CATHODE RAY OSCILLOSCOPE (CRO)

4.6 (a) Cathode rays

CORE

- Describe the production and detection of cathode rays
- Describe their deflection in electric fields
- State that the particles emitted in thermionic emission are electrons

4.6 (b) Simple treatment of cathode-ray oscilloscopes

EXT.

- Describe(in outline) the basic structure and action of the cathode-ray oscilloscope (detailed circuits are not required)
- Use and describe the use of a cathode-ray oscilloscope to display waveforms

Cathode rays are electron beams or streams of electrons that were observed for the first time in Crookes tubes (vacuum tubes).



Discovery of the Electron: Cathode Ray Tube Experiment

https://www.youtube.com/watch?v=Rb6MguN0Uj4

Thermionic emission is a process of emission of charge particle (known as thermion) from the surface of a heated metal. The charge particles normally are electrons.

The rate of emission (number of electrons emitted in 1 second) is affected by 4 factors: 1. the temperature of the heated metal,

When the temperature of the metal increase, the emission rate of electron will increase.

2. the surface area of the heated metal,

When the surface area of the metal increase, the emission rate of electron will increase.

3. the types of metal

The rates of thermionic emission are different with regard to different types of metals.

4. the coated material on the surface of the metal.

If the surface is coated by a layer of barium oxide or strontium oxide, the rate of emission will become higher.

Thermionic Diode

- 1. Thermionic emission is applied in thermionic diode.
- 2. A diode is an electrical component that only allowed current flows in one direction.
- 3. Figure below shows the illustration of a thermionic diode.
- 4. Electrons can only released from the tungsten filament (when it is hot) and move toward the anode which is connected to the positive terminal.
- 5. Electrons are not allowed to move in the opposite direction because no electrons will be released from the anode.
- 6. As such, the electrons can only move from left to right but not the other way round.



The cathode ray oscilloscope is an instrument which we use in laboratory to display measure and analyze various waveforms of various electrical and electronic circuits. The cathode-ray oscilloscope (C.R.O.) consists of the following components:

- 1. The electron gun.
- 2. The deflecting plates.
- 3. A fluorescent screen.



| Parts | Function | | | |
|----------|---|--|--|--|
| | the filament, a tiny tungsten which is heated by current, | | | |
| filament | gives off electrons due to heat generated by an electric | | | |
| | current. | | | |
| cathode | Release electrons when heated by filament | | | |
| grid | The grid is connected to a negative potential. The more | | | |
| | negative this potential, the more electrons will be repelled | | | |
| | from the grid and fewer electrons will reach the anode and | | | |
| | the screen. | | | |
| | The number of electrons reaching the screen determines the | | | |
| | brightness of the light. Hence, the negative potential of the | | | |
| | grid can be used as a brightness control. | | | |

| Focusing anode and accelerating anode | The anode at positive potential accelerates the electrons and the electrons are focused into a fine beam as they pass through the anode. | | | | | |
|---------------------------------------|--|--|--|--|--|--|
| Electron gun | The electron gun makes a narrow beam of electrons. Its cathode gives off electrons and anode accelerate them. | | | | | |
| y-plate | The Y-plates will cause deflection in the vertical direction when a voltage is applied across them. | | | | | |
| x-plate | The X-plates will cause the electron beam to be deflected in the horizontal direction if a voltage is applied across them. | | | | | |

The fluorescent screen

- 1. The screen is coated with a fluorescent salt, for example, zinc sulphide.
- 2. When the electrons hit the screen, it will cause the salt to produce a flash of light and hence a bright spot on the screen.

Using CRO



| Function |
|----------|
|----------|

| 1. Power switch | To switch on and off of the oscilloscope |
|----------------------|--|
| 2. Focus control | To control the focus of the spot on the screen. |
| 3. Intensity control | To control the brightness of the spot on the screen. |
| 4. X-offset | Y-offset moves the whole trace vertically up and down on the |
| 5. Y-offset | screen, while X-offset moves the whole trace from side to side on |
| | the screen. |
| 6. Time base | Whenever we switch on the time-base, we are actually applying a |
| control | sawtooth voltage to the X-plates (Figure below) |
| | * This make the electron beam sweep across the screen at a |
| | constant speed. |
| | * By knowing the period of each cycle, T, we can then know how |
| | fast the beam is sweeping across the screen. The time-base is thus |
| | a measure of time for the oscilloscope. |
| 7. Y gain control | * the "Volts/Div." wheels amplify an input signal so that for a |
| | division a given voltage level is in valid. A "division" is a segment, a |
| | square on the screen of the oscilloscope. |
| | * A setting of ".5" i.e. means, that the height of a single square |
| | equals a voltage of 0.5 V. An amplitude of 1 V would have a size of |
| | two divisions vertical to the abscissa. |
| 8. d.c./a.c. switch | d.c. – d.c. and a.c. voltage displayed. |
| | a.c. – only a.c. voltage displayed. |
| 9. X-input and Y- | Electric input connect to the X-plate and Y-plate. |
| input | |

