Grade 12 Physics
Gravitational, Electrical, Magnetic Fields Key

First Name: ____________________**KEY**________________________________

Last Name: ____

Directions:

- Please answer to 2 decimal points
- The test is designed to be completed in 75 minutes

For grading use only

Page:	2	3	4	5	6	7	8	Total
Points:	6	19	10	20	10	10	10	85
Score:								

Multiple Choice (10 marks)

1. (1 point) Which of the following is true about gravitational fields?
   A. Gravitational fields only exist near massive objects like planets.
   B. Gravitational fields are regions where a mass experiences a force.
   C. Gravitational fields are strongest at the center of a planet.
   D. Gravitational fields do not depend on the mass of the object creating them.

2. (1 point) What is the direction of the electric field around a positive point charge?
   A. Radially inward.
   B. Radially outward.
   C. Tangential to the charge.
   D. There is no electric field around a positive charge.

3. (1 point) A magnetic field is produced by:
   A. Stationary electric charges.
   B. Moving electric charges.
   C. Gravitational forces.
   D. Static electric fields.

4. (1 point) The force experienced by a charged particle in a magnetic field is maximum when:
   A. The particle is stationary.
   B. The particle moves perpendicular to the magnetic field.
   C. The particle moves parallel to the magnetic field.
   D. The particle is uncharged.

5. (1 point) The gravitational force between two masses is inversely proportional to:
   A. The product of the masses.
   B. The square of the distance between them.
   C. The sum of the masses.
   D. The distance between them.

6. (1 point) The unit of electric field strength is:
   A. Newton (N).
   B. Newton per Coulomb (N/C).
   C. Joule (J).
   D. Volt (V).

7. (1 point) A proton and an electron are placed in the same electric field. Which experiences a greater acceleration?
   - A. The proton.
   - **B. The electron.**
   - C. Both experience the same acceleration.
   - D. Neither accelerates.

8. (1 point) The magnetic field inside a long solenoid is:
   - A. Zero.
   - **B. Uniform and parallel to the axis.**
   - C. Non-uniform and radial.
   - D. Strongest at the ends.

9. (1 point) The force between two parallel current-carrying wires is:
   - A. Always attractive.
   - **B. Attractive if currents are in the same direction.**
   - C. Repulsive if currents are in the same direction.
   - D. Independent of the current direction.

10. (1 point) The work done in moving a charge in an electric field depends on:
    - A. The path taken.
    - **B. The potential difference.**
    - C. The charge's mass.
    - D. The magnetic field present.

Long Answer (40 marks)

11. A satellite of mass 500 kg orbits the Earth at a height of 300 km above the surface. The radius of the Earth is 6.37×10^6 m, and its mass is 5.97×10^{24} kg.
    (a) (5 points) Calculate the gravitational force acting on the satellite.
    (b) (5 points) Determine the orbital speed of the satellite.
    (c) (5 points) Find the period of the satellite's orbit.

Solution: 11. Gravitational Force, Orbital Speed, and Orbital Period of a Satellite

(a) Gravitational force acting on the satellite: The gravitational force is given by the formula:

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

Where: - $G = 6.674 \times 10^{-11}\,\mathbf{N\ m^2/kg^2}$ is the gravitational constant, - $M = 5.97 \times 10^{24}\,\mathbf{kg}$ is the mass of the Earth, - $m = 500\,\mathbf{kg}$ is the mass of the satellite, - $r = R + h = 6.37 \times 10^6 + 300 \times 10^3 = 6.67 \times 10^6\,\mathbf{m}$ is the distance from the center of the Earth to the satellite.

