



GRADE 12 PHYSICS (40S)

Final Practice Examination

Answer Key

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Instructions

The final examination will be weighted as follows

Modules 1–10 100%

The format of the examination will be as follows:

Part A: Multiple Choice 24 x 1 = 24 marks

Part B: Fill-in-the-Blanks 14 x 0.5 = 7 marks

Part C: Short Explanation Questions 5 x 4 = 20 marks

Part D: Problems 7 x 7 = 49 marks

Grade 12 Physics Final Practice Examination Key

Part A: Multiple Choice

Write the letter of the choice that best completes each statement.

1.	d		11.	d		21.	a		
2.	c		12.	a		22.	a		
3.	c		13.	b		23.	c		
4.	b		14.	d		24.	c		
5.	c		15.	b					
6.	c		16.	c					
7.	d		17.	d					
8.	c		18.	a					
9.	d		19.	c					
10.	c		20.	b					

Part B: Fill-in-the-Blanks

Write the word that best completes each statement in the space provided below.

1.	positron emission tomography		8.	armature
2.	gamma knife surgery		9.	induced
3.	radiowaves		10.	Voltage
4.	radiocarbon dating		11.	Coulomb
5.	Becquerel		12.	volts
6.	transmutation		13.	binding
7.	atomic number		14.	weight

Part A: Multiple Choice (24 x 1 = 21 Marks)

Enter the letter of the choice that best answers the question on the answer sheet provided. Please print the letters of your answers clearly.

1. One of the hazards associated with travelling in space is the
- a) extreme heat of deep space
 - b) extreme atmospheric pressure of deep space
 - c) very low energy of ionizing cosmic radiation
 - d) possible damage to hormonal and immune systems
- Answer (d)**
Outcome S4P-2-1
2. According to Kepler, planets move in
- a) circular orbits with the sun at the centre
 - b) elliptical orbits with the sun at the centre
 - c) elliptical orbits with the sun at one of the foci
 - d) elliptical orbits with the sun at both foci
- Answer (d)**
Outcome S4P-2-2
3. In Kepler's law, Kepler's constant K is
- a) greater when the mass is closest to the central body in its orbit
 - b) a constant for any mass orbiting any central body
 - c) a constant but lesser value for a satellite orbiting a less massive central body
 - d) a constant but greater value for a mass orbiting a less massive central body
- Answer (d)**
Outcome S4P-2-2
4. As a rocket moves farther and farther away from earth,
- a) the universal gravitational constant, G , decreases in value, and the gravitational field constant, \bar{g} , also decreases in value
 - b) the universal gravitational constant, G , remains constant in value, and the gravitational field constant, \bar{g} , decreases in value
 - c) the universal gravitational constant, G , remains constant in value, and the gravitational field constant, \bar{g} , also remains constant in value
 - d) the universal gravitational constant, G , increases in value, and the gravitational field constant, \bar{g} , also increases in value
- Answer (b)**
Outcome S4P-2-8

5. In a geosynchronous orbit, the satellite
- a) has a radius of orbit that is one-half the radius of orbit of the moon
 - b) has a radius of orbit that is equivalent to the radius of earth itself
 - c) has a period of orbit equivalent to one earth day
 - d) has a period of orbit that is of the same length as one orbit of the moon around earth

Answer (c)

Outcome S4P-2-8

6. The “Hohmann transfer” is used to allow a vehicle to
- a) pass safely through earth’s atmosphere upon re-entry
 - b) launch a vehicle from earth’s surface into orbit
 - c) pass from one radius of orbit to another
 - d) launch a vehicle from earth’s surface into deep space

Answer (c)

Outcome S4P-2-12

7. A proton is located at distance r to the left of an electron. The proton is then moved around the electron in a circle with a constant radius r . The force on the proton is
- a) greater in magnitude than the force on the electron and away from the electron
 - b) greater in magnitude than the force on the electron and towards the electron
 - c) the same in magnitude as the force on the electron and away from the electron
 - d) the same in magnitude as the force on the electron and towards the electron

Answer (d)

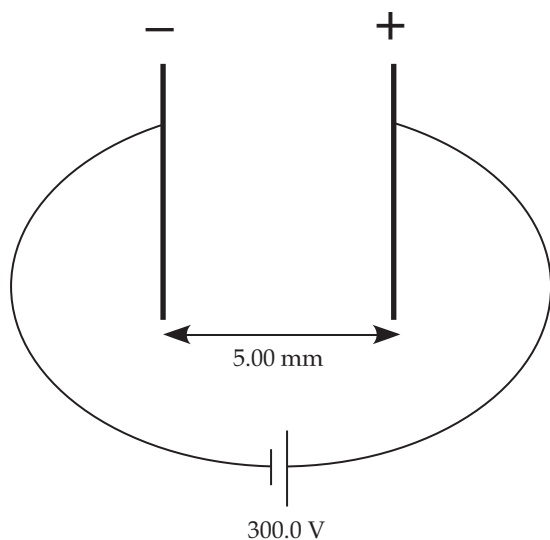
Outcome S4P-2-14

8. In comparing the gravitational force and the electric force, both forces
- a) are always attractive and can never be repulsive
 - b) are inversely proportional to the separation between the masses or charges to the first power
 - c) are directly proportional to the product of the masses or the charges
 - d) increase in magnitude and the distance between the masses or charges increases

Answer (c)

Outcome S4P-2-13

9. In a parallel plate apparatus, the plates are 5.00 mm apart. A potential difference of 300.0 V exists between the plates.



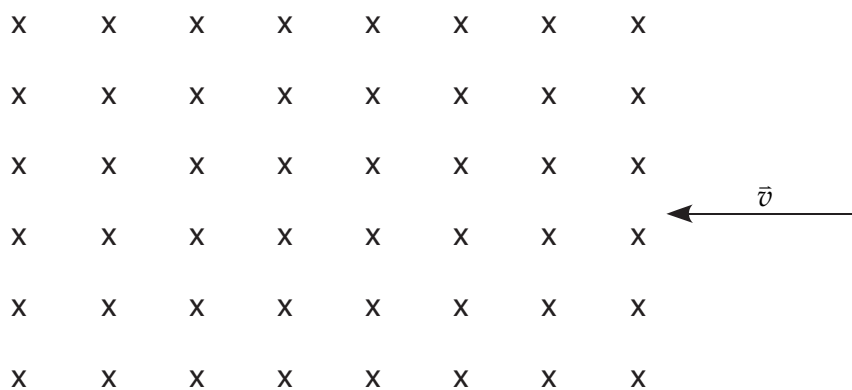
The electric field strength between the plates is

- a) 1.50 V/m
- b) 1.00×10^2 V/m
- c) 1.50×10^3 V/m
- d) 6.00×10^4 V/m

Answer (d)

Outcome S4P-2-19

10. A beam of electrons is moving towards the west. The beam, which is about to enter a magnetic field, is directed "into the page."



