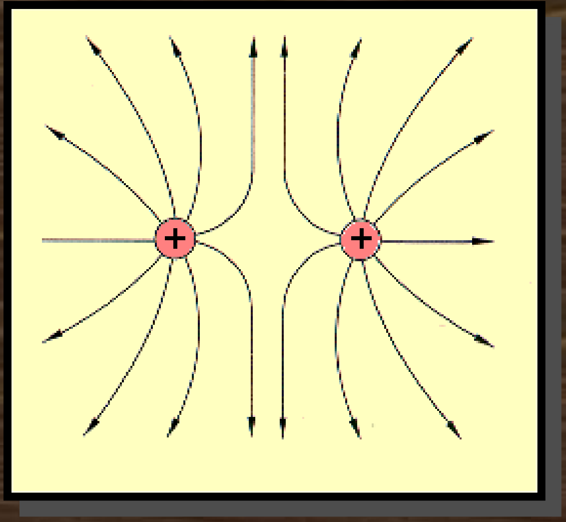


Examples of E-Field Lines

Two equal but opposite charges.



Two identical charges (both +).



Notice that lines leave + charges and enter - charges.

Also, E is strongest where field lines are most dense.

Summary of Formulas

The Electric Field Intensity *E*:

$$E = \frac{F}{q} = \frac{kQ}{r^2} \qquad \text{Units are } \frac{\text{N}}{\text{C}}$$

The Electric Field Near several charges:

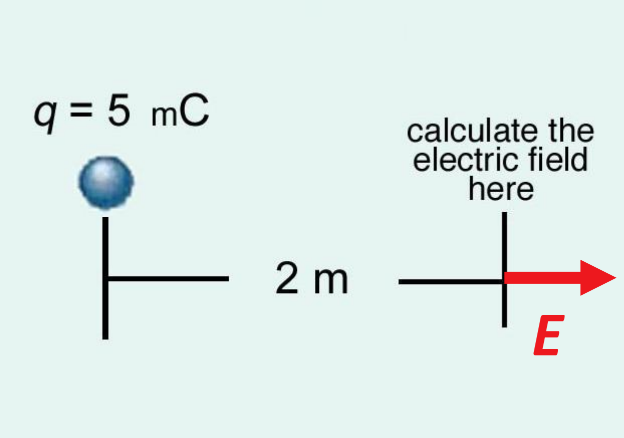
$$E = \sum \frac{kQ}{r^2} \qquad \text{Vector Sum}$$

$$\varepsilon_0 = \frac{1}{4\pi k}$$

$$\varepsilon_0 = \frac{1}{4\pi k} = 8.85 \text{ x } 10^{-12} \frac{\text{C}^2}{\text{N} \cdot \text{m}^2}$$

Tutorials

EXAMPLE 1



Find the electric field strength at 2 meters from the 5 millicoulomb charge.

$$E = \frac{kq}{r^2} \qquad E = \frac{\left(9\times10^{9}\ \mathrm{Nm^2/C^2}\right)\left(5\times10^{-3}\ \mathrm{C}\right)}{\left(2\ \mathrm{m}\right)^2}$$

$$E = 1.13\times10^{7}\ \mathrm{N/C},\ \text{to the right}$$

EXAMPLE 2

Find the force on a proton placed 2 meters from the 5 millicoulomb charge in the problem above.

$$E = \frac{F_e}{q} \qquad F_e = qE = \left(1.6\times10^{-19}\ \mathrm{C}\right)\left(1.13\times10^{7}\ \mathrm{N/C}\right) = 1.81\times10^{-12}\ \mathrm{N},\ \text{to the right}$$

OR

$$F_e = \frac{\left(9\times10^{9}\ \mathrm{Nm^2/C^2}\right)\left(5\times10^{-3}\ \mathrm{C}\right)\left(1.6\times10^{-19}\ \mathrm{C}\right)}{\left(2\ \mathrm{m}\right)^2} = 1.8\times10^{-12}\ \mathrm{N},\ \text{to the right}$$

Example 21.5 Electric-field magnitude for a point charge

What is the magnitude of the electric field at a field point 2.0 m from a point charge $q = 4.0$ nC? (The point charge could represent any small charged object with this value of q, provided the dimensions of the object are much less than the distance from the object to the field point.)

