$$n = \frac{7 \cdot 93 \times 10^{-19} \text{ C}}{1 \cdot 6 \times 10^{-19} \text{ C}} = 4 \cdot 96.$$

It is clear that 5 electrons are attached to the drop.

7. *Show that the dynamic plate resistance of a diode is $\frac{2}{3}\frac{V}{i}$ where V and i are the plate voltage and the plate current respectively. Assume Langmuir–Child equation to hold.*

Solution :

The dynamic plate resistance of the diode is $R = \frac{dV}{di}$.

The Langmuir–Child equation is

$$i = cV^{3/2} \qquad \ldots \text{(i)}$$

where c is a constant for a given diode. This gives

$$\frac{di}{dV} = \frac{3}{2} cV^{1/2}. \qquad \ldots \text{(ii)}$$

Dividing (ii) by (i), $\frac{1}{i}\frac{di}{dV} = \frac{3}{2V}$

or, $\frac{dV}{di} = \frac{2V}{3i}$.

8. *The mutual conductance of a triode valve is* 2·5 millimho. *Find the change in the plate current if the grid voltage is changed from* – 2·0 V *to* – 4·5 V.

Solution :

The mutual conductance of a triode valve is

$$g_m = \left[\frac{\Delta i_p}{\Delta V_g}\right]_{\Delta V_p = 0}$$

or, $\Delta i_p = g_m \, \Delta V_g$

$$= (2 \cdot 5 \times 10^{-3} \, \Omega^{-1}) \times (-4 \cdot 5 \text{ V} + 2 \cdot 0 \text{ V})$$

$$= -6 \cdot 25 \times 10^{-3} \text{ A}.$$

9. *A triode valve has amplification factor* 21 *and dynamic plate resistance* 10 kΩ. *This is used as an amplifier with a load of* 20 kΩ. *Find the gain factor of the amplifier.*

Solution :

The gain factor of a triode valve amplifier is

$$A = \frac{\mu}{1 + \frac{r_p}{R_L}}$$

where μ is the amplification factor, r_p is the plate resistance and R_L is the load resistance. Thus,

$$A = \frac{21}{1 + \frac{10 \text{ k}\Omega}{20 \text{ k}\Omega}} = 14.$$

□

QUESTIONS FOR SHORT ANSWER

1. Why is conduction easier in gases if the pressure is low ? Will the conduction continue to improve if the pressure is made as low as nearly zero ?
2. An AC source is connected to a diode and a resistor in series. Is the current through the resistor AC or DC ?
3. How will the thermionic current vary if the filament current is increased ?
4. Would you prefer a material having a high melting point or a low melting point to be used as a cathode in a diode ?
5. Would you prefer a material having a high work function or a low work function to be used as a cathode in a diode ?
6. An isolated metal sphere is heated to a high temperature. Will it become positively charged due to thermionic emission ?
7. A diode valve is connected to a battery and a load resistance. The filament is heated so that a constant current is obtained in the circuit. As the cathode continuously emits electrons, does it get more and more positively charged ?
8. Why does thermionic emission not take place in nonconductors ?
9. The cathode of a diode valve is replaced by another cathode of double the surface area. Keeping the voltage and temperature conditions the same, will the plate current decrease, increase or remain the same ?
10. Why is the linear portion of the triode characteristic chosen to operate the triode as an amplifier ?

OBJECTIVE I

1. Cathode rays constitute a stream of
(a) electrons (b) protons
(c) positive ions (d) negative ions.

2. Cathode rays are passing through a discharge tube. In the tube, there is
(a) an electric field but no magnetic field

(b) a magnetic field but no electric field
(c) an electric as well as a magnetic field
(d) neither an electric nor a magnetic field.

3. Let i_0 be the thermionic current from a metal surface when the absolute temperature of the surface is T_0. The temperature is slowly increased and the thermionic current is measured as a function of temperature. Which of the following plots may represent the variation in (i/i_0) against (T/T_0) ?

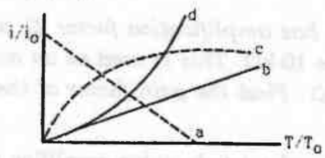


Figure 41-Q1

4. When the diode shows saturated current, dynamic plate resistance is
(a) zero (b) infinity
(c) indeterminate (d) different for different diodes.

