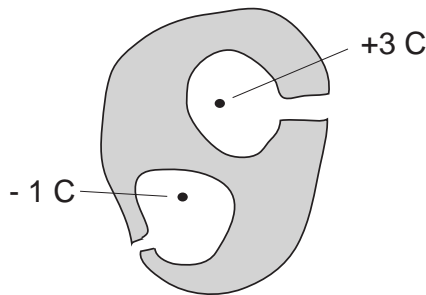


# Physics 120 – Midterm Exam

(Friday, February 8)

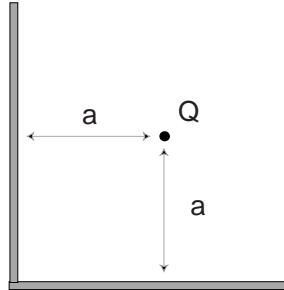
There are five problems, with point values indicated, for a grand total of 100 points.

1. (15 points) The situation shown in the figure was produced in the following way. I began with the conductor electrically neutral and sitting in empty space. Then I brought a charge of  $+3\text{ C}$  into one cavity in the conductor and a charge of  $-1\text{ C}$  into the other, as shown. This was done without touching the conductor or introducing any electrical contact. Carefully sketch the resulting distribution of charge in the conductor. What is the total charge on the conductor?



2. (15 points) Consider four fixed charges at the corners of a square:  $Q_1 = +1\text{ C}$  at  $(0, 0, 0)$ ,  $Q_2 = +1\text{ C}$  at  $(a, a, 0)$ ,  $Q_3 = -2\text{ C}$  at  $(a, 0, 0)$ ,  $Q_4 = -2\text{ C}$  at  $(0, a, 0)$ . Sketch the electric field lines.
3. (20 points) In the earth's atmosphere, the electrostatic potential rises with altitude by about  $100\text{ V/m}$ . However, in a storm, convection of the air inside a thundercloud brings charge down from high in the atmosphere, creating a potential difference of about  $30\text{ MV}$  ( $3 \times 10^7\text{ V}$ ) across a column of about  $1,000\text{ m}$  of air.
  - (a) Compute the surface charge on the cloud, per square kilometer.
  - (b) Compute the energy stored per square kilometer, in J.
  - (c) The large voltages cause the air to ionize, creating paths from the cloud to the ground with resistances of about  $10^{-3}\Omega$ . What is the initial current in the discharge?
  - (d) If an area of  $1\text{ km}^2$  discharges along one such path, how long does the discharge take?
4. (20 points) Three long parallel wires are positioned in the  $(x, y)$  plane with separation  $a$ . Each wire carries a static charge of  $\rho\text{ C/m}$ . By symmetry, the force on the middle wire is zero.

- (a) Lift the middle wire out of the plane by a small distance  $\Delta z$ , keeping it parallel to the other two wires. What is the force on this wire, to first order in  $\Delta z$ .
- (b) Is the equilibrium at  $\Delta z = 0$  stable or unstable?



5. (30 points) Two large conducting plates meet at a  $90^\circ$  angle, as shown in the figure. A charge  $Q$  is placed on the center line of the region between the plates, at a distance  $a$  from each plate.
- (a) Find the electrostatic potential in the region between the plates.
- (b) Find the force on the charge.
- (c) Find the work needed in bring the charge in from infinity to the location shown.

You might want to know that  $\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{Nm}^2$ .