The direction of the magnetic force on the electrons is

- a) in the same direction as the magnetic field into the page
- b) opposite the direction of the magnetic field, out of the page
- c) upwards (north)
- d) downwards (south)

Answer (c)

Outcome S4P-2-21

11. In a mass spectrograph, a charged particle, q , passes through a velocity selector whose electric field is E and of magnetic field strength B_1 . It then passes into a magnetic field B_2 where it follows a curved path of radius R . The mass of the charged particle is

a) $m = \frac{BB'R}{qE}$

b) $m = \frac{qE}{BB'R}$

c) $m = \frac{E}{qBB'R}$

d) $m = \frac{qBB'R}{E}$

Answer(d)

Outcome S4P-2-20, S4P-2-22

12. If a current of 0.15 mA flows through a pocket calculator for 5.0 minutes, then the amount of charge delivered to the calculator is

a) 0.045 C

b) 0.000 75 C

c) 45 C

d) 0.75 C

Answer (a)

Outcome S4P-3-1

13. In general, we can say that the resistance in a current-carrying wire increases when

a) the length decreases and the cross-sectional area decreases

b) the length increases and the cross-sectional area decreases

c) the length decreases and the cross-sectional area increases

d) the length increases and the cross-sectional area increases

Answer (b)

Outcome S4P-3-3

14. There are two resistors, R_1 and R_2 , connected in parallel to a power source. To measure the current passing through the resistor R_1 ,

a) a voltmeter should be connected in parallel with R_1

b) an ammeter should be connected in parallel with R_1

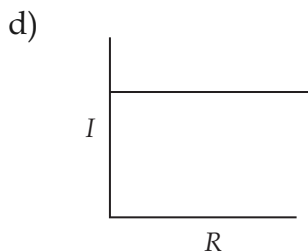
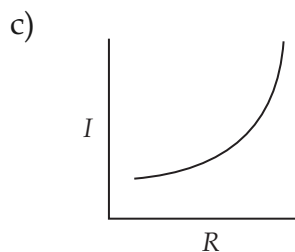
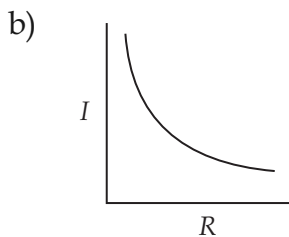
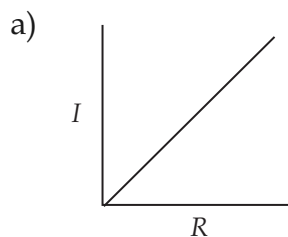
c) a voltmeter should be connected in series with R_1

d) an ammeter should be connected in series with R_1

Answer (d)

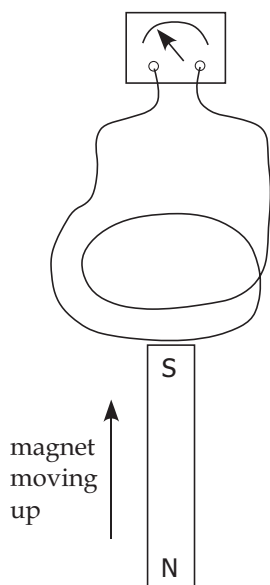
Outcome S4P-3-4

15. Based on experiments showing the relationship between current and resistance under conditions of constant voltage, the graph that shows this relationship is



Answer (b)
Outcome S4P-3-6

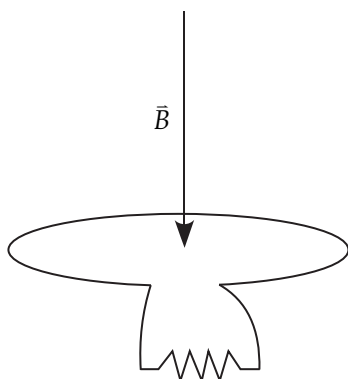
16. The diagram below shows the south pole of a magnet moving towards a coil of wire generating a current that is measured by the galvanometer. To achieve this same effect, one could



Answer (c)
Outcome S4P-3-8

- a) hold the magnet stationary and move the coil up
- b) move the south pole of the magnet downwards away from the stationary coil
- c) rotate the magnet so that the north pole faces the coil and moves downwards
- d) hold the coil and the magnet stationary but use a "stronger" magnet

17. A magnetic field of 0.10 T is directed downwards at 90.0° to a coil of wire with 10 turns. The coil has a radius of 0.39 m. The magnetic field is then removed in a time of 0.20 s. An external resistor is attached to the loop.



If more turns of wire are added to the loop, then that factor they would increase would be the

- a) resistance of the external resistor
- b) strength of the magnetic field
- c) size of the area of the coil
- d) magnitude of the induced current

Answer (d)

Outcome S4P-3-9

18. An armature had 50 turns of wire and a cross-sectional area of 0.0200 m². The armature is rotating at a frequency of 30.0 Hz to produce a peak EMF of 6.00 V. The magnetic field must be

- a) 0.0318 T
- b) 0.0637 T
- c) 0.200 T
- d) 31.4 T

Answer (a)

Outcome S4P-3-11

Answer:

$$\bar{B} = \frac{\xi}{NA2\pi f} = \frac{6.00 \text{ V}}{(50)(0.0200 \text{ m}^2)2\pi (30.0 \text{ Hz})} = 0.0318 \text{ T}$$

19. One of the isotopes of gold contains 79 protons and 118 neutrons. For this isotope, the
- a) atomic number is 79 and the mass number is 118
 - b) atomic number is 79 and the mass number is 39
 - c) atomic number is 79 and the mass number is 197
 - d) atomic number is 197 and the mass number is 79

Answer (c)

Outcome S4P-4-1

Answer:

The atomic number of an element is the number of protons in the nucleus of that element. In this case, there are 79 protons. The mass number is the sum of the number of protons and the number of neutrons. In this case, the sum of protons and neutrons is 197.

20. The strong nuclear force acts between
- a) the nucleus and the electrons to keep the atom together
 - b) all particles in the nucleus to keep the nucleus together
 - c) the protons only in a nucleus to keep the nucleus together
 - d) the neutrons only in a nucleus to keep the nucleus together

Answer (b)

Outcome S4P-4-1

Answer:

The strong nuclear force acts between all particles in the nucleus, the protons, and the neutrons to keep the nucleus together.

The strong nuclear force does not act between the nucleus and the electrons.

21. The equation showing the β^- decay of ${}^{35}_{16}\text{S}$ is

- a) ${}^{35}_{16}\text{S} \rightarrow {}^{35}_{17}\text{Cl} + {}^0_{-1}e + \bar{\nu}$
- b) ${}^{35}_{16}\text{S} \rightarrow {}^{35}_{15}\text{P} + {}^0_1e + \bar{\nu}$
- c) ${}^{35}_{16}\text{S} \rightarrow {}^{35}_{15}\text{P} + {}^0_{-1}e + \bar{\nu}$
- d) ${}^{35}_{16}\text{S} \rightarrow {}^{35}_{16}\text{S} + {}^0_{-1}e + \bar{\nu}$

Answer (a)

Outcome S4P-4-4

Answer:

The correct equation is ${}^{35}_{16}\text{S} \rightarrow {}^{35}_{17}\text{Cl} + {}^0_{-1}e + \bar{\nu}$.

In this equation, the nucleon number does not change, but the atomic number increases by one. The β^- particle is the electron.

