Q1.
As shown in Fig. 1, a point charge \( q_1 = +Q \) is placed at the center of a square, and a second point charge \( q_2 = -Q \) is placed at the upper-left corner. It is observed that an electrostatic force of 2.0 N acts on the positive charge at the center. What is the magnitude of the force that acts on the center charge if a third charge \( q_3 = -Q \) is placed at the lower-left corner as shown?

A) 2.8 N  
B) 2.0 N  
C) 4.0 N  
D) 5.3 N  
E) 0.0 N

Sec# Electric fields - Coulomb's Law  
Grade# 50

Q2.
A point charge \( Q = -500 \text{ nC} \) and two unknown point charges, \( q_1 \) and \( q_2 \), are placed as shown in Fig. 2. The net electric field at the origin \( O \), due to charges \( Q, q_1 \) and \( q_2 \), is equal to zero. The charges \( q_1 \) and \( q_2 \), respectively, are:

A) \(+131 \text{ nC}, -106 \text{ nC}\)  
B) \(+210 \text{ nC}, -206 \text{ nC}\)  
C) \(-210 \text{ nC}, +106 \text{ nC}\)  
D) \(+270 \text{ nC}, -301 \text{ nC}\)  
E) \(-100 \text{ nC}, +100 \text{nC}\)

Sec# Electric fields - The Electric Field  
Grade# 50

Q3.
A particle (\( m = 20 \text{ mg} \), \( q = -5.0 \mu\text{C} \)) moves in a uniform electric field \( \mathbf{E} = (60 \text{ N/C}) \mathbf{i} \). At \( t = 0 \), the particle has a velocity \( \mathbf{v} = (30 \text{ m/s}) \mathbf{i} \). Determine the velocity of the particle at \( t = 4.0 \text{ s} \).

A) \((-30 \text{ m/s}) \mathbf{i}\)  
B) \((-50 \text{ m/s}) \mathbf{i}\)  
C) \((5.0 \text{ m/s}) \mathbf{i}\)  
D) \((15 \text{ m/s}) \mathbf{i}\)  
E) \((-15 \text{ m/s}) \mathbf{i}\)

Sec# Electric fields - Motion of charge in uniform electric field  
Grade# 50

Q4.
An electric dipole of dipole moment \( \mathbf{p} = (5 \times 10^{-10} \text{ C.m}) \mathbf{i} \) is placed in an electric field \( \mathbf{E} = (2 \times 10^6 \text{ N/C}) \mathbf{i} + (2 \times 10^6 \text{ N/C}) \mathbf{j} \). What is magnitude of the maximum torque experienced by the dipole?
A) 1.00 × 10⁻³ N.m
B) 1.40 × 10⁻³ N.m
C) 2.80 × 10⁻³ N.m
D) 2.00 × 10⁻³ N.m
E) 3.00 × 10⁻³ N.m

Q5.
The flux of an electric field \( \mathbf{E} = (24 \text{N/C}) \mathbf{i} + (30 \text{N/C}) \mathbf{j} + (16 \text{N/C}) \mathbf{k} \) through a 2.0 m² portion of the yz plane is:

A) 48 N.m²/C
B) 34 N.m²/C
C) 42 N.m²/C
D) 32 N.m²/C
E) 60 N.m²/C

Q6.
Consider two large oppositely charged parallel metal plates, placed close to each other. The plates are square with sides L and carry charges Q and -Q. The magnitude of the electric field in the region between the plates is:

A) \( \mathbf{E} = \frac{2Q}{\varepsilon_0 L^2} \)
B) \( \mathbf{E} = \frac{4Q}{\varepsilon_0 L^2} \)
C) \( \mathbf{E} = \frac{Q}{2\varepsilon_0 L^2} \)
D) \( \mathbf{E} = 0 \)
E) \( \mathbf{E} = 0 \)

Q7.
A non-conducting sphere of radius \( R = 10 \text{ cm} \) carries a charge density \( \rho = 10^9 \text{ C/m}^3 \) distributed uniformly throughout its volume. At what distance within the sphere, measured from the center of the sphere, the magnitude of the electric field is \( E = 1.32 \text{ N/m} \)?
Q8. An infinitely long non-conducting cylinder of radius \( R = 2.00 \text{ cm} \) carries a uniform charge density \( \rho = 18.0 \text{ \mu C/m}^3 \). Calculate the electric field at distance \( r = 1.00 \text{ cm} \) from the axis of the cylinder?