Substituting the values:

$$F = \frac{(6.674 \times 10^{-11})(5.97 \times 10^{24})(500)}{(6.67 \times 10^6)^2} = 4.45 \times 10^3\,\mathbf{N}$$

(b) Orbital speed of the satellite: The orbital speed is given by:

$$v = \sqrt{\frac{GM}{r}}$$

Substituting the values:

$$v = \sqrt{\frac{(6.674 \times 10^{-11})(5.97 \times 10^{24})}{6.67 \times 10^6}} = 7.12 \times 10^3\,\mathbf{m/s}$$

(c) Orbital period of the satellite: The orbital period is given by:

$$T = \frac{2\pi r}{v}$$

Substituting the values:

$$T = \frac{2\pi(6.67 \times 10^6)}{7.12 \times 10^3} = 5.88 \times 10^3\,\mathbf{s} \approx 98\,\mathbf{minutes}$$

12. A proton moves with a velocity of 2×10^6 m/s perpendicular to a magnetic field of 0.5 T.
    (a) (5 points) Calculate the magnetic force acting on the proton.
    (b) (5 points) Determine the radius of the proton's circular path.

Solution: 12. Magnetic Force on a Proton

(a) Magnetic force acting on the proton: The magnetic force is given by:

$$F = qvB\sin\theta$$

Since the velocity is perpendicular to the magnetic field, $\sin\theta = 1$. The charge of a proton is $q = 1.6 \times 10^{-19}\,\mathbf{C}$, and the magnetic field is $B = 0.5\,\mathbf{T}$. Substituting the values:

$$F = (1.6 \times 10^{-19})(2 \times 10^6)(0.5) = 1.6 \times 10^{-13}\,\mathbf{N}$$

(b) Radius of the proton's circular path: The radius is given by:

$$r = \frac{mv}{qB}$$

The mass of a proton is $m = 1.67 \times 10^{-27}\,\mathbf{kg}$, and the velocity is $v = 2 \times 10^6\,\mathbf{m/s}$. Substituting the values:

$$r = \frac{(1.67 \times 10^{-27})(2 \times 10^6)}{(1.6 \times 10^{-19})(0.5)} = 4.17 \times 10^{-2}\,\mathbf{m} = 4.17\,\mathbf{cm}$$

13. Two point charges, $q_1 = 3\,\mu$C and $q_2 = -5\,\mu$C, are placed 10 cm apart.
   (a) (5 points) Calculate the electric force between the charges.
   (b) (5 points) Determine the electric field at the midpoint between the charges.

Solution: 13. Electric Force and Electric Field between Two Point Charges

(a) Electric force between the charges: The electric force is given by Coulomb's law:

$$F = k_e \frac{|q_1 q_2|}{r^2}$$

Where: - $k_e = 8.99 \times 10^9\,\mathbf{N\ m^2/C^2}$ **is Coulomb's constant, -** $q_1 = 3\,\mu\mathbf{C} = 3 \times 10^{-6}\,\mathbf{C}$**, -** $q_2 = -5\,\mu\mathbf{C} = -5 \times 10^{-6}\,\mathbf{C}$**, -** $r = 0.10\,\mathbf{m}$ **is the distance between the charges.**

Substituting the values:

$$F = (8.99 \times 10^9)\frac{|(3 \times 10^{-6})(-5 \times 10^{-6})|}{(0.10)^2} = 1.35 \times 10^{-2}\,\mathbf{N}$$

(b) Electric field at the midpoint between the charges: The electric field at the midpoint is the sum of the electric fields due to each charge. The electric field due to a point charge is:

$$E = k_e \frac{|q|}{r^2}$$

At the midpoint, the distance from each charge is $r/2 = 0.05\,\mathbf{m}$**. Therefore, the electric field due to** q_1 **is:**

$$E_1 = (8.99 \times 10^9)\frac{|3 \times 10^{-6}|}{(0.05)^2} = 1.08 \times 10^6\,\mathbf{N/C}$$

And the electric field due to q_2 **is:**

$$E_2 = (8.99 \times 10^9)\frac{|5 \times 10^{-6}|}{(0.05)^2} = 1.80 \times 10^6\,\mathbf{N/C}$$