5. The anode of a thermionic diode is connected to the negative terminal of a battery and the cathode to its positive terminal.
(a) No appreciable current will pass through the diode.
(b) A large current will pass through the diode from the anode to the cathode.
(c) A large current will pass through the diode from the cathode to the anode.
(d) The diode will be damaged.

6. A diode, a resistor and a 50 Hz AC source are connected in series. The number of current pulses per second through the resistor is
(a) 25 (b) 50 (c) 100 (d) 200.

7. A triode is operated in the linear region of its characteristics. If the plate voltage is slightly increased, the dynamic plate resistance will
(a) increase (b) decrease
(c) remain almost the same
(d) become zero.

8. The plate current in a triode valve is maximum when the potential of the grid is
(a) positive (b) zero (c) negative (d) nonpositive.

9. The amplification factor of a triode operating in the linear region depends strongly on
(a) the temperature of the cathode
(b) the plate potential (c) the grid potential
(d) the separations of the grid from the cathode and the anode.

OBJECTIVE II

1. Electric conduction takes place in a discharge tube due to the movement of
(a) positive ions (b) negative ions
(c) electrons (d) protons.

2. Which of the following are true for cathode ray ?
(a) It travels along straight lines.
(b) It emits X-ray when strikes a metal.
(c) It is an electromagnetic wave.
(d) It is not deflected by magnetic field.

3. Because of the space charge in a diode valve,
(a) the plate current decreases
(b) the plate voltage increases
(c) the rate of emission of thermions increases
(d) the saturation current increases.

4. The saturation current in a triode valve can be changed by changing
(a) the grid voltage
(b) the plate voltage
(c) the separation between the grid and the cathode
(d) the temperature of the cathode.

5. Mark the correct options.
(a) A diode valve can be used as a rectifier.
(b) A triode valve can be used as a rectifier.
(c) A diode valve can be used as an amplifier.
(d) A triode valve can be used as an amplifier.

6. The plate current in a diode is zero. It is possible that
(a) the plate voltage is zero
(b) the plate voltage is slightly negative
(c) the plate voltage is slightly positive
(d) the temperature of the filament is low.

7. The plate current in a triode valve is zero. The temperature of the filament is high. It is possible that
(a) $V_g > 0,\ V_p > 0$ (b) $V_g > 0,\ V_p < 0$
(c) $V_g < 0,\ V_p > 0$ (d) $V_g < 0,\ V_p < 0$.

EXERCISES

1. A discharge tube contains helium at a low pressure. A large potential difference is applied across the tube. Consider a helium atom that has just been ionized due to the detachment of an atomic electron. Find the ratio of the distance travelled by the free electron to that by the positive ion in a short time dt after the ionization.

2. A molecule of a gas, filled in a discharge tube, gets ionized when an electron is detached from it. An electric field of 5·0 kV/m exists in the vicinity of the event. (a) Find the distance travelled by the free electron in 1 μs assuming no collision. (b) If the mean free path of the electron is 1·0 mm, estimate the time of transit of the free electron between successive collisions.

