41. Electric Current through Gases

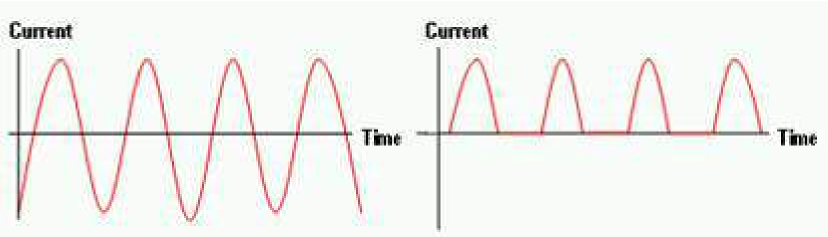
Short Answer

Answer.1

Conduction happens when an electron with enough kinetic energy collides with the electron of gas atoms. This process is called as ionization of gas atoms. This phenomenon is reported at low pressure, as at high pressure the mean free path of electron decrease which results in a collision of electron much before they get enough kinetic energy for ionization. Whereas at low pressure due to an increase in their mean free path they are able to gain enough kinetic energy for ionization process so conduction is easier. If the pressure is made too low, there won't be enough atoms to ionize and hence conductivity will decrease.

Answer.2

When an AC source is connected to a diode half rectification of the source will happen and we will get a pulsating DC output.



The resistor in series would be getting a pulsating DC output. The given circuit in question is analogous to half rectification of AC source by diode, in that circuit we use resistor for measuring the load of DC.

Answer.3

Thermionic current will increase if the filament current is increased as due to increase in temperature in filament. It is due to internal resistance through which the temperature of filament increases. This increase in temperature will give enough kinetic energy to electrons to leave the surface of filament and it will lead to increase in number of thermions number leaving per unit surface area of filament and hence thermionic current will increase.

Answer.4

We know that electrons which are responsible for thermionic current will leave the surface at high temperature. Therefore, cathode material should be able to handle high temperature which will only be possible if the material has a high melting point.

Answer.5

Work function's magnitude accounts for how much energy we need to provide for the emission of electron from the surface. Therefore, we would prefer material having low work function as less energy will be required for emission.

Answer.6

When an isolated metal sphere is heated to high temperature it will give enough kinetic energy to electrons and hence will the surface. This will decrease the number of electrons on the surface of metal sphere. And due this reason the sphere will become positively charged.

Answer.7

The important thing to note in this question is that diode's cathode is connected to battery's negative terminal. When filament is heated it will continuously emit electrons from it but battery's negative terminal will also provide electrons which makes the diode electrically neutral in nature

Answer.8

No, non-conductors will not take part in thermionic emission due to a high work function. Also, Non-conductors do not have free electrons present on its surface hence no electrons are able to emit from it. Whereas in conductors, due to the presence of free-electrons on its surface it accounts for thermionic emission.

Answer.9

The plate current will increase. We know the more the surface area of cathode more number of electrons will be present on it and hence probability of electrons leaving the surface also increases which in turn increase the plate's current.

Answer.10

We know that in the linear portion of the triode characteristic graph, it has the least amount of distortion as comparted to other region of graph. This gives an advantage that voltage across the resistor will vary accordingly to input signal and amplification can be achieved easily without risking the life of vacuum tube.

Objective I

Answer.1

Cathode is responsible for thermionic emission and thermionic emission is due to electrons which leave its surface. Therefore, rays should constitute a stream of electrons.

Ions are present due to gases but they do not account for rays from cathode surface as only electrons are the one leaving the surface.

Answer.2

We know that cathode rays constitute a stream of electrons which are responsible for thermionic emission. Therefore, field will be created hence option D should be ruled out. We know it is due to charge magnetic field is created. We also know that magnetic field and electric field complement each other. Magnetic and electric field concepts are relative to each other, that it depends on which frame of reference you are taking about hence both fields are created inside tube

Answer.3

We know that current in thermionic emission varies to square of Temperature. of cathode with exponential term

$J \propto T^2 * e^{-1/T}$

The best suited curve from the figures which satisfy the equation is the parabolic one.

