Problem 1. A point charge of magnitude +q produces an electric field pattern with a certain strength at distance r.

a) If another point charge produces an electric field that is twice as strong at the same distance r, what is the magnitude and sign of this second charge? (5 pts)

b) If a third point charge produces an electric field that is half as strong and directed inward at the same distance r, what is the magnitude and sign of this charge? (5 pts)

Problem 2.

The electric potential along a line is described by the function:

$$V(x) = 80 - 12x + 3x^2 \quad (\text{with } V \text{ in volts}, x \text{ in meters}).$$

a) Write the expression for the electric field $E(x)$ along the x-axis. (3 pts)

b) Calculate the electric field at $x = 0.0\,\text{m},\ 1.0\,\text{m},\ 2.0\,\text{m},\ 3.0\,\text{m}$. (7 pts)

### Problem 3 (10 pts) — Fill in the blanks

A uniform electric field of $900\,\text{N/C}$ points to the right.

- What is the potential difference $V_D - V_C$ if point D is 0.20 m to the right of point C? (3 pts)
- What is the potential difference $V_C - V_A$ if A is 0.35 m to the left of C? (3 pts)
- What is the potential difference $V_D - V_A$? (2 pts)
- Can we determine the absolute value of potential at C? Explain. (2 pts)

## Problem 4 (10 pts) — Fill in the blanks

The electric potential along the x-axis is given by

$$V(x) = 100 - 20x + 5x^2 \quad (\text{in volts, with } x \text{ in meters}).$$

Find the electric field at positions $x = 0.5$, $1.0$, $1.5$, and $2.0$ m.

## Problem 5 (10 pts) — Fill in the blanks

A steady current $I$ flows through a cylindrical copper wire of radius $r$.

a) How much charge passes through the wire in a time $t$? (4 pts)
b) What is the current density $J$? (3 pts)
c) If the resistivity of copper is $\rho$, what is the electric field inside the wire? (3 pts)

## Problem 6 (10 pts) — Fill in the blanks

A parallel-plate capacitor consists of two circular plates of radius $R$ separated by distance $d$.

a) Find its capacitance in vacuum. (4 pts)
b) If the capacitor holds charge $Q$, what is the potential difference? (3 pts)
c) If a dielectric with dielectric constant $K$ is inserted fully between the plates, what is the stored energy? (3 pts)

## Problem 7 (10 pts) — Long Question

Three resistors of $3\,\Omega$, $6\,\Omega$, and $12\,\Omega$ are connected in parallel across a 9 V battery.

a) What is the equivalent resistance? (3 pts)
b) What is the current through each resistor? (3 pts)
c) What is the power dissipated in each resistor? (2 pts)
d) What is the total power dissipated, and how does it compare with the power dissipated in the equivalent resistance? (2 pts)

**Problem 8 (10pts) Long question**

A circuit consists of a 12 V battery connected to two resistors $R_1 = 3\,\Omega$ and $R_2 = 6\,\Omega$ in series. In parallel with $R_2$, there is another resistor $R_3 = 4\,\Omega$.

a) Write down the loop and junction equations needed to analyze the circuit. (4 pts)
b) Solve for the current through each resistor ($I_1, I_2, I_3$). (6 pts)

*(Hint: Treat the branch containing $R_2$ and $R_3$ as a parallel combination.)*

## Problem 9 (10 pts) — Capacitance with moving dielectric

A parallel-plate capacitor has plates of area $A$ and separation $d$. A dielectric slab of constant $K = 4$ is inserted halfway between the plates.

a) Derive the expression for the effective capacitance. (6 pts)
b) If the dielectric is pulled out with velocity $u$, find the current in the external circuit. (4 pts)

## Problem 10 (10 pts) — Gauss's Law

A solid sphere of radius $a$ carries a uniform charge density $\rho$. Concentric with it is a conducting spherical shell of inner radius $b$ and outer radius $c$, which initially has no net charge.

a) Find the electric field in the regions: $r < a$, $a < r < b$, $b < r < c$, and $r > c$. (6 pts)
b) Find the induced charges on the inner and outer surfaces of the conducting shell. (4 pts)