The fields are in opposite directions because the charges have opposite signs. Therefore, the net electric field at the midpoint is:

$$E_{\mathbf{net}} = E_2 - E_1 = 1.80 \times 10^6 - 1.08 \times 10^6 = 7.2 \times 10^5\,\mathbf{N/C}$$

14. A wire carrying a current of 5 A is placed in a uniform magnetic field of 0.2 T. The wire is 0.5 m long and makes an angle of 30° with the magnetic field.
   (a) (5 points) Calculate the magnetic force acting on the wire.
   (b) (5 points) Determine the direction of the force using the right-hand rule.

Solution: (a) Magnetic force acting on the wire:

The magnetic force on a current-carrying wire is given by the formula:

$$F = BIL\sin\theta$$

where:

- $B = 0.2\,\mathbf{T}$ **is the magnetic field strength,**
- $I = 5\,\mathbf{A}$ **is the current,**
- $L = 0.5\,\mathbf{m}$ **is the length of the wire,**
- $\theta = 30^\circ$ **is the angle between the wire and the magnetic field.**

Substituting the values:

$$F = 0.2 \cdot 5 \cdot 0.5 \cdot \sin 30^\circ$$

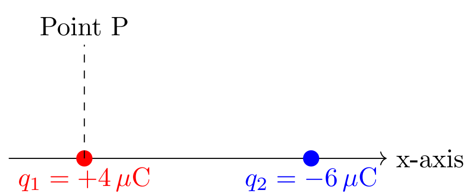
$$F = 0.2 \cdot 5 \cdot 0.5 \cdot 0.5 = 0.25\,\mathbf{N}$$

(b) Direction of the force using the right-hand rule:

To determine the direction of the magnetic force, use the right-hand rule. Point the fingers of your right hand in the direction of the current (along the wire) and curl them towards the magnetic field (at an angle of 30° to the wire). Your thumb will then point in the direction of the force.

Thus, the magnetic force will be perpendicular to both the current and the magnetic field, and in this case, it will be directed out of the plane of the wire (towards the observer).

15. Two point charges, $q_1 = +4\,\mu\text{C}$ and $q_2 = -6\,\mu\text{C}$, are placed 12 cm apart along the x-axis, as shown below.



A point P is located 5 cm above q_1.

(a) (4 points) Calculate the electric field at point P due to q_1.

(b) (4 points) Calculate the electric field at point P due to q_2.

(c) (2 points) Determine the direction of the **net** electric field at P.

Solution: (a) Electric field at P due to q_1:

The electric field due to a point charge is given by:

$$E = \frac{k|q|}{r^2}$$

Where $k = 9 \times 10^9\,\mathbf{N{\cdot}m^2/C^2}$, $q = +4\,\mu\mathbf{C} = 4 \times 10^{-6}\,\mathbf{C}$, and $r = 5\,\mathbf{cm} = 0.05\,\mathbf{m}$. Substituting the values:

$$E = \frac{9 \times 10^9 \times 4 \times 10^{-6}}{(0.05)^2} = \frac{36 \times 10^3}{0.0025} = 1.44 \times 10^7\,\mathbf{N/C}$$

(b) Electric field at P due to q_2:

The distance between q_2 and point P is given by Pythagoras' theorem:

$$r = \sqrt{(12\,\mathbf{cm})^2 + (5\,\mathbf{cm})^2} = \sqrt{0.12^2 + 0.05^2} = 0.13\,\mathbf{m}$$

The electric field due to $q_2 = -6\,\mu$C $= -6 \times 10^{-6}$ C is:

$$E = \frac{k|q_2|}{r^2}$$

Substituting the values:

$$E = \frac{9 \times 10^9 \times 6 \times 10^{-6}}{(0.13)^2} = \frac{54 \times 10^3}{0.0169} = 3.19 \times 10^6\,\mathbf{N/C}$$

(c) Direction of the net electric field at P:

The direction of the electric field is determined by the direction of the force that would be applied to a positive test charge. - The electric field due to q_1 is directed away from q_1 (positive charge), so it is pointing upward at point P. - The electric field due to q_2 is directed toward q_2 (negative charge), so it points downward at point P.