3. The mean free path of electrons in the gas in a discharge tube is inversely proportional to the pressure inside it. The Crookes dark space occupies half the length of the discharge tube when the pressure is 0·02 mm of mercury. Estimate the pressure at which the dark space will fill the whole tube.
4. Two discharge tubes have identical material structure and the same gas is filled in them. The length of one tube is 10 cm and that of the other tube is 20 cm. Sparking starts in both the tubes when the potential difference between the cathode and the anode is 100 V. If the pressure in the shorter tube is 1·0 mm of mercury, what is the pressure in the longer tube ?
5. Calculate $n(T)/n(1000\text{ K})$ for tungsten emitter at $T = 300$ K, 2000 K and 3000 K where $n(T)$ represents the number of thermions emitted per second by the surface at temperature T. Work function of tungsten is 4·52 eV.
6. The saturation current from a thoriated-tungsten cathode at 2000 K is 100 mA. What will be the saturation current for a pure-tungsten cathode of the same surface area operating at the same temperature ? The constant A in the Richardson–Dushman equation is 60×10^4 A/m^2-K^2 for pure tungsten and $3{\cdot}0 \times 10^4$ A/m^2-K^2 for thoriated tungsten. The work function of pure tungsten is 4·5 eV and that of thoriated tungsten is 2·6 eV.
7. A tungsten cathode and a thoriated-tungsten cathode have the same geometrical dimensions and are operated at the same temperature. The thoriated-tungsten cathode gives 5000 times more current than the other one. Find the operating temperature. Take relevant data from the previous problem.
8. If the temperature of a tungsten filament is raised from 2000 K to 2010 K, by what factor does the emission current change ? Work function of tungsten is 4·5 eV.
9. The constant A in the Richardson–Dushman equation for tungsten is 60×10^4 A/m^2–K^2. The work function of tungsten is 4·5 eV. A tungsten cathode having a surface area $2{\cdot}0 \times 10^{-5}$ m^2 is heated by a 24 W electric heater. In steady state, the heat radiated by the cathode equals the energy input by the heater and the temperature becomes constant. Assuming that the cathode radiates like a blackbody, calculate the saturation current due to thermions. Take Stefan constant $= 6 \times 10^{-8}$ W/m^2–K^4. Assume that the thermions take only a small fraction of the heat supplied.
10. A plate current of 10 mA is obtained when 60 volts are applied across a diode tube. Assuming the Langmuir–Child equation $i_p \propto V_p^{3/2}$ to hold, find the dynamic resistance r_p in this operating condition.
11. The plate current in a diode is 20 mA when the plate voltage is 50 V or 60 V. What will be the current if the plate voltage is 70 V ?
12. The power delivered in the plate circuit of a diode is 1·0 W when the plate voltage is 36 V. Find the power delivered if the plate voltage is increased to 49 V. Assume Langmuir–Child equation to hold.
13. A triode valve operates at $V_p = 225$ V and $V_g = -0{\cdot}5$ V. The plate current remains unchanged if the plate voltage is increased to 250 V and the grid voltage is decreased to $-2{\cdot}5$ V. Calculate the amplification factor.
14. Calculate the amplification factor of a triode valve which has plate resistance of 2 kΩ and transconductance of 2 millimho.
15. The dynamic plate resistance of a triode valve is 10 kΩ. Find the change in the plate current if the plate voltage is changed from 200 V to 220 V.
16. Find the values of r_p, μ and g_m of a triode operating at plate voltage 200 V and grid voltage -6 V. The plate characteristics are shown in figure (41-E1).

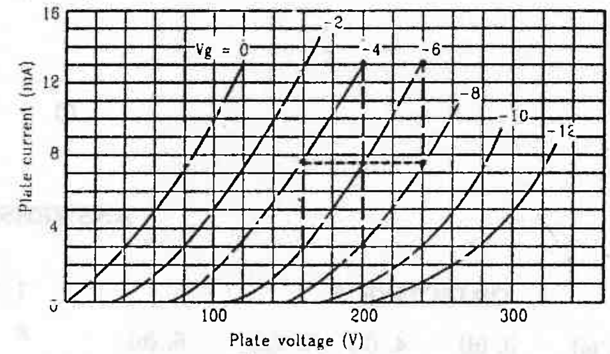


Figure 41-E1

17. The plate resistance of a triode is 8 kΩ and the transconductance is 2·5 millimho. (a) If the plate voltage is increased by 48 V, and the grid voltage is kept constant, what will be the increase in the plate current ? (b) With plate voltage kept constant at this increased value, how much should the grid voltage be decreased in order to bring the plate current back to its initial value ?
18. The plate resistance and the amplification factor of a triode are 10 kΩ and 20. The tube is operated at plate voltage 250 V and grid voltage $-7{\cdot}5$ V. The plate current is 10 mA. (a) To what value should the grid voltage be changed so as to increase the plate current to 15 mA ? (b) To what value should the plate voltage be changed to take the plate current back to 10 mA ?
19. The plate current, plate voltage and grid voltage of a 6F6 triode tube are related as

$$i_p = 41(V_p + 7\,V_g)^{1{\cdot}41}$$

where V_p and V_g are in volts and i_p in microamperes. The tube is operated at $V_p = 250$ V, $V_g = -20$ V. Calculate (a) the tube current, (b) the plate resistance, (c) the mutual conductance and (d) the amplification factor.
20. The plate current in a triode can be written as

$$i_p = k\left(V_g + \frac{V_p}{\mu}\right)^{3/2}.$$

Show that the mutual conductance is proportional to the cube root of the plate current.
21. A triode has mutual conductance = 2·0 millimho and plate resistance = 20 kΩ. It is desired to amplify a signal

by a factor of 30. What load resistance should be added in the circuit ?