22. A 1000 Bq source of $^{24}_{11}\text{Na}$ with a half-life of 15 h is placed in a container where its activity can be measured. How much time passes before the activity becomes 125 Bq?
- a) 45 h
 - b) 60 h
 - c) 90 h
 - d) 120 h
- Answer (a)**
Outcome S4P-4-2, S4P-4-3

Answer:

An activity of 125 Bq is $\frac{125 \text{ Bq}}{1000 \text{ Bq}} = \frac{1}{8} = \frac{1}{2^3}$ of the original value. Three half-lives have passed by. The total time passed is therefore $3(15 \text{ h}) = 45 \text{ h}$.

23. An example of ionizing radiation is
- a) radio waves
 - b) neutrons at rest
 - c) gamma waves
 - d) an α particle at rest
- Answer (c)**
Outcome S4P-4-5

Answer:

A gamma wave in a high-energy electromagnetic wave can cause matter to ionize.

24. The technique that makes use of collimated X-rays, detectors, and computer analysis to produce images of slices through the body is called
- a) MRI
 - b) endoscopy
 - c) CAT
 - d) photodynamic therapy
- Answer (c)**
Outcome S4P-4-9

Answer:

Computerized axial tomography (CAT), also called computerized tomography (CT), uses collimated X-rays, detectors, and computer analysis to produce images of body structures and lesions.

Part B: Fill-in-the-Blanks (14 x 0.5 = 7 Marks)

Fill in the blanks with one of the choices in the word bank. The terms in the word bank may be used once, more than once, or not at all.

Write your answers in the space provided on the answer sheet.

armature	current	positron emission tomography	ultrasound
atomic number	gamma knife surgery	radiocarbon dating	voltage
Becquerel	induced	radio waves	volts
binding	kinetic	resistance	weight
brushes	mass number	Rutherford	
Coulomb	Newton	transmutation	

1. A technique that allows a two-dimensional image to be taken of the body to learn about the metabolism and function of an organ is called ***positron emission tomography***. (Outcome S4P-4-9)
2. A medical technique that involves irradiating cancer cells with a highly focused beam directed through holes in a helmet is called ***gamma knife surgery***. (Outcome S4P-4-9)
3. An example of non-ionizing radiation is ***radio waves***. (Outcome S4P-4-5)
4. The age of a sample of material from once-living organisms can be determined using a process called ***radiocarbon dating***. (Outcome S4P-4-3)
5. The unit for the activity of a radioactive isotope is the ***Becquerel***. (Outcome S4P-4-2)
6. The process of the atom of one element changing into an atom of another element is called ***transmutation***. (Outcome S4P-4-4)
7. The number of protons in an atom gives the ***atomic number*** of that atom. (Outcome S4P-4-1)
8. The part of a generator that consists of a coil wound around an iron core is the ***armature***. (Outcome S4P-3-11)
9. The current that is produced by a rod moving through the magnetic field is called a(n) ***induced*** current. (Outcome S4P-3-8)
10. Two resistors are connected in parallel. In this case, which of voltage, current, or resistance will be the same for both resistors? ***Voltage*** (Outcome S4P-3-6)

11. The scientist who determined the relationship governing the electrostatic forces between point charges was **Coulomb**. (Outcome S4P-2-14)
12. Electric potential has units of **volts**. (Outcome S4P-2-18)
13. The amount of energy required to lift a satellite resting on the surface of the earth out to infinity is called the **binding** energy. (Outcome S4P-2-5)
14. The force of gravity acting on an object is also known as **weight**. (Outcome S4P-2-6)

Part C: Short Explanation Questions (5 x 4 = 20 Marks)

Answer any four (5) of the following questions. Be sure to indicate clearly which five questions are to be marked. Use proper English in your explanations.

Outcome S4P-2-1

1. Identify and briefly explain two advantages and two disadvantages of the following issue: Humans should continue to explore space.

Answer:

Advantages

Social and Economic: The curiosity of humans is a tremendous driving force. This curiosity has driven humans to explore all parts of the earth. This curiosity now drives humans to explore our neighbouring regions in space.

All organisms in nature also have a drive to spread their genetic material to ensure the survival of the species.

Many industries have developed, resulting in many jobs being created.

Technology: You enjoy the benefits of many technological advancements spurred on by space exploration. Not only do you use commonplace devices such as miniaturized cell phones, you also benefit from improved medical testing and treatment.

Your standard of living has definitely been raised.

International Cooperation: Nations from all parts of the world cooperate in the endeavour of space exploration. The International Space Station involves 16 countries.

Disadvantages

On the negative side, astronauts are exposed to great dangers while leaving the earth, returning to the earth, and actually travelling through space.

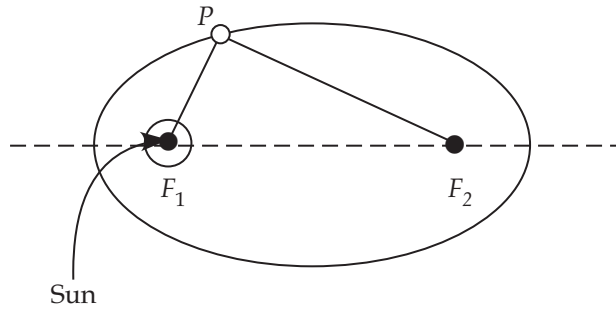
In addition to the exposure of these individuals to these dangers, there is the actual cost to all of society for the whole space program. This money could be better spent directly on finding the cures for diseases, easing world hunger, etc.

Outcome S4P-2-2

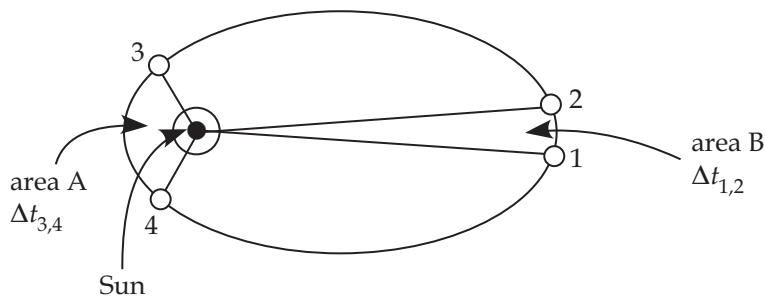
2. State Kepler's three laws of planetary motion.

Answer:

Kepler's First Law states that the planets move about the sun in elliptical orbits, with the sun at one focus of the ellipses.



Kepler's Second Law states that the straight line joining the sun and a given planet sweeps out equal areas in equal intervals of time.



Kepler's Third Law states that the square of the orbital period of a planet is proportional to the cube of its mean distance from the sun. It can be expressed mathematically as

$$\frac{R^3}{T^2} = K.$$

Outcome S4P-2-17, S4P-2-18, S4P-2-16

3. State the meaning of the following terms: electric potential energy, electric field, and electric potential. Give the units of each and state whether each is a vector or scalar.

Answer:

Electric potential energy is the energy possessed by an electric charge due to its position in an electric field. Electric potential energy is a scalar and has units of joules.

Electric field is the electric force acting on a positive unit charge. It is a vector with units of newtons/coulomb.

The electric potential is the electric potential energy per unit charge. It has units of volts or joules per coulomb. It also is a scalar.