Answer.4

We know the dynamic plate resistance is given by

$$R = \Delta V_p / \Delta I_p$$

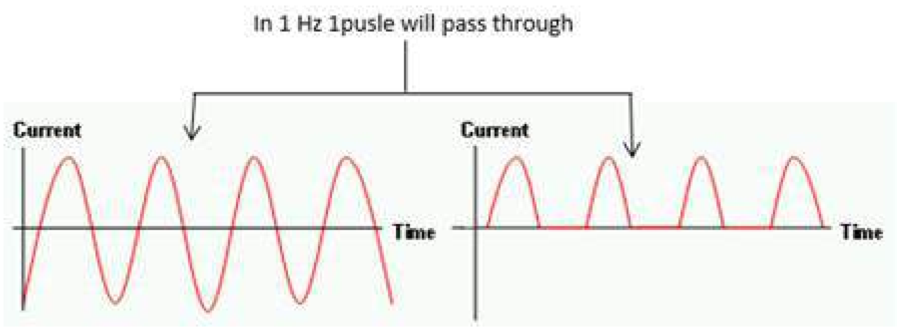
Now when diode is at saturated current region the change in ΔI_P will be very small or it will be near to zero, therefore dynamic resistance will at infinity.

It can't be indeterminate as although it will saturate current but still changes in decimal places will be still be visible and hence ΔI_P will not be equal to zero.

Answer.5

When cathode is connected to positive terminal and anode to negative terminal electrons will not able to leave the surface of cathode and hence no thermionic emission will be accounted. This will result in no current passing through diode.

Answer.6



We can see from figure that in one second 1 pulse will pass through when 1Hztherefore total of 50 pulses will pass through in one second

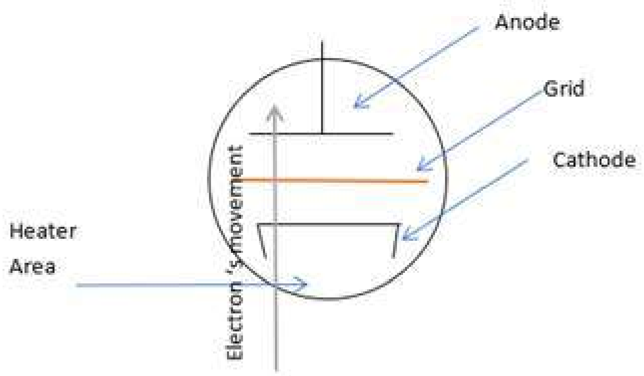
Answer.7

We know the formula for dynamic plate resistance is

$$R = \Delta V_p / \Delta I_p$$

When triode is operating in linear region, and plate voltage is slightly changed it will lead to change in current of plate and hence both of these effect will cancel each other and no change in resistance will be observed.

Answer.8



We know electrons get attracted to positive potential. When potential of the grid is made positive it makes easier for us to push electrons from cathode to anode which accounts for increase in current. Hence plate current in a triode valve is maximum when the potential of the grid is made positive

Answer.9

When the triode operating in the linear region, it indirectly

implies that the grid voltage, plate voltage and plate current is

specified and hence plays no contribution to the amplification factor in this question

Now if the grid is too near the cathode it will partially or completely lie in space charge region which comprises of electrons from the cathode. And hence it will pick electrons from cathode more rapidly which will increase the plate current and hence amplification factor will get affected. As amplification factors depend on the plate's current.

And when the grid is far away from cathode, it will able to pick as many electrons compared to when it was near to cathode and hence amplification factor will get affected

Objective II

Answer.1

Cathode ray which comprises of electrons is mainly responsible for electric conduction. But ions are also present in gases which play a role in conduction by getting ionized by colliding with electrons which are present in cathode rays. This process is called ionization which also contributes to electric conduction. Therefore, both positive and negative ions with electrons are responsible for conduction

Answer.2

Cathode rays are wave but due to their massless property they are not able to travel at speed which is equal to light hence they are not categorized under Electromagnetic wave.

Cathode consists of Electrons and they will travel from cathode to anode by the shortest route which is obliviously a straight line until any other forces are applied across the tube. In presence of magnetic field, they will deviate from their usual path.

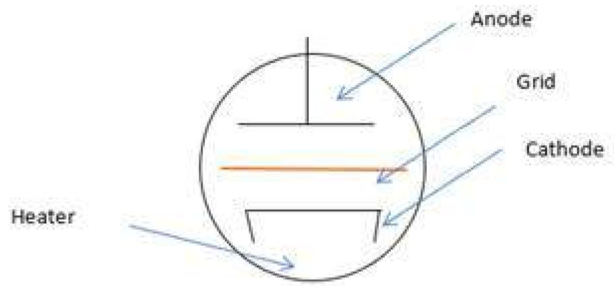
When cathode accelerated to the anode they produce X-rays, which is in accordance to Maxwell's principle that accelerating charge emit radiation when it strikes the surface of metal.

