14.7 DETERMINATION OF e/m OF AN ELECTRON

Consider narrow beam of electrons moving with a constant speed 'v', be projected perpendicularly to a known uniform magnetic field $\overline{B}$ directed in to the plane of paper.

The force experienced by electrons is given by: $\bar{F} = -e\, \vec{v} \times \vec{B}$

The direction of the force will be perpendicular to both $\vec{v}$ *and* $\overline{B}$. This force will change the direction of velocity. The magnitude of force is given by:

$$|\bar{F}| = |-evB\sin\theta| \qquad \because \theta = 90$$

$$F = evB\sin\theta = evB\sin 90$$

$$F = evB \text{..............(1)}$$

As magnitude of $\vec{v}$ *and* $\overline{B}$ remains constant, so the magnitude of the force $\overline{F}$ also remains constant. This force *F* provides the necessary centripetal force to the electron of mass *m* to move along a circular orbit of radius *r*.

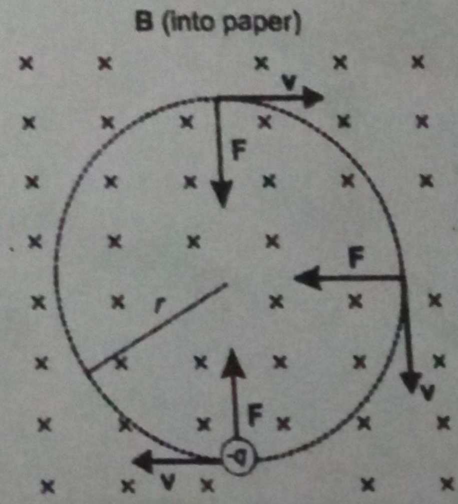


Fig 14.11

$$\therefore \qquad F_c = \frac{mv^2}{r} \text{..........(2)}$$

Comparing Eqs. (1) and (2),

$$F = F_c$$

$$\Rightarrow \qquad evB = \frac{mv^2}{r}$$

$$\frac{e}{m} = \frac{v}{Br} \text{................(3)}$$

v and r are known, e/m of an electron can be determined.

ermination of radius:

e radius r is measured by making the electronic trajectory visible. A glass tube is filled with a gas such as hydrogen at low pressure and is place in uniform magnetic field of known value. As electrons are projected into this tube they begin to move in a circular path. During motion electrons collides with atoms of the gas. This excites the atoms and when they de-excite emit light. The path of electron in the form of circular ring of light become visible. The diameter of ring is measured easily and hence radius of circular path is determined.

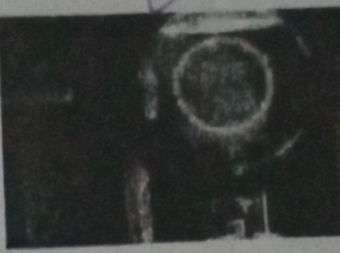


Fig 14.12

Velocity of electron: (POTENTIAL DIFFERENCE METHOD)

If V_o is the potential difference given to the electrons before entering into the magnetic field, then energy gained by electrons is given by:

$$P.E = eV_o$$

This energy appears as the kinetic energy of electrons, so

$$eV_o = \frac{1}{2}mv^2$$

$$\Rightarrow \quad v^2 = \frac{2V_o e}{m}$$

$$v = \sqrt{\frac{2V_o e}{m}}$$

Putting this value in Eq. (3),

$$\frac{e}{m} = \frac{1}{Br}\left(\sqrt{\frac{2V_o e}{m}}\right)$$

Squaring both sides,

$$\frac{e^2}{m^2} = \frac{1}{B^2r^2}\frac{2V_o e}{m}$$

$$\Rightarrow \quad \frac{e}{m} = \frac{2V_o}{B^2r^2}$$

The most accurate value of e/m for an electron is 1.7588×10^{11} C/Kg

MCQ's

FOR YOUR INFORMATION

Many electromagnetic devices are very sensitive to magnetic fields.

Explanation:

You can easily ruin your television screen, scramble your credit card or erase your hard drive by a magnet too close to it. Keep all magnets far away from anything with a screen or a memory.

14.8 CATHODE RAY OSCILLOSCOPE

"A device which traces the desired wave form with a beam of electrons or cathode rays is called cathode ray oscilloscope (CRO)."

OR

"An electronic device used for the plotting the graphs at a very high speed."

Principle:

A beam of electrons is deflected while passing through uniform electric field present between two sets of parallel plates. This beam then falls on a fluorescent screen where it makes a visible spot. It can display graphs of functions varying rapidly with time.