Outcome S4P-2-21

4. Describe how the right-hand rule (flat hand) relates the directions of the magnetic field, the velocity, and the magnetic force.

Answer:

Begin with your right hand flat, fingers outstretched, and thumb held perpendicular to the fingers.

Step 1: First orient your hand so that the thumb points in the direction of the conventional current (motion of positive charge---away from positive, towards negative).

Step 2: Align your fingers with the direction of the magnetic field lines (from the N towards S on a magnet).

Step 3: The magnetic force will then point out of the palm of your hand.

Outcome S4P-3-2

5. Briefly describe how **only one** of the following added to the scientific knowledge about current electricity by building on the work of those who had come before them.

a) Georg Simon Ohm

Answer:

Ohm built directly on the work of Stephen Gray and Öersted.

Stephen Gray's work was qualitative in nature. Gray demonstrated that certain materials called conductors allowed electricity to pass through them.

Öersted's discovery of an electric current being able to deflect the needle of a compass led to the development of the tangent galvanometer, which Ohm used to make measurements of current. Ohm's work was quantitative in nature. Ohm's investigations dealt with the relationship between the current through a wire and the resistance of the wire. Ohm discovered that the current through the wire varied inversely with the resistance of the wire if the voltage was kept constant: $I = \frac{a}{R}$.

b) James Prescott Joule

Answer:

Joule built directly on the work of Stephen Gray, Öersted, and Ohm.

Gray demonstrated that certain materials called conductors allowed electricity to pass through them. Joule's investigations involved the current in the wire being used to heat water.

To measure the current, Joule also used the tangent galvanometer, which was based on the work of Öersted.

Joule's work with power, current, and resistance was a natural follow-up to the work of Ohm.

Joule was able to determine that the rate of energy transfer (power) depended directly on the resistance (R) of the wire being used to heat the water and also directly on the square of the current through the water: $P = I^2R$.

c) Gustav Robert Kirchoff

Answer:

Kirchoff's work depended upon the work of Gray, Öersted, Ohm, and Joule.

Gray demonstrated that certain materials called conductors allowed electricity to pass through them. Kirchoff's work involved electric current.

To measure the current, Kirchoff also used the tangent galvanometer, which was based on the work of Öersted.

Kirchoff's main contribution was his ability to synthesize the work of Ohm and Joule using energy as the link. By considering the energy transferred in electric circuits, Kirchoff was able to synthesize the relationships developed in the work of Ohm

$I = \frac{a}{R}$ and Joule $P = I^2R$. Kirchoff arrived at $I = \frac{\Delta V}{R}$, which demonstrated that the proportionality constant, a , in Ohm's relationship was potential difference or voltage. By tying together these ideas about electric current, electric potential, resistance, and power, Kirchoff was able to demonstrate that the concepts and explanations put forth by all of the scientists formed a coherent theory.

Outcome S4P-3-13

6. Describe the operation of a transformer.

Answer:

A transformer consists of an iron core on which two coils are wound: the primary coil with N_p turns, and a secondary coil with N_s turns. In a transformer, the primary coil is connected to the AC generator. The secondary coil of a transformer is connected to the load where energy is dissipated.

The alternating current in the primary coil establishes a changing magnetic field in the iron core. Iron is easily magnetized so it greatly enhances the magnetic field compared to a coil with only air inside. The iron also carries the magnetic field lines to the secondary coil.

In a well-designed core, nearly all of the magnetic flux Φ that passes through each turn of the primary coil also goes through each turn of the secondary. Since the magnetic field is changing, the flux through the primary and secondary coils is also changing. Consequently, an emf is induced in both coils.

A transformer operates with AC electricity and not with DC.

Outcome S4P-3-8

7. Describe the three ways by which an induced emf and an induced current are produced in a coil of wire.

Answer:

The three ways in which an induced emf and an induced current are produced in a coil of wire are:

1. Moving the pole of the magnet into or out of the coil or moving the coil towards or away from the pole of the magnet
2. Physically changing the area of the coil while keeping the magnetic field constant
3. Rotating a coil in a uniform magnetic field

Outcome S4P-4-1

8. Describe the nuclear model of the atom. Include the subatomic particles (protons, neutrons, and electrons), their locations, and the forces that hold the particles together.

Answer:

Rutherford concluded that all of the atom's positive charge, as well as most of its mass, is concentrated in a very small core at the centre of the atom. He gave this core the name that is still used: the nucleus. Electrons moved around the positively charged nucleus in the empty space that made up most of the atom's volume. Rutherford's model of the atom became known as the "nuclear model."

Rutherford was able to show that the nucleus is positively charged, that it contains most of the mass of the atom, and that it occupies a tiny space inside the atom. Most of the space of the atom is outside the nucleus and is the region where the negatively charged electrons move.

He assumed that the nuclei of other atoms contain various numbers of protons. The positive charge of each nucleus depends on the number of protons it contains. Atoms are neutral because the number of protons in the nucleus equals the number of electrons occupying the rest of the space of the atom outside the nucleus.

Neutrons have a mass about equal to that of the proton and are also found in the nucleus.

The particles in the nucleus are held together by the strong nuclear force. This force is very strong but has a very short range. The electrons are held in the atom by the electrostatic attractive force between the positively charged protons in the nucleus and the negative charge of the electron.

Outcome S4P-4-4

9. Describe alpha radiation, beta radiation, and gamma radiation. Include in your description how each type of radiation is produced and how the parent nucleus is changed by the emission of this type of radiation.

Answer:

Alpha radiation consists of an alpha particle, which is really a helium nucleus ${}^3_2\text{He}$ being emitted from the parent nucleus. The parent nucleus undergoes a change in charge since it loses two protons. The charge on the parent nucleus is reduced by two, resulting in transmutation. The parent nucleus also undergoes a change in the number of nucleons since it loses two protons and two neutrons. The number of nucleons is reduced by four.

Beta radiation comes in two flavours. Negative beta radiation β^- is really an electron, ${}_{-1}^0e$. In this case, a neutron emits an electron, leaving behind an extra proton in the nucleus. The parent nucleus gains a proton, resulting in an increase in atomic number of one, resulting in transmutation. The proton replaces the neutron that emitted the electron, resulting in no change in the number of nucleons in the parent nucleus.

Positive beta radiation β^+ results from the emission of a positron ${}_{+1}^0e$ (a positive electron or an antielectron). Here, a proton in the nucleus emits a positron and is changed into a neutron. Since the proton disappears, the charge on the nucleus decreases by one, resulting in transmutation. A neutron appears in place of the proton that emitted the positron, resulting in no change in the number of nucleons in the parent nucleus.

Gamma (γ) rays are photons with very high energy. The nucleus exists in discrete energy states or levels, much like the electrons that orbit the nucleus. Like an atom, a nucleus can be in an “excited” state. An excited nucleus is denoted by an asterisk *. When it decays to a lower state, a photon is emitted. Since gamma rays are electromagnetic radiation and they carry no charge and no mass, there is no transmutation in this type of nuclear reaction. The charge on the parent nucleus remains the same and the number of nucleons in the parent nucleus remains the same.

Part D: Problems (7 x 7 = 49 Marks)

Answer any seven (7) problems. Please show your work. Number your answers clearly.