Answer.3

Space charge is three dimensional concept. It is a cloud of electrons which are distributed evenly over the 3D space rather than being at one place. As we know cathode emits electrons and this electron take some finite amount of time to travel and due to this a region near cathode is created which create repulsion for electrons which are coming cathode. This phenomenon is called space charge effect. This decrease the plate's current.

This Space charge has no effect on the rate of emission of thermions, as rate depend on how much energy we are providing to it. Also it is not related to saturation current or plate's voltage.

Answer.4



Grid Voltage when made negative, it will not allow the electrons from cathode to pass through, as electrons will start repealing from it hence this will decrease the electric conductivity. Whereas when grid voltage is made positive it will start attracting electrons and make it easier for electrons to leave the surface of cathode. Therefore, through grid voltage we are indirectly controlling the plate's current. Also in triode valve we know that the maximum current is the saturation current, hence by controlling the grid voltage we are in a way controlling the saturation current. Whereas separation won't make any difference as it is the voltage which is actually plays an important role in controlling the plate's current. Changing the separation will only effect the amplification.

No matter what is the temperature of cathode is, at the end it depends whether grid allows the electrons to pass through to it or not. Therefore, it is the grid voltage which effects the saturation current.

Answer5

We know triode has a property through which output can be controlled and it is due to this property triode is used as amplifier. This property of manipulating output is not present in diode therefore it can't be used as amplifier.

Also, it is well known fact that diode and triode allow only in single direction flow of current through it and hence they act as rectifier for AC input and convert it to pulsating DC.

Answer.6

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

When the temperature of the filament is low, then there is a possibility that not enough kinetic energy is being produced and due to these electrons may not able to leave the surface of the cathode and hence zero current in a diode. When plate voltage is zero it means indirectly that current is zero as we know both are in direct relation to each other. And when the plate's voltage is negative with respect to cathode no electrons will leave the surface and hence zero current. Now when the voltage is slightly positive, it may be that it is not greater than forward voltage and hence electrons are not able to accelerate towards the anode. As we know around cathode a cloud of electrons formed and when voltage is not enough for electrons, they will not able to reach the anode.

Answer.7

B. $V_g > 0, V_p < 0$

C. $V_g < 0, V_p > 0$

D. $V_g < 0, V_p < 0$

Here Vg means voltage grid and Vp means positive plate's voltage. Now it is already given in question that temperature of the filament is high therefore electrons have enough kinetic energy to leave the surface of cathode.

But still even if grid voltage is negative, electrons will not able to reach the surface of anode and hence no current will be visible Also if positive plate's voltage is negative, then also electrons won't be able to reach the anode's surface. Therefore, current will be zero even if one of the above conditions are met.

Exercises

Answer.1

Let the distance travelled by free electron and positive ion be S_E and S_H respectively. Also, mass of the electron and positive helium ion be m_e and m_h where,

$m_e=9.1\times10^{-31}$kg

$m_h=4\times$mass of proton

$=4\times1.6\times10^{-27}$kg

We know,

$$S = ut + \frac{at^2}{2}$$

where s is the distance travelled, u is the initial velocity, t is the time and a is the magnitude of acceleration

Here, initial velocity of electron and helium ion is zero

$$\therefore S = \frac{at^2}{2}$$

Now, magnitude of force experienced by electron,

$$F = qE$$

$$m_e a = qE$$

$$a = \frac{qE}{m_e}$$

where F is the magnitude of force, E is the electric field strength and q is the magnitude of charge of the particle.

∴ Distance travelled by free electron for dt duration is $S_e = \frac{qE}{2m_e} \times (dt)^2$

Magnitude of force experienced by positive helium ion,

$$F = qE$$

$$m_h a = qE$$

$$a = \frac{qE}{m_h}$$

∴ Distance travelled by positive helium ion for dt duration is $S_h = \frac{qE}{2m_h} \times dt^2$

The required ratio is

$$\frac{S_e}{S_h} = \frac{\frac{qE}{2m_e} \times dt^2}{\frac{qE}{2m_h} \times dt^2}$$

$$\frac{S_e}{S_h} = \frac{m_h}{m_e} = \frac{4 \times 1.6 \times 10^{-27}}{9.1 \times 10^{-31}}$$

$$\frac{S_e}{S_h} = \frac{m_h}{m_e} = 7340.6$$

Answer.2

a) Given electric field E= 5 kV m^{-1} = 5×10^3 V m^{-1}

Time t=1 μs = 1×10^{-6} s.