22. The gain factor of an amplifier is increased from 10 to 12 as the load resistance is changed from 4 kΩ to 8 kΩ. Calculate (a) the amplification factor and (b) the plate resistance.

23. Figure (41-E2) shows two identical triode tubes connected in parallel. The anodes are connected together, the grids are connected together and the cathodes are connected together. Show that the equivalent plate resistance is half of the individual plate resistance, the equivalent mutual conductance is double the individual mutual conductance and the equivalent amplification factor is the same as the individual amplification factor.

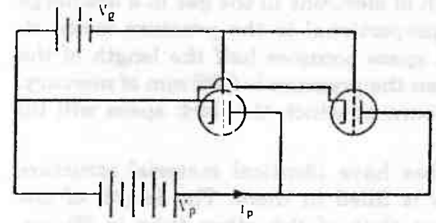


Figure 41-E2

ANSWERS

OBJECTIVE I

1. (a) 2. (c) 3. (d) 4. (b) 5. (a) 6. (b)
7. (c) 8. (a) 9. (d)

OBJECTIVE II

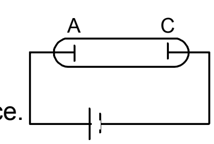
1. (a), (b), (c) 2. (a), (b) 3. (a)
4. (d) 5. (a), (b), (d) 6. all
7. (b), (c), (d)

EXERCISES

1. 7340
2. (a) 440 m (b) 1·5 ns
3. 0·01 mm of mercury
4. 0·5 mm of mercury
5. $6·57 \times 10^{-55}$, $9·73 \times 10^{11}$. $1·37 \times 10^{16}$
6. 33 μA
7. 1914 K
8. 1·14
9. 1·0 mA
10. 4 kΩ
11. 20 mA
12. 2·2 W
13. 12·5
14. 4
15. 2 mA
16. 8·0 kΩ, 20 and 2·5 millimho
17. (a) 6 mA (b) 2·4 V
18. (a) – 5·0 V (b) 200 V
19. (a) 30 mA (b) 2·53 kΩ (c) 2·77 millimho (d) 7
21. 60 kΩ
22. (a) 15 (b) 2 kΩ

ELECTRIC CURRENT THROUGH GASES
CHAPTER 41

1. Let the two particles have charge 'q'
   Mass of electron $m_a = 9.1 \times 10^{-31}$ kg
   Mass of proton $m_p = 1.67 \times 10^{-27}$ kg
   Electric field be E
   Force experienced by Electron = qE
   accln. = qE/m_e
   For time dt
   $$S_e = \frac{1}{2} \times \frac{qE}{m_e} \times dt^2 \qquad \ldots(1)$$
   For the positive ion,
   $$\text{accln.} = \frac{qE}{4 \times m_p}$$
   $$S_p = \frac{1}{2} \times \frac{qE}{4 \times m_p} \times dt^2 \qquad \ldots(2)$$
   $$\frac{S_e}{S_p} = \frac{4m_p}{m_e} = 7340.6$$
2. E = 5 Kv/m = 5×10^3 v/m ; t = 1 μs = 1×10^{-6} s
   F = qE = $1.6 \times 10^{-9} \times 5 \times 10^3$
   $$a = \frac{qE}{m} = \frac{1.6 \times 5 \times 10^{-16}}{9.1 \times 10^{-31}}$$
   a) S = distance travelled
   $$= \frac{1}{2}at^2 = 439.56 \text{ m} = 440 \text{ m}$$
   b) d = 1 mm = 1×10^{-3} m
   $$1 \times 10^{-3} = \frac{1}{2} \times \frac{1.6 \times 5}{9.1} 10^5 \times t^2$$
   $$\Rightarrow t^2 = \frac{9.1}{0.8 \times 5} \times 10^{-18} \Rightarrow t = 1.508 \times 10^{-9} \text{ sec} \Rightarrow 1.5 \text{ ns.}$$
3. Let the mean free path be 'L' and pressure be 'P'
   L $\propto$ 1/p for L = half of the tube length, P = 0.02 mm of Hg
   As 'P' becomes half, 'L' doubles, that is the whole tube is filled with Crook's dark space.
   Hence the required pressure = 0.02/2 = 0.01 m of Hg.