A) \( 1.02 \times 10^4 \text{ N/C} \)
B) \( 5.10 \times 10^3 \text{ N/C} \)
C) \( 2.01 \times 10^4 \text{ N/C} \)
D) \( 2.51 \times 10^3 \text{ N/C} \)
E) \( 3.04 \times 10^3 \text{ N/C} \)

Q9. A proton with a speed of \( 2.00 \times 10^5 \text{ m/s} \) enters a region of space in which source charges have created an electric potential. What is the proton’s speed after it has moved through a potential difference of \( +100 \text{ V} \)?

A) \( 1.44 \times 10^5 \text{ m/s} \)
B) \( 1.78 \times 10^5 \text{ m/s} \)
C) \( 2.78 \times 10^5 \text{ m/s} \)
D) \( 2.21 \times 10^5 \text{ m/s} \)
E) \( 1.08 \times 10^5 \text{ m/s} \)

Q10. The electric potential at points in xy plane is given by \( V= 2x^2y+32 \). What is the electric field at ( \( 2.0 \text{ m}, 3.0 \text{ m} \) )

A) \( -24 \text{ i} - 8.0 \text{ j} \)
B) \( 24 \text{ i} - 8.0 \text{ j} \)
C) \( 3.0 \text{ i} \)
D) \( 5.0 \text{ i} + 4.0 \text{ j} \)
E) \( 8 \text{ i} + 24 \text{ j} \)
Q11. Four equal positive charges, each 3.2 $\mu$C, are held at the four corners of a square of edge 0.50 m. How much work is required to move one of those charges far away from other three?

A) $-0.50$ J
B) $-0.89$ J
C) $0.50$ J
D) $+0.89$ J
E) $1.0$ J

Sec# Electric Potential - Potential of a Charged Conductor
Grade# 50

Q12. An electric field of 100 V/m strength is often observed near the surface of earth. What would be the electric potential at a point on the earth surface? (Radius of Earth = $6.37 \times 10^6$ m)

A) $6.37 \times 10^8$ V
B) $1.23 \times 10^9$ V
C) $8.18 \times 10^8$ V
D) $8.18 \times 10^9$ V
E) $100$ V

Sec# Electric Potential - Electric Potential and Potential Energy
Grade# 50

Q13. Each of the two 25-$\mu$F capacitors, as shown in Fig. 3, is initially uncharged. How many Coulombs of charge pass through ammeter A after the switch S is closed for long time?

A) $0.20$ C
B) $0.10$ C
C) $0.40$ C
D) $0.80$ C
E) Zero C

Sec# Capacitance and Dielectrics - Combinations of Capacitors
Grade# 50

Q14. Each of the two 25-$\mu$F capacitors, as shown in Fig. 4, is initially uncharged. How much energy is stored in the two capacitors after the switch S is closed for long time?

A) $100$ J
B) $200$ J
C) $50$ J
D) $300$ J
E) $80$ J

Sec# Capacitance and Dielectrics - Energy Stored in a Charged Capacitor
Q15. The plates of a parallel plate capacitor are connected to a battery. If the distance between the plates is halved, the energy stored in the capacitor:

A) Increases two-fold
B) Increases four-fold
C) Remains constant
D) Reduces to one-half
E) Reduces to one-fourth

Q16. A parallel-plate capacitor has a capacitance of 10 \( \mu \text{F} \) and is charged with a 20 V power supply. The power supply is then removed and a dielectric of dielectric constant 4 is filled in the space between the plates. The voltage across the capacitor with dielectric is:

A) 5 V
B) 20 V
C) 10 V
D) 80 V
E) 50 V

Q17. A 10-ohm resistor has a constant current. If 1200 C of charge flow through it in 4 minutes, what is the value of the current?

