EXPERIMENT 2: Electron Tube

Introduction

Free electrons in a metal may be thought of as being "electron gas" confined in potential or energy walls. Under normal conditions or even when a voltage is applied near the surface of the metal, these electrons cannot leave the potential walls (see fig. 19.11)

If however the metal or the electron gas is heated, the electrons have enough thermal energy (kinetic energy) to overcome the energy barrier W (W is known as "work function"). If a voltage is applied across the metal and the anode, these thermally activated electrons may reach the anode.

The number of electrons arriving at the anode per unit time depends on the nature of the cathode and the temperature, i.e. all electrons freed from the potential wall will reach the anode no longer increase with applied voltage (see fig. 19.11)

The saturated current corresponding to the number of thermally activated electrons freed from the metal surface per unit time obeys what is generally known as Richardson´s equation i.e.

$$I_B = C \cdot T^2 \cdot e^{-\frac{W}{k \cdot T}}$$

where

C is a constant

T temperature of the cathode in Kelvin

k Boltzmann´s constant = 1,38 . 10^{-23} J/K

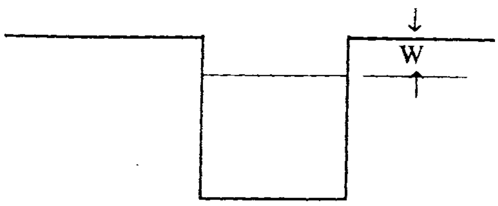

Fig 19.11

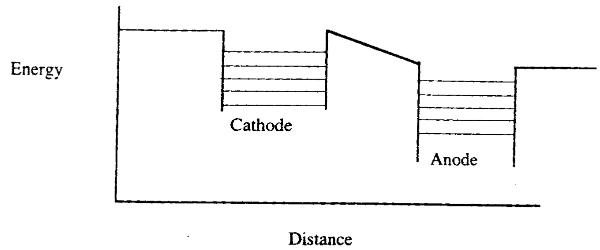

Fig.19.12

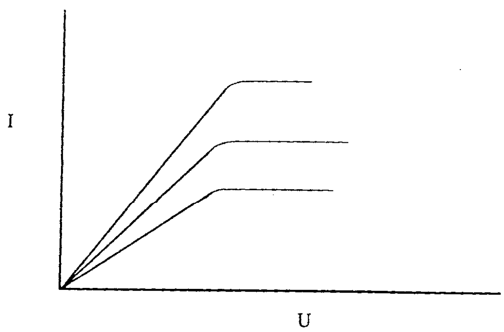

Fig 19.13 Graph of current as a function of voltage across anode-cathode

Determine the value of the work function W of tungsten metal in the form of heating filament of the vacuum tube provided.

The following items of equipment are placed at the disposal of the contestants:

- Electron tube AZ 41 which is a high-vacuum, full-wave rectifying diode. The cathode is made from a coated tungsten filament the work function of which is to be ascertained. According to the manual prepared by its manufacturer, no more than 4 V should be used when applying heating current to the cathode. Since the tube has two anodes, it is most desirable to have them connected for all measurements. The diagram in fig. 19.14 is a guide to identifying the anodes and the cathode.

- multimeter 1 unit, internal resistance for voltage measurement: 10 MΩ
- battery 1,5 V (together with a spare)
- battery 9 V; four units can be connected in series as shown in fig. 19.15
- connectors
- resistors; each of which has specifications as follows:
  1000 Ω ± 2% (brown, black, black, brown, brown, red)
  100 Ω ± 2% (brown, black, black, black, brown, red)
  47,5 Ω ± 1% (yellow, violet, green, gold, brown)
- resistors; 4 units, each of which has the resistance of about 1 Ω and coded
- connecting wires
- screw driver
- graph paper (1 sheet)
- graph of specific resistance of tungsten as a function of temperature; 1 sheet

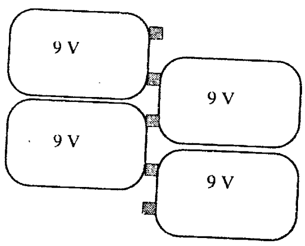

Fig 19.15

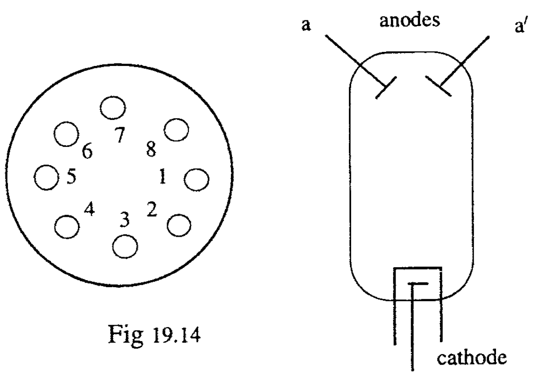

Fig 19.14

Solve the following problems:

2.1

Determine the resistance of 4 numerically-coded resistors. Under no circumstances must the multimeter be used as an ohmmeter.

2.2

Determine the saturated current for 4 different values of cathode temperatures, using 1,5 V battery to heat the cathode filament. A constant value of voltage between 35 V – 40 V between the anode and the cathode is sufficient to produce a saturated current. Obtain this value of voltage by connecting the four 9 V batteries in series. Describe how the different values of temperature are determined.

2.3

Determine the value of W. Explain the procedures used.

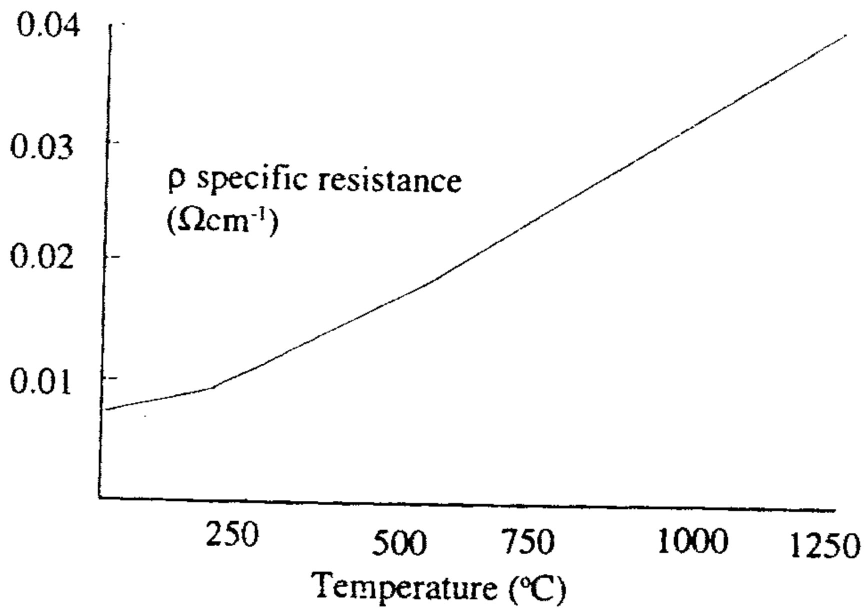

Fig 19.16