4. V = f(Pd)
   $v_s = P_s d_s$
   $v_L = P_l d_l$
   $$\Rightarrow \frac{V_s}{V_l} = \frac{P_s}{P_l} \times \frac{d_s}{d_l} \Rightarrow \frac{100}{100} = \frac{10}{20} \times \frac{1mm}{x}$$
   $\Rightarrow$ x = 1 mm / 2 = 0.5 mm
5. i = ne or n = i/e
   'e' is same in all cases.
   We know,

$i = AST^2\ e^{-\phi/RT}$ $\quad \phi$ = 4.52 eV, K = 1.38×10^{-23} J/k

$n(1000) = As \times (1000)^2 \times\ e^{-4.52\times1.6\times10^{-19}/1.38\times10^{-23}\times1000}$

$\Rightarrow 1.7396 \times 10^{-17}$

a) T = 300 K

$$\frac{n(T)}{n(1000K)} = \frac{AS\times(300)^2\times e^{-4.52\times1.6\times10^{-19}/1.38\times10^{-23}\times300}}{AS\times1.7396\times10^{-17}} = 7.05 \times 10^{-55}$$

b) T = 2000 K

$$\frac{n(T)}{n(1000K)} = \frac{AS\times(2000)^2\times e^{-4.52\times1.6\times10^{-19}/1.38\times10^{-23}\times2000}}{AS\times1.7396\times10^{-17}} = 9.59 \times 10^{11}$$

c) T = 3000 K

$$\frac{n(T)}{n(1000K)} = \frac{AS\times(3000)^2\times e^{-4.52\times1.6\times10^{-19}/1.38\times10^{-23}\times3000}}{AS\times1.7396\times10^{-17}} = 1.340 \times 10^{16}$$

6. $i = AST^2\ e^{-\phi/KT}$

$i_1 = i$	i_2 = 100 mA
$A_1 = 60 \times 10^4$	$A_2 = 3 \times 10^4$
$S_1 = S$	$S_2 = S$
$T_1 = 2000$	$T_2 = 2000$
ϕ_1 = 4.5 eV	ϕ_2 = 2.6 eV

K = 1.38×10^{-23} J/k

$$i = (60 \times 10^4)\,(S) \times (2000)^2\ e^{\frac{-4.5\times1.6\times10^{-19}}{1.38\times10^{-23}\times2000}}$$

$$100 = (3 \times 10^4)\,(S) \times (2000)^2\ e^{\frac{-2.6\times1.6\times10^{-19}}{1.38\times10^{-23}\times2000}}$$

Dividing the equation

$$\frac{i}{100} = e^{\left[\frac{-4.5\times1.6\times10}{1.38\times2}\left(\frac{-2.6\times1.6\times10}{1.38\times20}\right)\right]}$$

$$\Rightarrow \frac{i}{100} = 20\times e^{-11.014} \Rightarrow \frac{i}{100} = 20\times0.000016$$

$\Rightarrow$ i = 20 × 0.0016 = 0.0329 mA = 33 μA

7. Pure tungsten

ϕ = 4.5 eV

A = 60×10^4 A/m^2 – k^2

Thoriated tungsten

ϕ = 2.6 eV

A = 3×10^4 A/m^2 – k^2

$i = AST^2 e^{-\phi/KT}$

$i_{\text{Thoriated Tungsten}} = 5000\ i_{\text{Tungsten}}$

$$\text{So, } 5000 \times S \times 60 \times 10^4 \times T^2 \times\ e^{\frac{-4.5\times1.6\times10^{-19}}{1.38\times T\times10^{-23}}}$$

$$\Rightarrow S \times 3 \times 10^4 \times T^2 \times\ e^{\frac{-2.65\times1.6\times10^{-19}}{1.38\times T\times10^{-23}}}$$

$$\Rightarrow 3 \times 10^8 \times\ e^{\frac{-4.5\times1.6\times10^{-19}}{1.38\times T\times10^{-23}}} = e^{\frac{-2.65\times1.6\times10^{-19}}{1.38\times T\times10^{-23}}} \times 3 \times 10^4$$