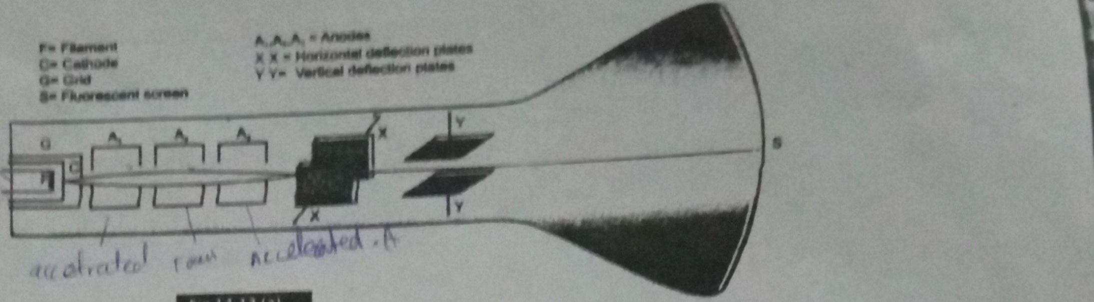


Fig 14.13 (a)

Construction:
It consists of highly evacuated glass tube. One end of tube has an electron gun to produce beam of electrons and oth end has a fluorescent screen which is coated with a material like Zinc sulphide.

Electron gun:
It consists of an indirectly heated cathode, a grid and three anodes and provide beam of electrons.

Filament:
The filament *F* heats the cathode which emits electrons.

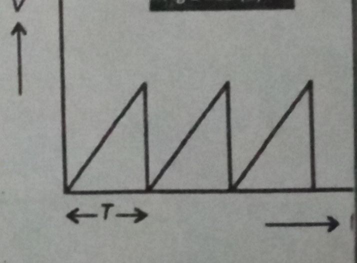
Grid:
The grid *G* is at a negative potential with respect to cathode. It controls the number of electrons which are accelerat by anodes and so it controls the brightness of the spot formed on the screen.

Anodes:
The anodes A_1, A_2 and A_3 are at a high positive potential with respect to cathode. They not only accelerate th electronic beam but also focus them on a fixed spot on the screen *S*.

Deflecting plates:
X and *Y* are the two sets of deflecting plates. When voltage is applied between the *X* plates, it deflects the bea horizontally on the screen *i.e.* parallel to x-axis. When a voltage is applied across the *Y* plates it deflects the bea vertically on the screen *i.e.* along the y-axis.

Sweep or time base generator:
The voltage that is applied across the x-plates is usually provided by a circuit that is built in the CRO. It is known as "Sweep or Time Base Generator".
Its output wave form is a saw tooth voltage of period *T* as shown in Fig.14.13 (b).
The voltage increases linearly with time for a period *T* and then drops to zero.
When this voltage is applied across the x plates then the spot is deflected linearly along x-axis for a time *T*, the spot then returns to its starting point on the screen very quickly because saw tooth wave falls to its initial value at the end of each period. If the time period 'T' is very small we see just a bright line on the screen.

Fig 14.13 (b)



Sinusoidal wave and synchronization controls:
If a sinusoidal voltage is applied across the *Y* plates and time base voltage is applied across the x-plate, then th sinusoidal voltage will appear as sinusoidal trace on the screen. The pattern will appear stationary if *T* becomes equal time period or some multiple of the voltage on y-plates.

It is thus necessary to synchronize the frequency of the time base generator with the frequency of the voltage the y-plates. This is possible by adjusting the synchronization controls provided on the front panel of the CRO.

Display system:
The screen of CRO is coated with a fluorescent material (zinc sulphide). The zinc sulphide gives a glow of light wh electrons collide with it.

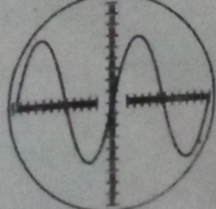


Fig 14.14 (a)

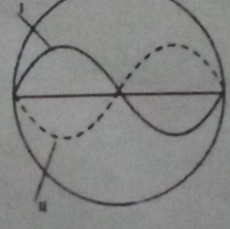


Fig 14.14 (b)

Ayesha Room

prop
11.

CRO:

e CRO is used for displaying the wave form of a given voltage.

When the wave form is displayed, we can measure the voltage, frequency and phase.

As the y-axis is calibrated in volts and x-axis in time, the instantaneous value and peak value of the voltage can be measured.

4) The time period can also be determined by using the time calibration of x-axis. Phase difference between two voltages can be obtained by displaying their wave form. In Fig.14.14 (b), the wave forms of two voltages are shown. These waveforms show that when the voltage of I is increasing, the voltage of II is decreasing and vice versa. Thus phase difference between these voltages is 180.

L/Q imp

14.9 TORQUE ON A CURRENT CARRYING COIL

Consider a rectangular coil *ABCD* carrying a current I. The coil has the ability to rotate a about axis XX'. Suppose coil is placed in a uniform magnetic field *B* with its plane parallel to the field. If '*L*' is its length and 'a' is the width of coil, then the force acting on a current carrying conductor in magnetic field is given by $F = ILB\sin\theta$,

x