Let m be the mass of electron and q be the charge of electron where m=9.1×10^{-31} kg

q =1.6×10^{-19} C

We know,

$$F = qE$$

$$ma = qE$$

$$a = \frac{qE}{m}$$

where F is the force, E is the electric field strength and q is the magnitude of charge.

Also, distance travelled by an electron is

$S = \frac{at^2}{2}$ (as initial velocity is 0)

$$S = \frac{qE}{2m} \times t^2$$

$$= \frac{1.6 \times 10^{-19} \times 5 \times 10^3 \times 10^{-12}}{2 \times 9.1 \times 10^{-31}}$$

$$= 439.5 \text{ m}$$

b) Here mean free path S travelled by electron is given as S=1mm

$=10^{-3}$ m

We know,

$$a = \frac{qE}{m} = \frac{1.6 \times 10^{-19} \times 5 \times 10^3}{9.1 \times 10^{-31}} = 0.87 \times 10^{15}$$

Also,

$$S = \frac{at^2}{2}$$

$$\Rightarrow t^2 = \frac{2S}{a}$$

$$\Rightarrow t^2 = \frac{2 \times 10^{-3}}{0.87 \times 10^{15}} = 2.29 \times 10^{-18} \text{ s}$$

$$\Rightarrow t = 1.51 \times 10^{-9} \text{ s} = 1.5 \text{ ns.}$$

Answer.3

Let the mean free path be L and pressure be P

Given, $L \propto \frac{1}{P}$ where L = half of the tube length and P = 0.02 mm of Hg

∴ When P becomes half, L doubles, i.e. the whole tube is filled with Crook's dark space.

Hence the required pressure $= \frac{0.02}{2} = 0.01 \text{ m of Hg}$.

Answer.4

Let d1 and p1 be the length and pressure of short tube. Also d2 and p2 be the length and pressure of long tube.i.e. p1=1.0 mm d1=10 cm, d2=20 cm

According to Paschen's law,

$V = f(pd)$, i.e. the sparking potential of a gas in a discharge tube is the function of the product of pressure of the gas and separation between the electrodes.

$\therefore\ V = p1d1 = p2d2$

$\Rightarrow p2 = \frac{p1d1}{d2} = \frac{1 \times 10}{20} = 0.5 \text{ mm}$

Answer.5

According to Richardson-Dushman Equation thermionic current i is

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

where, n is the thermions emitted, S is the surface area, T is the absolute temperature, k is the Boltzmann constant, A is the constant depend on nature of metal and ϕ is the work function.

Case 1

T=300 K

Now, $$\frac{n(T)}{n(1000)} = \frac{AS300^2\ e^{\frac{-4.52\times1.6\times10^{-19}}{1.38\times10^{-23}\times300}}}{AS1000^2\ e^{\frac{-4.52\times1.6\times10^{-19}}{1.38\times10^{-23}\times1000}}} = 7.057\times10^{-55}$$

Case 2

T=2000 K

Now, $$\frac{n(T)}{n(1000)} = \frac{AS2000^2\ e^{\frac{-4.52\times1.6\times10^{-19}}{1.38\times10^{-23}\times2000}}}{AS1000^2\ e^{\frac{-4.52\times1.6\times10^{-19}}{1.38\times10^{-23}\times1000}}} = 9.59\times10^{11}$$

Case 3

T=3000 K

Now, $$\frac{n(T)}{n(1000)} = \frac{AS3000^2\ e^{\frac{-4.52\times1.6\times10^{-19}}{1.38\times10^{-23}\times3000}}}{AS1000^2\ e^{\frac{-4.52\times1.6\times10^{-19}}{1.38\times10^{-23}\times1000}}} = 1.34\times10^{16}$$

Answer.6

According to Richardson-Dushman Equation thermionic current i is

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

where, n is the thermions emitted, S is the surface area, T is the absolute temperature, k is the Boltzmann constant, A is the constant depend on nature of metal and ϕ is the work function.