Outcomes S4P-2-2, S4P-2-3, S4P-2-8

1. Mars orbits the sun with a mean radius of orbit of 2.28×10^{11} m and a period of 5.94×10^7 seconds. The universal gravitational constant is $6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2$.

- a) Calculate the speed of Mars as it orbits the sun.

Answer: (2 marks)

Given: $R = 2.28 \times 10^{11}$ m

$T = 5.94 \times 10^7$ seconds

Unknown: speed $v = ?$

Equation: $v = \frac{2\pi R}{T}$

Substitute and solve: $v = \frac{2(3.14)(2.28 \times 10^{11} \text{ m})}{5.94 \times 10^7 \text{ s}} = 2.41 \times 10^5 \text{ m/s}$

The speed of Mars is 2.41×10^5 m/s.

- b) Calculate K for the sun.

Answer: (2 marks)

Equation: $K = \frac{R^3}{T^2}$

Substitute and solve: $K = \frac{(2.28 \times 10^{11} \text{ m})^3}{(5.94 \times 10^7 \text{ s})^2} = 3.36 \times 10^{18} \text{ m}^3/\text{s}^2$

The constant for the sun is $3.36 \times 10^{18} \text{ m}^3/\text{s}^2$.

- c) Calculate the mass of the sun.

Answer: (3 marks)

Equation: $4\pi^2 K_S = Gm_S$ rearranged to $m_S = \frac{4\pi^2 K_S}{G}$

Substitute and solve: $m_S = \frac{4(3.14)^2 (3.36 \times 10^{18} \text{ m}^3/\text{s}^2)}{6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2} = 1.99 \times 10^{30} \text{ kg}$

The mass of the sun is 1.99×10^{30} kg.

Outcome S4P-2-4, S4P-2-5, S4P-2-6

2. A spacecraft of mass 1240 kg orbits the earth with a radius of orbit of 7.05×10^7 m. The earth has a radius of 6.38×10^6 m and a mass of 5.98×10^{24} kg. The value of the universal constant, G , is $6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2$.

a) What is the gravitational potential energy of the orbiting spacecraft?

Answer: (3 marks)

Given: Mass of spacecraft	$m_s = 1240 \text{ kg}$
Mass of Earth	$m_E = 5.98 \times 10^{24} \text{ kg}$
Radius of orbit	$R = 7.05 \times 10^7 \text{ m}$
Unknown: Gravitational potential energy	$PE_G = ?$

Equation:
$$PE_G = -\frac{Gm_s m_E}{R}$$

Substitute and solve:
$$PE_G = -\frac{(6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2)(1240 \text{ kg})(5.98 \times 10^{24} \text{ kg})}{7.05 \times 10^7 \text{ m}}$$

$$PE_G = -7.02 \times 10^9 \text{ J}$$

The gravitational potential energy of the spacecraft is -7.02×10^9 J.

b) What is the binding energy of the spacecraft?

Answer: (1 mark)

Since the spacecraft is orbiting the earth, the binding energy is given by:

$$BE = \frac{1}{2} |PE_G|$$

$$BE = \frac{1}{2} |-7.02 \times 10^9 \text{ J}| = 3.51 \times 10^9 \text{ J}$$

c) What is the gravitational field at the position that the spacecraft is located?

Answer: (3 marks)

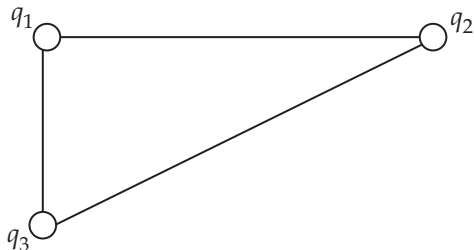
Equation:
$$\bar{g} = \frac{Gm_E}{R^2}$$

Substitute and solve:
$$\bar{g} = \frac{(6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2)(5.98 \times 10^{24} \text{ kg})}{(7.05 \times 10^7 \text{ m})^2}$$

The gravitational field strength is 0.0802 N/kg towards the earth's centre.

Outcome S4P-2-14

3. In the diagram below, $q_1 = +4.50 \times 10^{-6} \text{ C}$, $q_2 = -3.25 \times 10^{-6} \text{ C}$ and $q_3 = +3.73 \times 10^{-6} \text{ C}$. Charges 1 and 2 are separated by 3.00 cm and charges 1 and 3 are separated by 1.50 cm. The constant in Coulomb's Law, k , is $8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2$.



- a) Determine the electric force acting on q_1 .

Answer: (5 marks)

Since these are point charges determine the electric force of 2 on 1 (\vec{F}_{2-1}) and the force of 3 on 1 (\vec{F}_{3-1}) then add these as vectors to find \vec{F}_{NET} .

Given: Charge 1	$q_1 = +4.50 \times 10^{-6} \text{ C}$
Charge 2	$q_2 = -3.25 \times 10^{-6} \text{ C}$
Charge 3	$q_3 = +3.73 \times 10^{-6} \text{ C}$
Separation of 1 and 2	$R_{12} = 3.00 \text{ cm} = 0.0300 \text{ m}$
Separation of 1 and 3	$R_{13} = 1.50 \text{ cm} = 0.0150 \text{ m}$

Unknown: Force of 2 on 1 $\vec{F}_{2-1} = ?$

Equation:
$$\vec{F}_{E2-1} = \frac{kq_1q_2}{R_{12}^2}$$

Substitute and solve:

$$\vec{F}_{E2-1} = \frac{(8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2)(4.50 \times 10^{-6} \text{ C})(3.25 \times 10^{-6} \text{ C})}{(0.0300 \text{ m})^2} = 146 \text{ N}$$

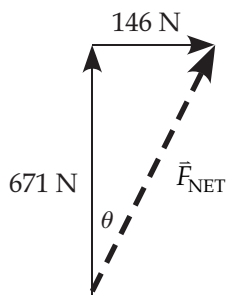
The force of charge 2 on 1 is 146 N [right]. Since the signs of the charges are opposite, the force is attractive.

Similarly,
$$\vec{F}_{E3-1} = \frac{(8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2)(4.50 \times 10^{-6} \text{ C})(3.73 \times 10^{-6} \text{ C})}{(0.0150 \text{ m})^2} = 671 \text{ N}$$

Charge 3 repels charge 1 with a force of 671 N [up].

Find \vec{F}_{NET} using $\vec{F}_{\text{NET}} = \vec{F}_{E2-1} + \vec{F}_{E3-1}$

$$\vec{F}_{\text{NET}} = 146 \text{ N [right]} + 671 \text{ N [up]}$$



$$F_{\text{NET}} = \sqrt{(146)^2 + (671)^2} = \sqrt{471557} = 687 \text{ N}$$

$$\theta = \tan^{-1} \frac{146}{671} = 12.3^\circ$$

The net force on charge 1 is 687 N 12.3° clockwise from up.

b) Determine the electric field at q_1 .