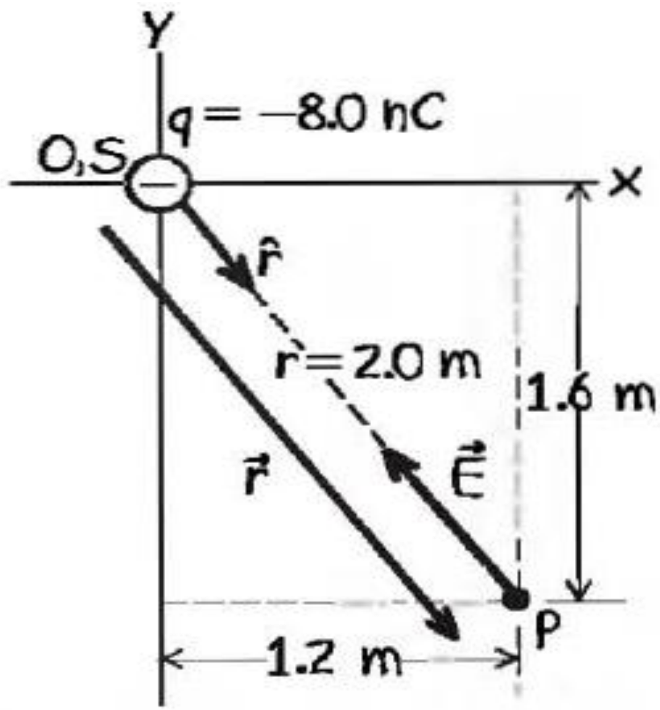
$$E = \frac{1}{4\pi\epsilon_0}\frac{|q|}{r^2} = (9.0 \times 10^9\ \mathrm{N \cdot m^2/C^2})\frac{4.0 \times 10^{-9}\ \mathrm{C}}{(2.0\ \mathrm{m})^2}$$

$$= 9.0\ \mathrm{N/C}$$

Example 21.6 Electric-field vector for a point charge

A point charge $q = -8.0\ \text{nC}$ is located at the origin. Find the electric-field vector at the field point $x = 1.2\ \text{m}$, $y = -1.6\ \text{m}$.

$$r = \sqrt{x^2 + y^2} = \sqrt{(1.2\ \text{m})^2 + (-1.6\ \text{m})^2} = 2.0\ \text{m}$$



Example 21.6 Electric-field vector for a point charge

$$\hat{r} = \frac{\vec{r}}{r} = \frac{x\hat{\imath} + y\hat{\jmath}}{r}$$

$$= \frac{(1.2\,\text{m})\hat{\imath} + (-1.6\,\text{m})\hat{\imath}}{2.0\,\text{m}} = 0.60\hat{\imath} - 0.80\hat{\jmath}$$

Hence the electric-field vector is

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r}$$

$$= (9.0 \times 10^9\,\text{N}\cdot\text{m}^2/\text{C}^2)\frac{(-8.0 \times 10^{-9}\,\text{C})}{(2.0\,\text{m})^2}(0.60\hat{\imath} - 0.80\hat{\jmath})$$

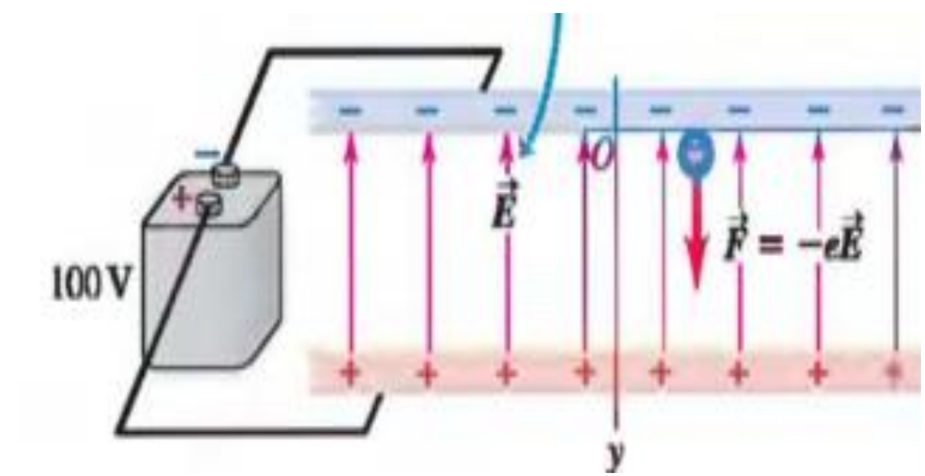
$$= (-11\,\text{N/C})\hat{\imath} + (14\,\text{N/C})\hat{\jmath}$$

Example 21.7 Electron in a uniform field

Consider an electron release from rest at the top of a pair of plates as shown.

The distance between the plates is 1 cm. Determine

a) The acceleration of the electron
b) The speed of the electron
c) The kinetic energy acquired by the electron as it hits the lower plate
d) The time it takes to reach the lower plate.



Charged Particle in a Uniform Electric Field

(a) Acceleration of the particle

$$a_y = \frac{F_y}{m} = \frac{-eE}{m} = \frac{(-1.60 \times 10^{-19}\ \mathrm{C})(1.00 \times 10^{4}\ \mathrm{N/C})}{9.11 \times 10^{-31}\ \mathrm{kg}}$$
$$= -1.76 \times 10^{15}\ \mathrm{m/s^2}$$

(b) Speed of particle $v_y^2 = v_{0y}^2 + 2a_y(y - y_0)$

(c) Time taken $v = v_o + a_y t$ $t = \dfrac{v_y - v_{0y}}{a_y} = 3.4 \times 10^{-9}\ \mathrm{s}$

(d) Kinetic energy of the particle $K = \frac{1}{2}mv^2$

NB: When position of plates are interchanged, E is downward and F = (-e)(-E) = eE