Year 1 Assessed Problems

Semester 2

Problem Sheet 5

SOLUTIONS TO BE SUBMITTED ON CANVAS

By 17:00hrs on Wednesday 26th February 2025

Electromagnetism I – Problem sheet 5

Problem 1.

N charged raindrops each with radius a all have the the same potential. Assume that they are far enough apart so that the charge distribution on each is not affected by the others (that is, each are spherically symmetric).

1. What is the total capacitance of the system? **[2]**
2. If there is a total charge Q on the raindrops, what is the potential of each of them? **[1]**
3. How does the capacitance compare with the capacitance in the case where the drops are combined into one big drop? (the total volume of water does not change) **[2]**

Problem 2.

A spherical conducting shell has radius R and potential ϕ. (If you wish, you may consider it to be part of a capacitor with the other shell at infinity.) You compress the shell down to zero size (always keeping it spherical), while a battery holds the potential constant at ϕ.

1. What are the initial and final energies stored in the system? **[2]**
2. What is the final charge on the shell? **[1]**
3. What is the work done *by or on* the battery? **[1]**
4. What is the work done *by or on* you? **[1]**

[Be sure to specify clearly what your conservation-of-energy statement is, paying careful attention to the signs of the various quantities]

Classical Mechanics and Special Relativity 2
Assessed problem 3

A K meson, travelling through the laboratory, decays into two π mesons. One of the π mesons is left at rest in the laboratory frame.

According to an observer in the laboratory frame:

(i) What is the energy of the moving π meson? [4]
(ii) What is the energy of the K meson? [1]
(iii) What is the momentum of the K meson? [1]
(iv) What is the speed of the K meson? [1]

The K meson lives for $\tau = 0.9 \times 10^{-10}$ seconds in its own rest frame before decaying. How far is it observed to travel in the laboratory frame before decaying? [3]

[Mass of a K meson is 494 MeV/c^2; mass of a π meson is 137 MeV/c^2]

Problem 3.1 **A thermodynamic process**
An ideal gas is initially in a state i labelled by p_i, V_i and T_i. It undergoes an isothermal expansion to an intermediate state m for which the pressure is $p_m = p_i/2$. The gas is then isobarically compressed to a final state f until the volume has returned to its initial value, V_i.

1. Define the terms isothermal and isobaric. If the ideal gas was in a closed container and unable to exchange heat with its surroundings, what kind of expansion would this be? **[3]**
2. Determine the values of the variables p, V and T for the states m and f in terms of p_i, V_i and T_i. **[7]**