Answer: (2 marks)

Equation:
$$\vec{E}_{\text{at } q_1} = \frac{\vec{F}_{E \text{ on } q_1}}{q_1}$$

Substitute and solve:
$$\vec{E}_{\text{at } q_1} = \frac{687 \text{ N } 12.3^\circ \text{ clockwise from up}}{4.50 \times 10^{-6} \text{ C}}$$

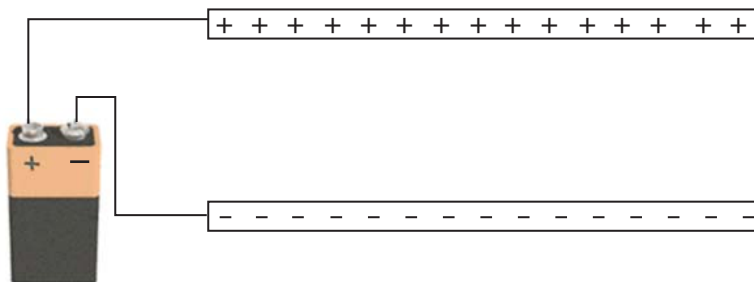
$$\vec{E}_{\text{at } q_1} = 1.53 \times 10^8 \text{ N/C } 12.3^\circ \text{ clockwise from up}$$

The electric field at the position of q_1 is $1.53 \times 10^8 \text{ N/C}$ 12.3° clockwise from up.

Outcome S4P-2-20, S4P-2-15

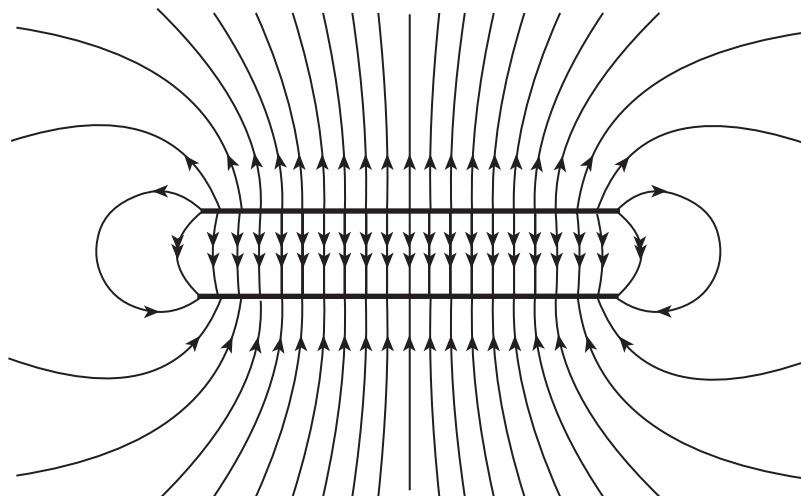
4. An electron of mass 9.11×10^{-31} kg is at rest on the negative plate of a parallel plate capacitor. The electron is repelled by the negative plate and attracted to the positive plate by a force of 6.45×10^{-16} N. The distance between the plates is 2.50 mm. The charge on 1 electron is -1.60×10^{-19} C.

a) Sketch the electric field between the plates of the charged parallel plate capacitor.



Answer: (2 marks)

The electric field pattern should resemble the one below.



- b) Calculate the electric field between the plates of the charged parallel plate capacitor.

Answer: (2 marks)

Given: Separation of plates	$d = 2.50 \text{ mm} = 2.50 \times 10^{-3} \text{ m}$
Charge on electron	$q = -1.60 \times 10^{-19} \text{ C}$
Electric force	$\vec{F}_E = 6.45 \times 10^{-16} \text{ N}$
Mass of electron	$m_E = 9.11 \times 10^{-31} \text{ kg}$
Unknown: Electric field	$\vec{E} = ?$

Equation:
$$\vec{E} = \frac{\vec{F}_E}{q}$$

Substitute and solve:
$$\vec{E} = \frac{6.45 \times 10^{-16} \text{ N}}{1.60 \times 10^{-19} \text{ C}} = 4030 \text{ N/C}$$

The electric field between the plates is 4030 N/C towards the negative plate.

- c) What is the velocity of the electron just before it crashes into the positive plate?

Answer: (3 marks)

The work done by the electric force will become the kinetic energy of the electron.

Equation:
$$W = \vec{F}_E \cdot d = \frac{1}{2} m_E v_f^2$$

Substitute and solve:
$$(6.45 \times 10^{-16} \text{ N})(2.50 \times 10^{-3} \text{ m}) = \frac{1}{2} (9.11 \times 10^{-31} \text{ kg}) v_f^2$$
$$v_f = 1.88 \times 10^6 \text{ m/s}$$

The electron hits the positive plate travelling at $1.88 \times 10^6 \text{ m/s}$.

Outcome S4P-3-3, S4P-3-5, S4P-3-6

5. A high-voltage transmission line has a distance of 185 m between its towers. The wires are made of aluminum, which has a resistivity of $2.82 \times 10^{-8} \Omega \cdot \text{m}$. The wires are made of strands of aluminum braided together. Each strand has a diameter of $1.20 \times 10^{-3} \text{ m}$ and there are 235 strands in each wire.

- a) What is the area of one strand of wire?

Answer: (2 marks)

Given: Length	$l = 185 \text{ m}$
Aluminum resistivity	$\rho = 2.82 \times 10^{-8} \Omega \cdot \text{m}$
Diameter	$D = 1.20 \times 10^{-3} \text{ m}$
Radius	$R = 6.00 \times 10^{-4} \text{ m}$
Strands of wire	$N = 235$

Unknown: Area $A = ?$

Equation: $A = \pi R^2$

Substitute and solve: $A = (3.14)(6.00 \times 10^{-4} \text{ m})^2$

$$A = 1.13 \times 10^{-6} \text{ m}^2$$

The area of one strand is $1.13 \times 10^{-6} \text{ m}^2$.

- b) What is the resistance of each strand?

Answer: (2 marks)

Unknown: Resistance $R = ?$

Equation: $R = \rho \frac{L}{A}$

Substitute and solve: $R = (2.82 \times 10^{-8} \Omega \cdot \text{m}) \frac{(185 \text{ m})}{(1.13 \times 10^{-6} \text{ m}^2)} = 4.62 \Omega$

The resistance of one strand of wire is 4.62Ω .

- c) What is the total resistance of one of the braided wires between two towers, assuming the strands of wire are connected in parallel?

Answer: (1 mark)

For a parallel connection, $\frac{1}{R_{\text{TOTAL}}} = \frac{1}{R_1} + \frac{1}{R_2} \dots$

So if there are 235 strands, each of resistance 4.62Ω , then

$$\frac{1}{R_{\text{TOTAL}}} = \frac{1}{4.62 \Omega} + \frac{1}{4.62 \Omega} + \dots + \frac{1}{4.62 \Omega} = \frac{235}{4.62 \Omega}$$

$$R_{\text{TOTAL}} = \frac{4.62 \Omega}{235} = 0.0196 \Omega$$

The resistance of all of the strands in parallel is 0.0196Ω .

- d) If the voltage drop along the line between the two towers is 88.8 volts, what is the current in a braided wire?

Answer: (2 marks)

Unknown: Current $I = ?$

Equation: $V = IR$

Substitute and solve: $88.8 \text{ V} = I(0.0196 \Omega)$

$$I = 4530 \text{ A}$$

The current along the wire is 4530 A.