Given,

$I_{ttungsten}$=100 mA

T=2000 K

$A_{ttungsten}=3\times10^4\ A\ m^{-2}\ K^{-2}$

$A_{ptungsten}=60\times10^4\ A\ m^{-2}\ K^{-2}$

$\Phi_{ttungsten}$ =2.6 eV

$\Phi_{ptungsten}$ =4.5 eV

Now,

$$\frac{I_{ttungsten}}{I_{ptungsten}} = \frac{3 \times 10^4 \times S \times 2000^2\ e^{\frac{-2.6\times1.6\times10^{-19}}{1.38\times10^{-23}\times2000}}}{60 \times 10^4 \times S \times 2000^2\ e^{\frac{-4.5\times1.6\times10^{-19}}{1.38\times10^{-23}\times2000}}}$$

$$\frac{100}{I_{ptungsten}} = \frac{3 \times 10^4 \times S \times 2000^2\ e^{\frac{-2.6\times1.6\times10^{-19}}{1.38\times10^{-23}\times2000}}}{60 \times 10^4 \times S \times 2000^2\ e^{\frac{-4.5\times1.6\times10^{-19}}{1.38\times10^{-23}\times2000}}}$$

$$\frac{100}{I_{ptungsten}} = \frac{e^{\frac{(-2.6+4.5)\times1.6\times10^{-19}}{1.38\times10^{-23}\times2000}}}{20}$$

$$I_{ptungsten} = \frac{100 \times 20}{e^{\frac{(-2.6+4.52)\times1.6\times10^{-19}}{1.38\times10^{-23}\times2000}}} = 2000 \times e^{-11.01} = 33\mu A$$

Answer.7

According to Richardson-Dushman Equation thermionic current i is

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

where, n is the thermions emitted, S is the surface area, T is the absolute temperature, k is the Boltzmann constant, A is the constant depend on nature of metal and ϕ is the work function.

Given,

$A_{ttungsten}$=3 × 10^4 A m-^{2} K^{-2}

$A_{ptungsten=}$60× 10^4 A m-^{2} K^{-2}

$\Phi_{ttungsten}$ =2.6 eV

$\Phi_{ptungsten}$ =4.5 eV

$I_{ttungsten}$=5000$I_{ptungsten}$

$$\Rightarrow \frac{I_{ttungsten}}{I_{ptungsten}} = 5000 = \frac{3 \times 10^4 \times S \times T^2\, e^{\frac{-2.6\times1.6\times10^{-19}}{1.38\times10^{-23}\times T}}}{60 \times 10^4 \times S \times T^2\, e^{\frac{-4.5\times1.6\times10^{-19}}{1.38\times10^{-23}\times T}}}$$

$$\Rightarrow 5000 = \frac{e^{\frac{(-2.6+4.5)\times1.6\times10^{-19}}{1.38\times10^{-23}\times T}}}{20}$$

$$\Rightarrow 100000 = e^{\frac{(-2.6+4.5)\times1.6\times10^{-19}}{1.38\times10^{-23}\times T}}$$

Taking log on both sides,

$$11.512 = \frac{22028.98}{T}$$

$$\Rightarrow T = \frac{22028.98}{11.512} = 1913.56\ \text{K}$$

Answer.8

According to Richardson-Dushman Equation thermionic current i is

$$i = ne = AST^2\, e^{-\phi/kT}$$

where, n is the thermions emitted, S is the surface area, T is the absolute temperature, k is the Boltzmann constant, A is the constant depend on nature of metal and ϕ is the work function

Given,T1=2000 K

T2=2010 K , Φ =4.5 eV

$$\text{Now,} \frac{I_1}{I_2} = \frac{A \times S \times 2000^2\, e^{\frac{-4.5\times1.6\times10^{-19}}{1.38\times10^{-23}\times2000}}}{A \times S \times 2010^2\, e^{\frac{-4.5\times1.6\times10^{-19}}{1.38\times10^{-23}\times2010}}}$$

$$\frac{I_1}{I_2} = \frac{2000^2\, e^{\frac{-4.5\times1.6\times10^{-19}}{1.38\times10^{-23}}\left(\frac{1}{2000}-\frac{1}{2010}\right)}}{2010^2} = \frac{2000^2 \times 0.87828}{2010^2} = .869564$$

