Year 1 Assessed Problems

Semester 2

Assessed Problems 3

SOLUTIONS TO BE SUBMITTED ON CANVAS BY

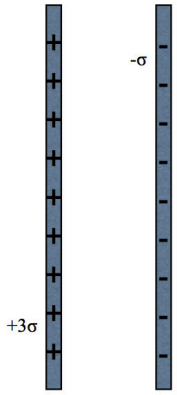
Wednesday 12th February 2025 at 17:00

Electromagnetism I – Problem sheet 2 – Week 3

Problem 1.

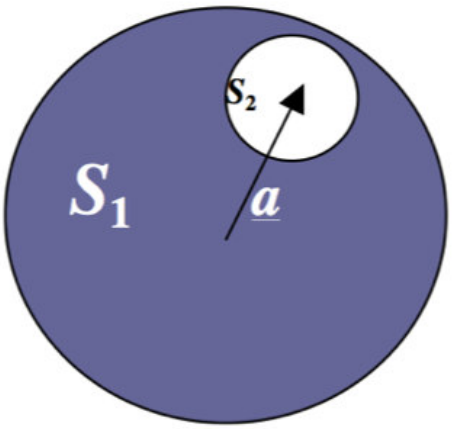
The figure shows, in cross-section, portions of two infinitely large, parallel, non-conducting sheets, each with a uniform charge distribution. The charge density for the sheet on the left is $+3\sigma$ and that for the sheet on the right is $-\sigma$. Find the magnitude and direction of the total electric field $\underline{\mathbf{E}}$ in terms of σ:

1. To the left of both sheets; **[2]**
2. Between the sheets; **[1]**
3. To the right of both sheets. **[2]**



Problem 2.

A sphere S_1 of radius R_1 contains charge with a uniform density ρ. A spherical cavity S_2 of radius R_2 is cut out of the sphere. The centres of the spheres are separated by a vector distance $\underline{\mathbf{a}}$, with $R_2 + a < R_1$. Derive an expression for the electric field $\underline{\mathbf{E}}$ as a function of $\underline{\mathbf{a}}$ and ρ in a generic location inside the spherical cavity. (*Hint:* Use the superposition principle to replace this sphere by two objects which are equavalent and keep everything in vector form.) **[5]**



Classical Mechanics and Special Relativity 2
Assessed problem sheet 2

(1) Two alien spaceships approach The Earth from opposite directions, moving with equal and opposite velocities as measured by a stationary observer on The Earth. Their relative speed, as measured by the aliens, is 0.8c. Determine the speed of the spaceships as measured by the stationary observer on Earth. [3]

(2) Three events, labelled **A**, **B**, and **C,** are observed in the same inertial frame. Their 2-D space-time (y=z=0) coordinates are: **A**(x=4m, t=10^{-8} s), **B** (x=1m, t=10^{-8} s), and **C** (x=6m, t=$2x10^{-8}$ s). Determine which, in any, of these events could be caused by which others. [3]

(3) Two events occur in the same place in the laboratory frame of reference and are separated by 3 seconds.

(a) Calculate the space-time interval between these events [2]

(b) What is the spatial distance between these events in a different frame of reference in which they are separated by 5s? [2]

[You may take the speed of light, c to have the value $3x10^{8}$ ms^{-1}]

1. At room temperature, mercury (molar mass of 200.6 g mol^{-1}) is in liquid form with a density of $\rho = 13.35 \times 10^3$ kg m^{-3}. Its surface tension is measured to be $\gamma = 465 \times 10^{-3}$ N m^{-1}.

   (a) Estimate the number of atoms per m^2 on the surface of liquid mercury. [7 marks]

   (b) Using a reasonable value for the co-ordination number, estimate the value of ϵ in the Lennard-Jones potential for mercury. [3 marks]