Taking ‘ln’

$\Rightarrow$ 9.21 T = 220.29

$\Rightarrow$ T = 22029 / 9.21 = 2391.856 K

8. $i = AST^2\ e^{-\phi/KT}$

$i' = AST^{12}\ e^{-\phi/KT'}$

$$\frac{i}{i'} = \frac{T^2}{T^{12}}\frac{e^{-\phi/KT}}{e^{-\phi/KT'}}$$

$$\Rightarrow \frac{i}{i'} = \left(\frac{T}{T'}\right)^2 e^{-\phi/KT+\phi KT'} = \left(\frac{T}{T'}\right)^2 e^{\phi KT'-\phi/KT}$$

$$= \frac{i}{i'} = \left(\frac{2000}{2010}\right)^2 e^{\frac{4.5\times1.6\times10^{-19}}{1.38\times10^{-23}}}\left(\frac{1}{2010} - \frac{1}{2000}\right) = 0.8690$$

$$\Rightarrow \frac{i}{i'} = \frac{1}{0.8699} = 1.1495\ = 1.14$$

9. $A = 60 \times 10^4\ A/m^2 - k^2$

$\phi = 4.5$ eV $\qquad \sigma = 6 \times 10^{-8}\ \omega/m^2 - k^4$

$S = 2 \times 10^{-5}\ m^2 \qquad K = 1.38 \times 10^{-23}$ J/K

$H = 24\ \omega'$

The Cathode acts as a black body, i.e. emissivity = 1

$\therefore E = \sigma A T^4$ (A is area)

$$\Rightarrow T^4 = \frac{E}{\sigma A} = \frac{24}{6\times10^{-8}\times2\times10^{-5}} = 2\times10^{13}K = 20\times10^{12}K$$

$\Rightarrow T = 2.1147 \times 10^3 = 2114.7$ K

Now, $i \quad = AST^2 e^{-\phi/KT}$

$$= 6 \times 10^5 \times 2 \times 10^{-5} \times (2114.7)^2 \times\ e^{\frac{-4.5\times1.6\times10^{-19}}{1.38\times T\times10^{-23}}}$$

$= 1.03456 \times 10^{-3}$ A = 1 mA

10. $i_p = CV_p^{3/2}$ …(1)

$\Rightarrow di_p = C\ 3/2\ \ V_p^{(3/2)-1}dv_p$

$$\Rightarrow \frac{di_p}{dv_p} = \frac{3}{2}CV_p^{1/2} \qquad \text{…(2)}$$

Dividing (2) and (1)

$$\frac{i}{i_p}\frac{di_p}{dv_p} = \frac{3/2CV_p^{1/2}}{CVp^{3/2}}$$

$$\Rightarrow \frac{1}{i_p}\frac{di_p}{dv_p} = \frac{3}{2V}$$

$$\Rightarrow \frac{dv_p}{di_p} = \frac{2V}{3i_p}$$

$$\Rightarrow R = \frac{2V}{3i_p} = \frac{2\times60}{3\times10\times10^{-3}} = 4\times10^3 = 4k\Omega$$

11. For plate current 20 mA, we find the voltage 50 V or 60 V.

Hence it acts as the saturation current. Therefore for the same temperature, the plate current is 20 mA for all other values of voltage.

Hence the required answer is 20 mA.

