

GENERAL PHYSICS



## I. MOLECULAR BEAMS\*

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## RESEARCH OBJECTIVES AND SUMMARY OF RESEARCH

We have started a series of experiments in which we apply newly developed atomic beam techniques to certain problems in low temperature physics. These experiments can be classified as follows.

- (i) Studying the scattering of cold He beams by gas, by other beams and from surfaces, both liquid and solids.
- (ii) Observing the diffraction of atoms from gratings and apertures.
- (iii) Investigating various properties of liquid helium as exhibited by the emitted atoms.
- (iv) Using beams of magnetic atoms as microscopic probes of superconductors.

We are also constructing a first model of a molecular microscope in which we shall study the evaporation of K and  $K_2O$  from a potassium feldspar matrix containing alumina grains. The principles and possibilities of this device were described in Quarterly Progress Report No. 84, January 15, 1967, pp. 1-2.

During the past year we have been equipping the Molecular Beam Laboratory so that we can perform experiments at low temperatures. Three cryostats of standard design with associated pumping and gas lines have been installed. A helium dilution refrigerator intended to attain temperatures below 0.1°K has nearly been completed. Low temperature molecular beam apparatus is being constructed to go into the cryostats. Preliminary results have been obtained in experiments under headings (iii) and (iv) above.

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### A. MOLECULAR BEAM UNIVERSAL IONIZER

We are developing a new type of universal ionizer as a molecular beam detector (see Fig. I-1). The detector has 20 tungsten filaments arranged cylindrically outside a concentric accelerating grid. The molecular beam that is to be detected is directed along the axis of the cylinder and is ionized by the electrons accelerated inwardly by the grid. Detection of the ions takes place at the end of the cylindrical region. In order to overcome the low efficiency of conventional ionization detectors, we

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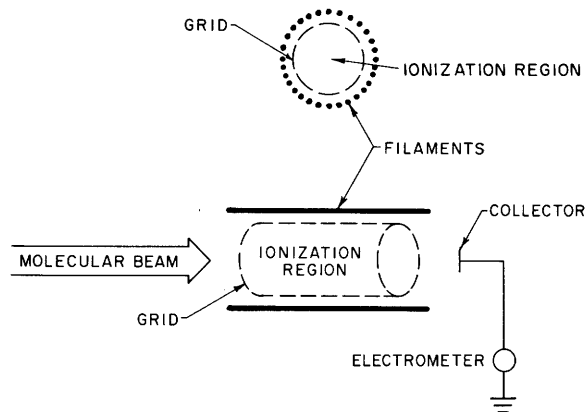


Fig. I-1. Diagram of the ionizer.

hope that the electrons entering the central region will produce a space charge large enough to provide a focusing of the positive ions in a region close to the axis of the cylinder. This idea was first used by R. Weiss,<sup>1</sup> but the present construction is simpler.

Calculations have been made to determine if such a space charge would exist and if it would affect the ionizing efficiency of the electrons.

Using the facilities of the R.L.E. computation group, we have solved the differential equation for the electron distribution inside the ionizer. Poisson's equation  $\nabla^2 V = -4\pi\rho$  is to be solved. Assuming cylindrical symmetry, we can eliminate all but the dependence on  $r$ . We also assume monoenergetic electrons.

We use following definitions:

$n$  = number of electrons entering the ionizer per unit angle per unit length per unit time

$v$  = velocity of the electrons

$R$  = radius of the grid

$V$  = potential.

The charge density of electrons in the central region is

$$\rho = - \frac{2ne}{rv}.$$

By choosing the total energy to be zero, Poisson's equation becomes

$$\frac{1}{r} \frac{\partial}{\partial r} r \frac{\partial V}{\partial r} = 4\pi \frac{2ne}{r} \sqrt{\frac{m}{2eV}}.$$

We use the dimensionless variables

$$X = \frac{r}{R} \quad \phi = \frac{2eV}{mv_o^2} \quad v_o = v(R).$$

Then the equation becomes

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$$\frac{\partial}{\partial X} X \frac{\partial \phi}{\partial X} = C \phi^{-1/2},$$

where

$$C = \frac{16\pi n e^2 R}{m v_0^3},$$

and the boundary conditions are  $\phi(1) = 1$ ,  $\phi(0)$  is finite.