The net electric field at point P will be the vector sum of these fields, and since the magnitudes are different, the net field will be directed slightly upward, but closer to the direction of the field from q_1.

16. A proton enters a uniform magnetic field $\vec{B} = 0.4\,\mathrm{T}\,\hat{k}$ with a velocity $\vec{v} = 3 \times 10^5\,\mathrm{m/s}\,\hat{\imath} + 4 \times 10^5\,\mathrm{m/s}\,\hat{\jmath}$.
   (a) (4 points) Calculate the magnetic force acting on the proton.
   (b) (3 points) Describe the resulting motion of the proton.
   (c) (3 points) What would happen to the motion if the proton were replaced with an electron?

Solution: 16 (a) Magnetic force on the proton:

The magnetic force is given by:

$$F = qvB\sin\theta$$

Where $q = 1.6 \times 10^{-19}$ C (proton charge), $v = 3 \times 10^5$ m/s, $B = 0.4$ T, and $\theta = 90^\circ$ (since the velocity and magnetic field are perpendicular).

Substituting the values:

$$F = (1.6 \times 10^{-19}) \times (3 \times 10^5) \times 0.4 = 1.92 \times 10^{-14}\,\mathbf{N}$$

(b) Resulting motion of the proton:

Since the force is perpendicular to the proton's velocity, the proton will undergo circular motion with a constant speed. The magnetic force acts as the centripetal force, causing the proton to move in a circle.

(c) Effect of replacing the proton with an electron:

If the proton were replaced with an electron, the magnitude of the magnetic force would remain the same because the speed and magnetic field are unchanged. However, since the electron has a negative charge, the direction of the force (and thus the direction of the proton's motion) would be reversed.

17. A 500 kg satellite orbits Earth ($M_{\text{Earth}} = 5.97 \times 10^{24}\,\text{kg}, R_{\text{Earth}} = 6.37 \times 10^6\,\text{m}$) at an altitude of 400 km.
    (a) (4 points) Calculate the gravitational potential energy of the satellite.
    (b) (3 points) Determine the satellite's orbital speed.
    (c) (3 points) Explain why the gravitational potential energy is **negative**.

Solution: 17 (a) Gravitational potential energy of the satellite:

The gravitational potential energy is given by:

$$U = -\frac{GM_{\textbf{Earth}}m_{\textbf{satellite}}}{r}$$

Where $G = 6.67 \times 10^{-11}\,\textbf{N·m}^2/\textbf{kg}^2$**,** $M_{\textbf{Earth}} = 5.97 \times 10^{24}\,\textbf{kg}$**,** $m_{\textbf{satellite}} = 500\,\textbf{kg}$**, and** $r = R_{\textbf{Earth}} + h = 6.37 \times 10^6 + 400 \times 10^3 = 6.77 \times 10^6\,\textbf{m}$**.**

Substituting the values:

$$U = -\frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24} \times 500}{6.77 \times 10^6} = -4.63 \times 10^{10}\,\textbf{J}$$

(b) Orbital speed of the satellite:

The orbital speed is given by:

$$v = \sqrt{\frac{GM_{\textbf{Earth}}}{r}}$$

Substituting the values:

$$v = \sqrt{\frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24}}{6.77 \times 10^6}} = 7.12\,\textbf{km/s}$$

(c) Why the gravitational potential energy is negative:

Gravitational potential energy is negative because the gravitational force is attractive. By convention, the potential energy is set to zero at infinite separation, and since the satellite is bound to the Earth, the potential energy at a finite distance is negative, indicating that work is required to separate the two objects.