Required factor is

$$\frac{I_2}{I_1} = \frac{1}{0.87} = 1.14$$

Answer.9

Given

A=60 × 10^4 A m^{-2} K^{-2}

S=2.0 × 10–5 m^2

P=24 W

σ=6 × 10^{-8} W m^{-2} K^{-4}

The power radiated by Stefen's law is given by

$$P = S\sigma T^4$$

$$\Rightarrow 24 = 6 \times 10^{-8} \times 2 \times 10^{-5} \times T^4$$

$$\Rightarrow T^4 = 20 \times 10^{12}$$

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

According to Richardson-Dushman Equation thermionic current i is

$$i = ne = AST^2 e^{-\frac{\phi}{kT}}$$

where, n is the thermions emitted, S is the surface area, T is the absolute temperature, k is the Boltzmann constant, A is the constant depend on nature of metal and ϕ is the work function

$$= 60 \times 10^4 \times 2 \times 10^{-5} \times 2114.7^2 \times e^{\frac{-4.5\times1.6\times10^{-19}}{1.38\times10^{-23}\times2114.7}}$$

$$= 1.034 \times 10^{-3} A$$

$$\approx 1 \text{ mA}$$

Answer.10

Given,

$i_p \propto (V_p)^{\frac{3}{2}}$

where i_p is the plate current and V_p is the plate voltage

V= 60 volts

I =10 mA

$\Rightarrow i_p = K(V_p)^{\frac{3}{2}}$ (1) (k is a constant)

Taking derivative on both sides with respect to i_p

$1 = \frac{3}{2}K(V_p)^{\frac{1}{2}} \times \frac{dV_P}{dI_P}$ (2)

Dividing (2)/(1)

$$\frac{1}{i_p} = \frac{3}{2V}\left(\frac{dV_P}{dI_P}\right)_{V_g=constant}$$

$$\Rightarrow \left(\frac{dV_P}{dI_P}\right) = \frac{2V}{3i_p} = \frac{2 \times 60}{3 \times 10 \times 10^{-3}} = 4K\Omega$$

Answer.11

Given the plate current is 20 mA for 50 V and 60 V, i.e. 20 mA is the saturation current.

∴, for a given temperature current remains same for all voltages. . i.e. for 70 V current is 20 mA.

Answer.12

Given P1=1 W, V_{P1}= 36 V, V_{P2}= 49 V

We know, $P = VI \Rightarrow P1 = V1 i_{p1} \Rightarrow i_{p1} = \frac{P1}{V1} = \frac{1}{36}$

According to Langmuir-Child equation $i_p \propto V_p^{3/2}$

where i_p is the plate current and V_p is the plate voltage

$$\text{Now,} \frac{i_{p1}}{i_{p2}} = \frac{V_{p1}^{\frac{3}{2}}}{V_{p2}^{\frac{3}{2}}} = \frac{36^{\frac{3}{2}}}{49^{\frac{3}{2}}} = \frac{216}{343}$$

$$\Rightarrow i_{p2} = \frac{343}{36 \times 216} = 0.04411$$

$\therefore P2 = i_{p2} \times V_{P2}$=.04411×49=2.16

W=2.2 W

Answer.13

Given V_{P1}=225 V, V_{P2}=250 V, Vg_1=-0.5, Vg_2=-2.5 V

$$\text{Amplification factor for triode} = -\left(\frac{\triangle V_p}{\triangle V_g}\right)$$

where VT is the change in plate voltage and VT is the change in grid voltage

$$= -\left(\frac{V_{p1} - V_{p2}}{V_{g1} - V_{g2}}\right) = -\left(\frac{225 - 250}{-0.5 + 2.5}\right)$$

$$= \frac{25}{2} = 12.5$$

Answer.14

Given r_P = 2 KΩ = 2× 10^3 (plate resistance)

g_m =2 millimho = 2× 10^{-3} mho(transconductane)

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

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.

Answer.15

Given r_p=10 KΩ = 10^4Ω, V_{P1}=200V, V_{P2}=220 V

The dynamic resistance of triode is defined as,

$$r_p = \left(\frac{\triangle V_P}{\triangle I_P}\right)_{V_g=constant}$$

where ΔV_p is the change in plate voltage and V_g is the grid voltage and ΔI_p is the change in plate current

$$\Rightarrow 10^4 = \frac{220 - 200}{\triangle I_P} \Rightarrow \triangle I_P = \frac{20}{10^4} = 2mA$$

Answer.16

The dynamic resistance of triode is defined as,

$$r_p = \left(\frac{\triangle V_P}{\triangle I_P}\right)_{V_g=constant}$$

where ΔV_p is the change in plate voltage and V_g is the grid voltage and ΔI_p is the change in plate current

From figure, considering the line V_g=-6 V, we get two value of V_P i.e.