Outcome S4P-3-6

6. A 1600-watt iron is connected to a 120 volt line and is operated for 2.75 hours.

a) Calculate the current drawn by the iron.

Answer: (1.5 marks)

Given: Power $P = 1600 \text{ W}$
Voltage $V = 120 \text{ V}$
Time $\Delta t = 2.75 \text{ hours} = 2.75 \text{ h} (60 \text{ min/h})(60 \text{ s/min})$
 $= 9.90 \times 10^3 \text{ s}$

Unknown: Current $I = ?$

Equation: $P = IV$ rearranged to $I = \frac{P}{V}$

Substitute and solve: $I = \frac{1600 \text{ W}}{120 \text{ V}} = 13.3 \text{ A}$

The current drawn by the iron is 13.3 A.

b) What is the resistance of the iron?

Answer: (1.5 marks)

Unknown: Resistance $R = ?$

Equation: $P = \frac{V^2}{R}$ rearranged to $R = \frac{V^2}{P}$

Substitute and solve: $R = \frac{(120 \text{ V})^2}{1600 \text{ W}} = 9.00 \text{ } \Omega$

The resistance of the iron is 9.00 Ω .

- c) Calculate the charge, in coulombs, that flowed through the iron during the 2.75 hours.

Answer: (2 marks)

Unknown: Charge $q = ?$

Equation: $q = I\Delta t$

Substitute and solve: $q = (13.3\text{A})(9.90 \times 10^3 \text{ s}) = 1.32 \times 10^5 \text{ C}$

The charge that flowed is $1.32 \times 10^5 \text{ C}$.

- d) What is the maximum wattage that can be used for an iron if the breaker for this circuit is rated at 20.0 amperes?

Answer: (2 marks)

Given: Maximum current $I = 20.0 \text{ A}$

Voltage $V = 120 \text{ V}$

Unknown: Maximum wattage or power $P = ?$

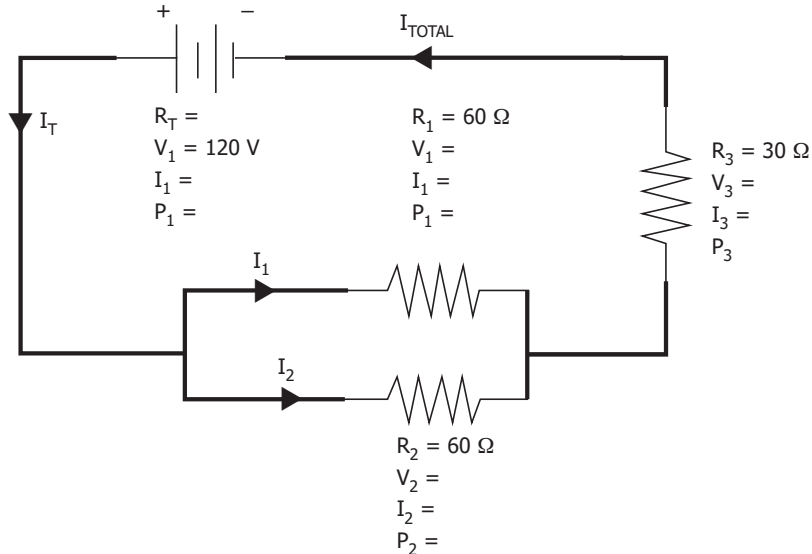
Equation: $P = IV$

Substitute and solve: $P = (20.0 \text{ A})(120 \text{ V}) = 2400 \text{ W}$

The maximum power of the iron is 2400 Watts.

Outcome S4P-3-5, S4P-3-6

7. Two $60\ \Omega$ resistors are connected in parallel. This parallel arrangement is connected in series with a $30\ \Omega$ resistor. The combination is then placed across a $120\ \text{V}$ potential difference. A circuit diagram is drawn below.



- a) What is the equivalent resistance of the parallel portion of the circuit?

Answer: (1.5 marks)

The equivalent resistance for the parallel part of the circuit is:

$$\frac{1}{R_{1,2}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{60\ \Omega} + \frac{1}{60\ \Omega}$$

$$R_{1,2} = 30\ \Omega$$

b) What single resistance could replace the three original resistors?

Answer: (1.5 marks)

The resistance R_3 is in series with the parallel combination $R_{1,2}$. Therefore, the total equivalent resistance for the circuit is:

$$R_{1,2,3} = R_{1,2} + R_3 = 30 \, \Omega + 30 \, \Omega = 60 \, \Omega$$

c) What is the current in the circuit?

Answer: (1 mark)

The current in the circuit can be found using Ohm's law and the value of the resistance for the combination circuit.

$$I_T = \frac{V_T}{R_T} = \frac{120 \, \text{V}}{60 \, \Omega} = 2 \, \text{A}$$

d) What is the potential drop across the $30 \, \Omega$ resistor?

Answer: (1 mark)

The potential drop across the $30 \, \Omega$ resistor is found using Ohm's law, and keeping in mind that the current through the $30 \, \Omega$ resistor is equal to the total current.

$$V_3 = I_T R_3 = (2 \, \text{A})(30 \, \Omega) = 60 \, \text{V}$$

e) What is the voltage drop across the parallel portion of the circuit?

Answer: (1 mark)

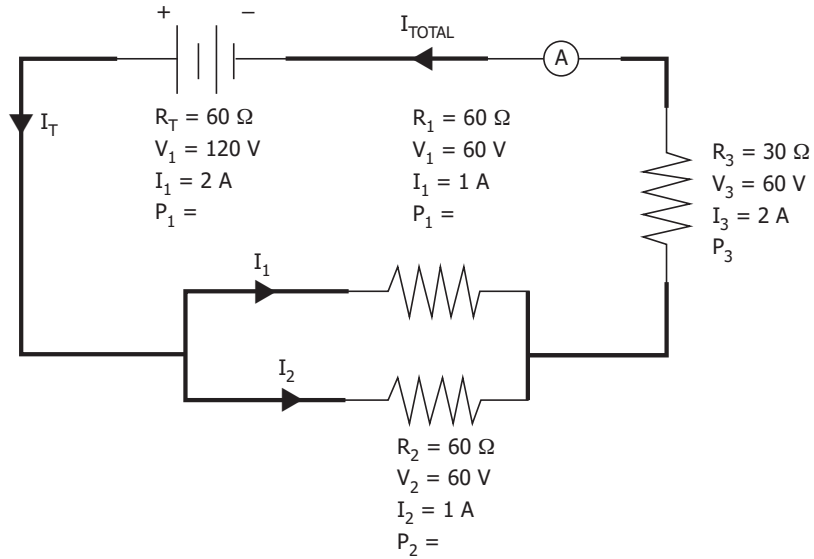
The parallel branch, R_1 and R_2 , behaves like a $30 \, \Omega$ resistor. Therefore, the voltage drop across it is

$$V_P = IR_{1,2} = (2 \, \text{A})(30 \, \Omega) = 60 \, \text{V}$$

- f) Using the proper symbol for an ammeter, show one possible location for the ammeter to measure the current through the $30\ \Omega$ resistor.