A) 5.0 A
B) 3.0 A
C) 11 A
D) 15 A
E) 20 A

Q18. Two cylindrical resistors \( R_1 \) and \( R_2 \) are made from the same material and have the same length. When connected across the same battery, \( R_1 \) dissipates twice as much power as \( R_2 \). The ratio of diameter of resistor \( R_1 \) to that of \( R_2 \) is:

A) \( \sqrt{2} \)
B) 2
Q19. A carbon resistor has a resistance of 18 Ω at a temperature of 20°C. What is its resistance at a temperature of 120°C?

(The temperature coefficient of resistivity for carbon is $-5.0 \times 10^{-4}/\text{C}^\circ$.)

A) 17 Ω  
B) 22 Ω  
C) 11 Ω  
D) 32 Ω  
E) 10 Ω  

Q20. Electric charges flow through a wire shaped as shown in Fig. 5. The cross-sectional areas are $A_1 = 4 \text{ mm}^2$ and $A_2 = 1 \text{ mm}^2$ respectively. What is the drift speed of the electrons in the narrow section of the wire if their speed is 0.08 m/s in the wider region?

A) 0.32 m/s  
B) 0.02 m/s  
C) 0.04 m/s  
D) 0.16 m/s  
E) 0.08 m/s  

Test Expected Average = 50
Figure 1

Figure 2

Figure 3

Figure 4

Figure 5
### Physics 102
**Formula sheet for Second Major**

- **Electric Force**
  \[ F = \frac{kq_1 q_2}{r^2}, \quad F = q_0 E \]

- **Electric Potential**
  \[ \Phi = \int \vec{E} \cdot d\vec{A}, \quad E = \frac{kq}{r^2} \]

- **Electric Field**
  \[ E = \frac{kQ}{R^3} r, \quad E = \frac{2k\lambda}{r} \]

- **Electric Flux**
  \[ \Phi_c = \oint \vec{E} \cdot d\vec{A} = \frac{q_{in}}{\varepsilon_0}, \quad E = \frac{\sigma}{2\varepsilon_0}; \quad E = \frac{\sigma}{\varepsilon_0} \]

- **Electric Potential Energy**
  \[ V = \frac{kQ}{r}, \quad W = -\Delta U \]

- **Work Energy**
  \[ \Delta V = V_B - V_A = -\int_{V}^{B} \frac{\vec{E} \cdot d\vec{s}}{q_0} = \frac{\Delta U}{q_0} \]

- **Electric Field Components**
  \[ E_x = -\frac{\partial V}{\partial x}, \quad E_y = -\frac{\partial V}{\partial y}, \quad E_z = -\frac{\partial V}{\partial z} \]

- **Force Components**
  \[ U = \frac{kq_1 q_2}{r_{12}} \]

- **Capacitance**
  \[ C = \frac{Q}{V}, \quad C_o = \frac{\varepsilon_o A}{d}, \quad C = 4\pi\varepsilon_o \frac{ab}{b-a}, \]

- **Kinetic Energy**
  \[ U = \frac{1}{2} CV^2, \quad u = \frac{1}{2} \varepsilon_o E^2, \quad C = \kappa C_o, \]

- **Current**
  \[ I = \frac{dQ}{dt}, \quad I = J A, \quad \vec{J} = (ne)\vec{v}_d \]

- **Resistance**
  \[ R = \frac{V}{I} = \rho \frac{L}{A} \]

- **Density**
  \[ \rho = \rho_o [1 + \alpha(T - T_o)], \quad \rho = \rho_o \frac{1}{[1 + \alpha(T - T_o)]} \]

- **Physical Constants**
  \[ \varepsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{N.m}^2 \]
  \[ k = 9.0 \times 10^9 \text{ N.m}^2/\text{C}^2 \]
  \[ q_e = -1.6 \times 10^{-19} \text{ C} \]
  \[ m_e = 9.11 \times 10^{-31} \text{ kg} \]
  \[ m_p = 1.67 \times 10^{-27} \text{ kg} \]
  \[ 1 \text{ eV} = 1.6 \times 10^{-19} \text{ J} \]
  \[ \text{micro (} \mu \text{)} = 10^{-6}, \quad \text{nano (n)} = 10^{-9}, \]
  \[ \text{pico (p)} = 10^{-12} \]
  \[ g = 9.8 \text{ m/s}^2 \]