12. P = 1 W, p = ?

$V_p = 36$ V, $V_p = 49$ V, $P = I_pV_p$

$\Rightarrow I_p = \dfrac{P}{V_p} = \dfrac{1}{36}$

$I_p \propto (V_p)^{3/2}$

$I'_p \propto (V'_p)^{3/2}$

$\Rightarrow \dfrac{I_p}{I'_p} = \dfrac{(V_p)^{3/2}}{V'_p}$

$\Rightarrow \dfrac{1/36}{I'_p} = \left(\dfrac{36}{49}\right)^{3/2}$

$\Rightarrow \dfrac{1}{36\, I'_p} = \dfrac{36}{49} \times \dfrac{6}{7} \Rightarrow I'_p = 0.4411$

$P' = V'_p\, I'_p = 49 \times 0.4411 = 2.1613$ W = 2.2 W

13. Amplification factor for triode value

$= \mu = \dfrac{\text{Charge in Plate Voltage}}{\text{Charge in Grid Voltage}} = \dfrac{\delta V_p}{\delta V_g}$

$= \dfrac{250-225}{2.5-0.5} = \dfrac{25}{2} = 12.5$ [$\therefore$ $\delta Vp = 250 - 225$, $\delta Vg = 2.5 - 0.5$]

14. $r_p = 2\ K\Omega = 2 \times 10^3\ \Omega$

g_m = 2 milli mho = 2×10^{-3} mho

$\mu = r_p \times g_m = 2 \times 10^3 \times 2 \times 10^{-3} = 4$ Amplification factor is 4.

15. Dynamic Plate Resistance $r_p = 10\ K\Omega = 10^4\ \Omega$

$\delta I_p = ?$

$\delta V_p = 220 - 220 = 20$ V

$\delta I_p = (\delta V_p / r_p) / V_g$ = constant.

$= 20/10^4 = 0.002$ A = 2 mA

16. $r_p = \left(\dfrac{\delta V_p}{\delta I_p}\right)$ at constant V_g

Consider the two points on $V_g = -6$ line

$r_p = \dfrac{(240-160)V}{(13-3)\times 10^{-3} A} = \dfrac{80}{10} \times 10^3 \Omega = 8K\Omega$

$g_m = \left(\dfrac{\delta I_p}{\delta V_g}\right) v_p$ = constant

Considering the points on 200 V line,

$g_m = \dfrac{(13-3)\times 10^{-3}}{[(-4)+(-8)]} A = \dfrac{10 \times 10^{-3}}{4} = 2.5$ milli mho

$\mu = r_p \times gm$

$= 8 \times 10^3\ \Omega \times 2.5 \times 10^{-3}\ \Omega^{-1} = 8 \times 1.5 = 20$

17. a) $r_p = 8\ K\Omega = 8000\ \Omega$

$\delta V_p = 48$ V $\quad \delta I_p = ?$

$\delta I_p = (\delta V_p / r_p) / V_g$ = constant.

So, $\delta I_p = 48 / 8000 = 0.006$ A = 6 mA

b) Now, V_p is constant.

$\delta I_p = 6$ mA = 0.006 A

$g_m = 0.0025$ mho

$\delta V_g = (\delta I_p / g_m) / V_p$ = constant.

$= \dfrac{0.006}{0.0025} = 2.4$ V

18. $r_p = 10\ K\Omega = 10 \times 10^3\ \Omega$

$\mu = 20$ $V_p = 250$ V

$V_g = -7.5$ V $I_p = 10$ mA

a) $g_m = \left(\dfrac{\delta I_p}{\delta V_g}\right) V_p$ = constant

$\Rightarrow \delta V_g = \dfrac{\delta I_p}{g_m} = \dfrac{15\times10^{-3} - 10\times10^{-3}}{\mu / r_p}$

$= \dfrac{5\times10^{-3}}{20/10\times10^3} = \dfrac{5}{2} = 2.5$

$r'_g = +2.5 - 7.5 = -5$ V

b) $r_p = \left(\dfrac{\delta V_p}{\delta I_p}\right) V_g$ = constnant

$\Rightarrow 10^4 = \dfrac{\delta V_p}{(15\times10^{-3} - 10\times10^{-3})}$

$\Rightarrow \delta V_p = 10^4 \times 5 \times 10^{-3} = 50$ V

$V'_p - V_p = 50 \Rightarrow V'_p = -50 + V_p = 200$ V

19. $V_p = 250$ V, $V_g = -20$ V

a) $i_p = 41(V_p + 7V_g)^{1.41}$

$\Rightarrow 41(250 - 140)^{1.41} = 41 \times (110)^{1.41} = 30984\ \mu A = 30$ mA

b) $i_p = 41(V_p + 7V_g)^{1.41}$

Differentiating,

$di_p = 41 \times 1.41 \times (V_p + 7V_g)^{0.41} \times (dV_p + 7dV_g)$

Now $r_p = \dfrac{dV_p}{di_p} V_g$ = constant.