V_{P1}=160 V , V_{P2}=240 V , Also i_{p1}=3 mA i_{p2}=13mA

Substituting values in equation we get,

$$r_p = \left(\frac{240 - 160}{(13 - 3) \times 10^{-3}}\right)_{V_g=\text{constant}} = 8\ \text{K}\Omega$$

The mutual inductance g_m of a triode valve is defined as

$$g_m = \left(\frac{\triangle I_p}{\triangle V_g}\right)_{V_p=\text{constant}}$$

Considering two points in the graph where $V_{p=}$200 V we get i_{p1}=13 mA i_{p2}=3mA V_{g1}=-4 V, V_{g2}=-8 V

Substituting values in equation we get.

$$g_m = \left(\frac{(3 - 13) \times 10^{-3}}{-8 + 4}\right)_{V_p=200V} = 2.5 \text{ milli mho}$$

$$\text{Amplification factor for triode} = \mu = r_p \times g_m = 2.5 \times 8 \times 10^3 \times 10^{-3} = 20$$

Answer.17

Give $_p$=8 kΩ, gm=2.5 millimho

a) CASE 1: $\triangle V_P$=48 V, V_g= constant

The dynamic resistance of triode is defined as,

$$r_p = \left(\frac{\triangle V_P}{\triangle I_P}\right)_{V_g=\text{constant}}$$

where ΔV_p is the change in plate voltage and V_g is the grid voltage and ΔI_p is the change in plate current

substituting the values

$$\Rightarrow 8000 = \frac{48}{\triangle I_P}$$

$$\Rightarrow \triangle I_p = \frac{48}{8000} = 6 \text{ mA}$$

b) CASE 2: g_m=2.5 millimho=.0025 mho, $\triangle I_p$ =6 mA =.006 A

The mutual inductance g_m of a triode valve is defined as

$$g_m = \left(\frac{\triangle I_p}{\triangle V_g}\right)_{V_p=\text{constant}}$$

$$0.0025 = \left(\frac{.006}{\triangle V_g}\right)$$

$$\triangle V_g = \frac{0.006}{.0025} = 2.4\text{V}$$

Answer.18

Given, r_p=10kΩ, μ=20, V_{P1}=250 V. Vg_1=-7.5 V, ip_1=10 mA

a) CASE 1: i_{p2}=15 mA. V_P= Constant, Vg_2=? i_{p1}=10 mA

We know, $\text{Amplification factor for triode} = \mu = r_p \times g_m$

where r_p is the plate resistance and g_m is the trans-conductance

$$g_m = \frac{20}{10000} = 2 \times 10^{-3} \text{ mho}$$

Now,

$$g_m = \left(\frac{\triangle I_p}{\triangle V_g}\right)_{V_p=\text{constant}}$$

where ΔV_g is the change in grid voltage and V_p is the plate voltage and ΔI_p is the change in plate current

$$0.002 = \left(\frac{(15-10)\times 10^{-3}}{\triangle V_g}\right)$$

$$\triangle V_g = \frac{0.005}{.002} = 2.5V$$

$$V_{g2} - V_{g1} = 2.5 \text{ V}$$

$$V_{g2} = 2.5 - 7.5 = 5 \text{ V}$$

b)CASE 2: V_{P3}=?,i_{p3}=10 mA, i_{p2}=15mA, i_{p3}=10mA

The dynamic resistance of triode is defined as,

$$r_p = \left(\frac{\triangle V_P}{\triangle I_P}\right)_{V_g=constant}$$

where ΔV_p is the change in plate voltage and V_g is the grid voltage and ΔI_p is the change in plate current

$$\Rightarrow 10000 = \frac{\triangle V_P}{(10-15)\times 10^{-3}}$$

$$\Rightarrow \triangle V_P = -50$$

$$\Rightarrow V_{p3}\text{-}V_{p2} = -50$$

$\Rightarrow V_{p3} = 200$ V, required voltage

Answer.19

a) Given, V_P = 250 V, V_g = −20 V

Also, $i_P = 41(V_P + 7V_g)^{1.41}$

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

b) Differentiating the given equation with respect to i_p keeping Vg constant.

