Physics 23 Practice Final - 3 hours

Harry Nelson

Tuesday, December 11

Write your answers in a bluebook. Calculators and two page of notes allowed. No textbooks or other material allowed. Please make your work neat, clear, and easy to follow. It is hard to grade sloppy work accurately. Generally, make a clear diagram, and label quantities. Make it clear what you think is known, and what is unknown and to be solved for. Except for extremely simple problems, derive symbolic answers, and then plug in numbers (if necessary) after a symbolic answer is available. Use Gaussian centimeters-grams-seconds units for the electrostatic problems. **Put a box around your final answer... otherwise we may be confused about which answer you really mean, and you could lose credit.**

---

1. The length of each side of a cube of copper is 1 cm, and each of its 6 surfaces has been blackened. Initially, the cube is at $T_i = 1200\,\mathrm{K}$, and then the cube cools down to $T_f = 300\,\mathrm{K}$. The cube is in the vacuum of intergalactic space, and does not lose heat by conduction or by convection; there are no other nearby sources of radiation. The molar heat capacity of copper is what you'd expect for an ideal monatomic solid. The mass density of copper is $9\,\mathrm{gm/cm^3}$, and the atomic weight of copper is $63.5\,\mathrm{gm/mole}$. The Stephan-Boltzmann constant is $\sigma = 5.7\times10^{-8}\,\mathrm{W/m^2/K^4}$, and the ideal gas constant $R = 8.3\,\mathrm{J/mole/K}$.

   (a) How much heat is lost by the cube when it cools?

   (b) What is initial rate of heat lost by the cube?

   (c) How long does it take for the cube to cool from T_i to T_f? Assume that the rate of heat conduction *inside* the cube is so high that all points inside the cube are always at the same temperature.

2. A quantity of two moles of nitrogen starts at $T_i = 0^\circ\,\mathrm{C}$ and is heated to $T_f = 100^\circ\,\mathrm{C}$, and is always at atmospheric pressure. Find, symbolically and numerically:

   (a) The change in internal energy of the gas.

   (b) The work done by the gas.

   (c) The heat transferred to the gas.

   (d) The change in entropy of the gas.

   One atmosphere is $10^5\,\mathrm{Pa}$ and the ideal gas constant is $R = 8.3\,\mathrm{J/mole/K}$.

3. At what temperature would the root-mean-squared velocity of xenon atoms equal $10\,\mathrm{m/s}$? The atomic weight of xenon is 131 gm/mole, and the ideal gas constant is $R = 8.3\,\mathrm{J/mole/K}$.

4. A positive charge q is stationary, and sits where two infinitely long straight wires intersect at angle θ. Two identical negative charges $-q'$ are free to travel along the infinite straight wires, and they come to rest at positions so each is a distance $x = 10\,\mathrm{cm}$ from q, as shown in Figure 1.

   (a) Evaluate (q/q') in terms of the variables θ and x.

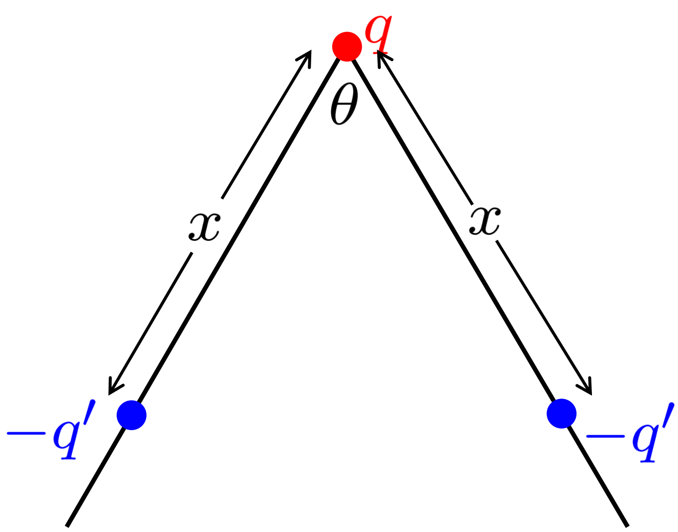

Figure 1: For use in Problem 4.

(b) Numerically evaluate (q/q') when $\theta = 60°$.

(c) With $\theta = 60°$ and $(q/q') < (1/2)$, you hold the negative charges initially at rest as in Figure. 1 and then release them. Where do the negative charges end up and why?

5. A cylindrical shell of radius a and infinite length has uniform surface charge density σ. Find:

   (a) The electric field (magnitude and direction) for all space.

   (b) The force per unit area (aka the pressure) on the surface charge. Be sure to give the direction.

6. A **hemispherical** shell is covered with uniform charge density σ. Find the electric field at the origin of the hemisphere.