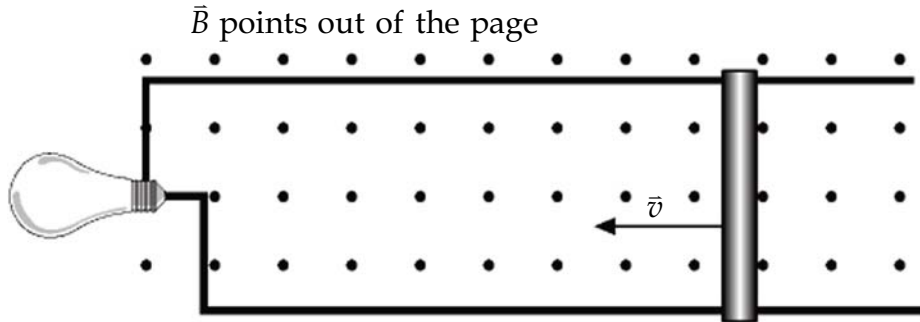
Answer: (1 mark)

To measure current, it is necessary to break a connection either before or after the $30\ \Omega$ resistor to insert the ammeter.



S4P-3-7, S4P-3-9, S4P-3-10

8. The rod below is moving at a speed of 8.00 m/s in a direction perpendicular to a 0.500 T magnetic field. The rod has a length of 1.50 m and a negligible resistance. The conducting rails also have a negligible resistance. The light bulb has a resistance of 96.0 Ω .



- a) Find the emf produced in the rod.

Answer: (1.5 marks)

Speed of the rod $v = 8.00 \text{ m/s}$

Length of the rod $L = 1.50 \text{ m}$

Magnetic field $B = 0.500 \text{ T}$

Resistance of bulb $R = 96.0 \Omega$

The motional emf is $\xi = vBL = (8.00 \text{ m/s})(0.500 \text{ T})(1.50 \text{ m}) = 6.00 \text{ V}$.

- b) Find the induced current in the circuit.

Answer: (1.5 marks)

The induced current is found using Ohm's law.

$$I = \frac{6.00 \text{ V}}{96.0 \Omega} = 0.0625 \text{ A}$$

c) Find the electrical power delivered to the bulb.

Answer: (1.5 marks)

The electrical power delivered to the light bulb is

$$P = I\xi = (0.0625 \text{ A})(6.00 \text{ V}) = 0.375 \text{ W}.$$

d) Find the energy used by the bulb in 45.0 s.

Answer: (1.5 marks)

The energy used by the bulb is $E = Pt = (0.375 \text{ W})(45.0 \text{ s}) = 16.9 \text{ J}$.

e) Describe the direction of flow of conventional current.

Answer: (1 mark)

The direction of the conventional current is counter-clockwise. The direction of electron flow is clockwise.

Outcome S4P-3-9, S4P-3-10

9. A coil of wire consists of 20 turns, each of which has an area of $1.50 \times 10^{-2} \text{ m}^2$. A magnetic field is perpendicular to the surface at all times. At a time t_0 , the magnitude of the magnetic field at the location of the coil is $B_0 = 0.0500 \text{ T}$. At a later time $t = 0.100 \text{ s}$, the magnitude of the field at the coil has increased to $B = 0.0600 \text{ T}$. The magnetic field originates to the left of a coil and is therefore directed to the right towards the coil. The points B and C are closer to you than the point A.



- a) Find the average emf induced in the coil during this time.

Answer: (3 marks)

Given: Number of loops in the coil	$N = 20$
Area of one loop	$A = 1.50 \times 10^{-2} \text{ m}^2$
Initial magnetic field	$B_0 = 0.0500 \text{ T}$
Final magnetic field	$B = 0.0600 \text{ T}$
Angle between magnetic field and normal	$\theta = 0^\circ$
Time interval	$\Delta t = 0.100 \text{ s}$

Unknown: Induced emf $\xi = ?$

Equation: Find the flux change using $\Delta\Phi = \Delta BA \cos \theta$

Then, find the time interval using $\xi = -\frac{N\Delta\Phi}{\Delta t}$.

Substitute and solve: $\Delta\Phi = \Delta BA \cos \theta$

$$\Delta\Phi = (0.0600 \text{ T} - 0.0500 \text{ T})(0.0150 \text{ m}^2)\cos 0^\circ = 0.000150 \text{ Wb}$$

The induced emf is then: $\xi = -\frac{N\Delta\Phi}{\Delta t}$

$$\xi = -\frac{(20)(0.000150 \text{ Wb})}{0.100 \text{ s}} = -0.0300 \text{ V}$$

b) In what direction is the induced magnetic field?

Answer: (1 mark)

The magnetic flux through the coil is increasing and pointing to the right. The induced magnetic field must oppose this change in flux, and is therefore to the left.

c) Using the letters A, B, and C, give the direction of flow of the induced current?

Answer: (1 mark)

Using the right-hand rule, this shows that the direction of the current must be clockwise when viewed from the right side of the coil or B to C to A (it is counter-clockwise when viewed from the left side where the magnetic field lines originate).

d) Label the polarity of points A and B.

Answer: (1 mark)

Since the direction of the conventional current through the external circuit is from A to B, A is labelled the positive pole and B is labelled the negative pole.

e) What would be the average induced emf if the magnitude of the magnetic field decreased from 0.0600 T to 0.0500 T in 0.100 s?

Answer: (1 mark)

The calculation here is similar to that in part a), except that the initial and final values of B are interchanged. This interchange reverses the sign of the emf, so $\xi = +0.0300$ V. Because the algebraic sign or polarity of the emf is reversed, the direction of the induced current is opposite to that in part (a).

Outcome S4P-4-2, S4P-4-4

Some of the following masses are required to solve the problem.

Isotope	Mass in atomic mass units (u)
${}^4_2\text{He}$	4.002 602 u
${}^{14}_6\text{C}$	14.003 241 u
${}^{14}_7\text{N}$	14.003 074 u
${}^{22}_{10}\text{Ne}$	21.991 383 u
${}^{22}_{11}\text{Na}$	21.994 434 u
${}^{228}_{90}\text{Th}$	228.028 716 u
${}^{232}_{92}\text{U}$	232.037 131 u

10. One of the ways in which the element neon can be formed is through the beta positive decay of ${}^{23}_{11}\text{Na}$. The speed of light is 3.00×10^8 m/s and $1 \text{ u} = 1.660 56 \times 10^{-27}$ kg.

a) Write an equation for this decay.

Answer: (2 marks)



b) If the mass defect is 5.06637×10^{-30} kg, determine the energy released in units of joules.

Answer: (2 marks)

$$E = \Delta mc^2$$

The energy released is $E = (1.660 56 \times 10^{-30} \text{ kg})(3.00 \times 10^8 \text{ m/s})^2 = 4.57 \times 10^{-13} \text{ J}$.

c) The half-life of ${}^{22}_{11}\text{Na}$ is 2.60 years. If 25.0 grams of ${}^{22}_{11}\text{Na}$ is given to you today, after how many years would you have 0.391 grams remaining?

Answer: (3 marks)

$$25.0 \times \left(\frac{1}{2}\right)^6 = 0.391 \text{ g}$$

The time required is 6 half-lives.

$$6 \times 2.60 \text{ years} = 15.6 \text{ years}$$