or $\dfrac{dV_p}{di_p} = \dfrac{1\times10^6}{41\times1.41\times110^{0.41}} = 10^6 \times 2.51 \times 10^{-3} \Rightarrow 2.5 \times 10^3\ \Omega = 2.5\ K\Omega$

c) From above,

$dI_p = 41 \times 1.41 \times 6.87 \times 7\ d\ V_g$

$g_m = \dfrac{dI_p}{dV_g} = 41 \times 1.41 \times 6.87 \times 7\ \mu$ mho

$= 2780\ \mu$ mho = 2.78 milli mho.

d) Amplification factor

$\mu = r_p \times g_m = 2.5 \times 10^3 \times 2.78 \times 10^{-3} = 6.95 = 7$

20. $i_p = K(V_g + V_p/\mu)^{3/2}$ …(1)

Diff. the equation :

$di_p = K\ 3/2\ (V_g + V_p/\mu)^{1/2}\ d\ V_g$

$\Rightarrow \dfrac{di_p}{dV_g} = \dfrac{3}{2} K \left(V_g + \dfrac{V_0}{\mu}\right)^{1/2}$

$\Rightarrow$ $g_m = 3/2\ K\ (V_g + V_p/\mu)^{1/2}$ …(2)

From (1) $i_p = [3/2\ K\ (V_g + V_p/\mu)^{1/2}]^3 \times 8/K^2\ 27$

$\Rightarrow i_p = k'\ (g_m)^3 \Rightarrow g_m \propto 3\sqrt{i_p}$

21. $r_p = 20\ K\Omega$ = Plate Resistance

Mutual conductance = g_m = 2.0 milli mho = 2×10^{-3} mho

Amplification factor $\mu = 30$

Load Resistance = R_L = ?

We know

$A = \dfrac{\mu}{1+\dfrac{r_p}{R_L}}$ where A = voltage amplification factor

$\Rightarrow A = \dfrac{r_p \times g_m}{1+\dfrac{r_p}{R_L}}$ where $\boxed{\mu = r_p \times g_m}$

$\Rightarrow 30 = \dfrac{20\times10^3 \times 2\times10^{-3}}{1+\dfrac{20000}{R_L}} \Rightarrow 3 = \dfrac{4R_L}{R_L + 20000}$

$\Rightarrow$ $3R_L + 60000 = 4\ R_L$

$\Rightarrow$ $R_L = 60000\ \Omega = 60\ K\Omega$

22. Voltage gain = $\dfrac{\mu}{1+\dfrac{r_p}{R_L}}$

When A = 10, $R_L = 4\ K\Omega$

$10 = \dfrac{\mu}{1+\dfrac{r_p}{4\times10^3}} \Rightarrow 10 = \dfrac{\mu\times4\times10^3}{4\times10^3 + r_p}$

$\Rightarrow$ $40 \times 10^3 \times 10r_p = 4 \times 10^3\ \mu$ …(1)

when A = 12, $R_L = 8\ K\Omega$

$12 = \dfrac{\mu}{1+\dfrac{r_p}{8\times10^3}} \Rightarrow 12 = \dfrac{\mu\times8\times10^3}{8\times10^3 + r_p}$

$\Rightarrow$ $96 \times 10^3 + 12\ r_p = 8 \times 10^3\ \mu$ …(2)

Multiplying (2) in equation (1) and equating with equation (2)

$2(40 \times 10^3 + 10\ r_p) = 96 \times 10+3 + 12r_p$

$\Rightarrow$ $r_p = 2 \times 10^3\ \Omega = 2\ K\Omega$

Putting the value in equation (1)

$40 \times 10^3 + 10(2 \times 10^3) = 4 \times 10^3\ \mu$

$\Rightarrow$ $40 \times 10^3 + 20 \times 10^3) = 4 \times 10^3\ \mu$

$\Rightarrow$ $\mu = 60/4 = 15$

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