Example

Table below shows the sample display of direct current and alternating current when the time base is switched ON and OFF.



EXAM QUESTIONS



EXTENDED

(a) A cathode-ray oscilloscope makes use of the process known as thermionic emission.

Describe what happens during this process.

.....[1]

(b) In the space below, draw a labelled diagram of a cathode-ray oscilloscope.

Include in your diagram the tube, the cathode, the accelerating anode, the focusing anode and both X- and Y-plates. Do not attempt to show any external circuits.

(c) A cathode ray is a beam of electrons.

Suggest one way of controlling the number of electrons in the beam.

.....[1]

(d) One cathode-ray tube has 5000∨ between the accelerating anode and the cathode. The beam of electrons carries a total charge of 0.0095 C in 5.0 s.

Calculate

(i) the current caused by the beam,

current =[2]

(ii) the energy transferred by the beam in 20 s.

energy =[2]

[Total: 9]

.....

To create cathode rays in a vacuum, what might be a suitable potential difference to connect between the cathode and anode?

- A 6V a.c.
- **B** 6 V d.c.
- C 600 V a.c.
- **D** 600 V d.c.

.....

CORE S12

Fig. 11.1 shows an electron beam about to enter, at point A, the electric field between two charged metal plates.





- (a) On Fig. 11.1, carefully draw the path of the electron beam between A and the line BC.
 [3]
- (b) The voltage across the plates is reversed. State what difference this makes to the path of the electron beam.

.....[1] [Total: 4]) (a) Fig. 10.1 shows a type of tube in which cathode rays can be produced.



Fig. 10.1

(i) A p.d. is connected between two terminals in order to cause thermionic emission. Between which two of the four labelled terminals is the p.d. connected?

 between point
 and point
 [1]

 (ii) Where does the thermionic emission occur?
 [1]

 (iii) What particles are emitted during thermionic emission? Tick one box.
 [1]

 (iii) what particles
 [1]

 electrons
 [1]

 neutrons
 [1]

 protons
 [1]

- (iv) On Fig. 10.1, draw the path of the cathode rays that are created when all the electrical connections are correctly made. [1]
- (v) State what is seen when the cathode rays strike the fluorescent screen.

......[1]

Fig. 10.1 shows a simplified diagram of the front of a cathode-ray oscilloscope (c.r.o.).





- (a) When the oscilloscope is switched on, a bright spot is seen at the centre of the screen.
 - (i) Describe what causes this bright spot.

(ii) The spot is rather blurred. Which control should be adjusted to make it sharper?
[1]
(iii) Which control would be switched on to turn the spot into a horizontal line?
[1]
(iv) Describe what happens inside the oscilloscope to turn the spot into a horizontal line.
[3]

- (b) You have an alternating p.d. whose waveform you wish to display on the screen.
 - (i) Where would you connect this alternating p.d. to the oscilloscope?

.....

(ii) Fig. 10.2 shows what the trace on the screen might look like.

| Ц | | | | (| 7 | | | | | | 4 | Ц |
|----------------------|-------|---|---|---|---|---|----|---|---|---|----------|--------|
| \square | | | / | |) | | | | | | <u> </u> | N |
| | | | / | | | 7 | | | | 1 | | 1 |
| $\overline{\Lambda}$ | | 1 | | | | | | | | / | | |
| \square | | 4 | | | | | Ą. | | 4 | | | Ц |
| Н | 4 | | | | | | 7 | _ | / | | | 4 |
| Ĥ | | | | | | | | | | | | H |
| \sim | | | | | | | | | | | | \sim |

Fig. 10.2

What change would you see on the screen if you adjusted the x-shift control?
 What change would you see on the screen if you adjusted the y-shift control?