A program that supplied a value of  $\frac{\partial \phi}{\partial X}$  at  $X = 1$  and adjusted this to give a finite value

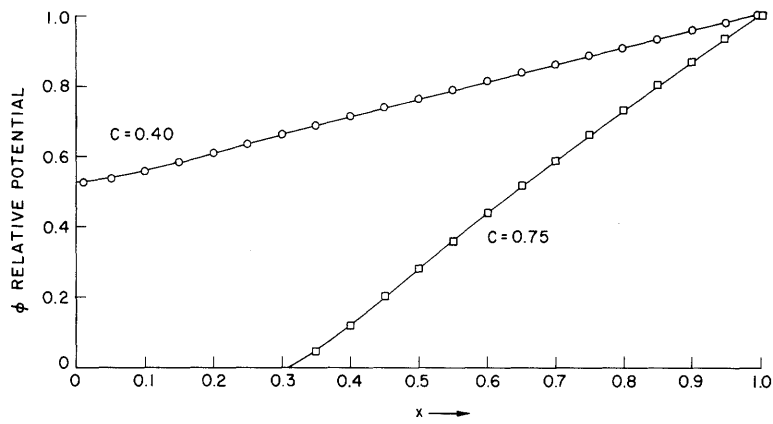


Fig. I-2. Potential.

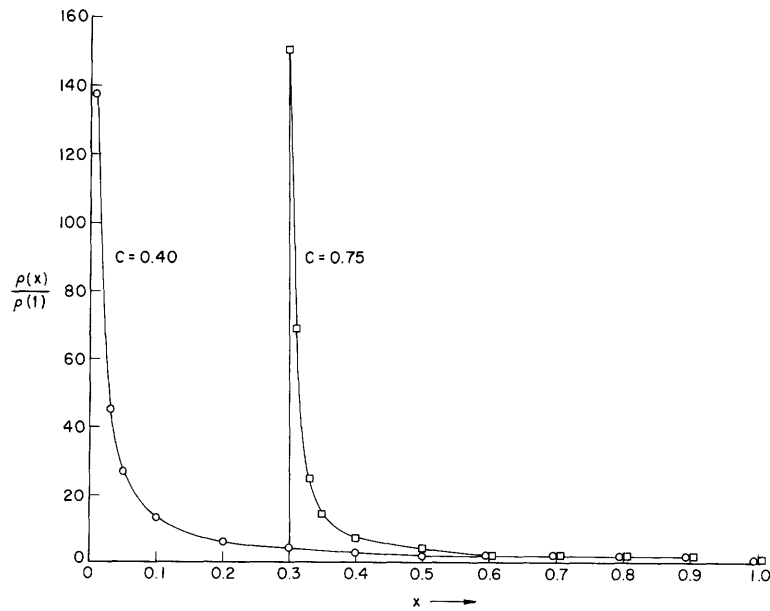


Fig. I-3. Charge density.

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of  $\phi$  at  $X = 0$  was run for various values of  $C$ . Two families of solutions occur. For  $C < 1/2$ ,  $\phi(0)$  is positive, which indicates that electrons traverse the center with a non-vanishing speed. For  $C > 1/2$ ,  $\phi(X_0)$  becomes zero for  $X_0 > 0$ , which indicates that the electron space charge is sufficient to exclude electrons from the central region  $X < X_0$ . Figures I-2 and I-3 are plots of  $\phi$  and  $\rho$  for  $C = 0.4$  and  $C = 0.75$ .

We would like to thank Eloise Kleban for her help with this problem. We also thank Professor George G. Harvey for his help.

D. E. Oates, R. F. Tinker

### References

1. R. Weiss, Rev. Sci. Instr. 32, 397 (1961).