$$1 = 41 \times 1.41(V_P + 7V_g)^{0.41} \times (dV_P/di_p)$$

The dynamic resistance of triode is defined as,

$$r_p = \left(\frac{dV_P}{dI_P}\right)_{V_g=\text{constant}} = \frac{10^6}{41 \times 1.41 \times 110^{.41}} = 2.5 \times 10^3 = 2.5\ \text{K}\Omega$$

c) Differentiating the given equation with respect to V_g keeping V_p constant

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

$$g_m = \left(\frac{dI_P}{dV_g}\right)_{V_p=\text{constant}} \Rightarrow 41 \times 1.41 \times 110^{.41} \times 7 = 2780.18\ \mu\ \text{mho}$$

$$= 2.78\ \text{millimho}$$

d) Amplification factor for triode $= \mu = r_p \times g_m$

where r_p is the plate resistance and g_m is the trans-conductance

$$= 2.5 \times 10^3 \times 2.78 \times 10^{-3}$$

$$= 6.95 \approx 7$$

Answer.20

Given:

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

g_m is the mutual conductance, i_p is the plate current, V_p is the plate current and V_g is the grid voltage.

$$g_m = \frac{di_p}{dV_g} = \frac{3}{2}k\left(V_g + \frac{V_P}{\mu}\right)^{1/2}$$

Taking cube on both sides,

$$g_m^3 = \frac{27}{8}k^3\left(V_g + \frac{V_p}{\mu}\right)^{\frac{3}{2}}$$

$$g_m^3 = \frac{27}{8}k^2 i_p \Rightarrow g_m \propto i_p^{1/3}$$ hence proved

Answer.21

Given g_m=2millimho=2×10^{-3}mho, rP=20 kΩ, A=30

Here,$\mu = r_p \times g_m$

where r_p is the plate resistance and g_m is the trans-conductance

$$= 20 \times 10^3 \times 2 \times 10^3 = 40$$

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

where A is the voltage gain, μ is the amplification factor, R_L is the load resistance and r_p is the plate resistance

$$30 = \frac{40}{1 + \frac{20000}{R_L}}$$

$$\Rightarrow 1 + \frac{20000}{R_L} = \frac{4}{3} \Rightarrow \frac{20000}{R_L} = \frac{1}{3} \Rightarrow R_L = 60\ K\Omega$$

Answer.22

$A = \frac{\mu}{1+\frac{r_p}{R_L}}$ ...(i)

where A is the voltage gain, μ is the amplification factor, R_L is the load resistance and r_p is the plate resistance

Given:

A_1=10, R_{l1} = 4kΩ

A_2=12, R_{l2} = 8kΩ

Putting these two values in equation (i)

$$10 = \frac{u}{1 + \frac{r_p}{4000}}$$

$$10(4000 + r_p) = 4000\mu$$

We get a linear equation in 2 variables (r_p and μ)

$$4000\mu - 10r_p = 40000$$

$$400\mu - r_p = 4000 \text{ ...(ii)}$$

We will get another equation by substituting the values of A_2 and R_{l2} is equation (i)

$$12 = \frac{\mu}{1 + \frac{r_p}{8000}}$$

$$12(8000 + r_p) = 8000\mu$$

$$8000\mu - 12r_p = 96000 \text{ ... (iii)}$$

Solving (ii) and (iii) to find the values amplification factor and the plate resistance.

$$400\mu - r_p = 4000 \;\&\; 8000\mu - 12r_p = 96000$$

From (ii)

$$r_p = 400\mu - 4000 \text{ ...(iv)}$$

Substituting (iv) in (iii)

$$8000\mu - 12(400\mu - 4000\,) = 96000$$

$$3200\mu = 48000$$

$$\mu = 15$$

Using μ =15, the value of r_p is 2000Ω or 2 kΩ

Answer.23

Given the anodes are connected together, the grids are connected together and the cathodes are connected together i.e. two triodes have same voltage and same current which means $r_{P1} = r_{P2} = r$

Here the equivalent resistance,

$$R = \frac{(r_{P1} \times r_{P2})}{(r_{p1} + r_{p2})} = \frac{r^2}{2r} = \frac{r}{2}$$

i.e., the equivalent plate resistance is half to the individual plate resistance.

Let g_{m1} and g_{m2} be the individual conductance.

From figure, $g_{m1} = g_{m1} = g$. As two triodes are parallel i.e. equivalent conductance

$$G = (g_{m1} + g_{m2}) = 2g$$

i.e. The equivalent mutual conductance is double the individual mutual conductance

Now, $\mu 1 = g_{m1} r_{p1} = gr$

Also, $\mu 2 = g_{m2} r_{p2} = gr$

equvalent amplification factor, $\mu = RG = \frac{r}{2} \times 2g = rg$

I.e. the equivalent amplification factor is the same as the individual amplification factor