PHYSICS

BOOKS - HC VERMA

ELECTRIC CURRENT THROUGH GASES

Examples

1. The work function of a thermionic emitter is $4.5eV$. By what factor does the thermionic current incease if its temperature is raised from $1500K \rightarrow 2000K$?

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2. When the plate voltage applied to a diode valve is changed from $40V$ to $42V$, the plate current increases from $50mA \rightarrow 60mA$. Calculate the dynamic plate resistance at the operating condition.

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Worked Out Examples

1. The mean free path of the electrons in a discharge tube is 20 cm. The tube itself is 10cm long. What is the length of the Crookes dark space?

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2. Consider a cylindrical tube closed at one end and fitted with a conducting, movable piston at the other end. A cathode is fixed in the tube near the closed end and an anode is fixed with the piston. A gas is filled in the tube at pressure p. Using Paschen equation `V = f(pd), show that the sparking potential does not change as the piston is slowly moved in or out. Assume that the temperature does not change in the process.

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3. The number of thermions emitted in a given time increases 100 times as the temperature of the emitting surface is increased from $600K \rightarrow 800K$. Find the work function of the emitter. Boltzmann constant $k = 8.62 \times 10^{-5} eVk^{-1}$.

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4. The constant A in the Richordson-Dushman equation is $60 \times 10^4 Am^{-2}K^{-2}$ for tungsten. A tungsten cathode has a total surface area of $2.0 \times 10^{-5} m^2$ and operates at $2000K$. The work function of tungsten is $4.55eV$. Calculate the electric current due to thermionic emission.

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5. Calculate the saturation thermionic current if $120W$ is applied to a thoriated-tungsten filament of surface area $1.0cm^2$. Assume that the surface radiates like a blackbody. The required constants are $A = 3 \times 10^4 Am^{-2} - K^2$,

$\varphi = 2.6eV, k = 8.62 \times 10^{-5} eVkK^{-1}$

and $\sigma = 6 \times 10^{-8} Wm^{-2} K^{-4}$

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6. In a Millikan-type oil-drop experiment, the plates are $8mm$ apart. An oil drop is found to remain at rest when the upper plate is at a potential $135V$ higher than that of the lower one. When the electric field is switched off, the drop is found to fall a distance of $2.0mm$ in 36 seconds with a uniform speed. Find (a) the charge on the drop and (b) the number of electrons attached to this drop. Density of oil $= 880kgm^{-3}$ and coefficient of viscosity of $air = 180\mu poise.$

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

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8. The mutual conductance of a triode value is 2.5 millimho. Find the change in the plate current if the grid voltage is changed from $-2.0V$ to $-4.5V$.

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

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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?

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2. An AC source is connected to a diode and a resistor in series. Is the current through the resistor AC or DC?

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3. How will the thermionic current vary if the filament current is increased?

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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?

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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?

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6. An isolated metal sphere is heated to a high temperature. Will it become positively charged due to thermionic emission?

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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?

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8. Why does thermionic emission not take place in nonconductors?

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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?

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10. Why is the linear portion of the triode characteristic chosen to operate the triode as an amplifier?

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Objective 1

1. Cathode rays constitute a stream of

A. electrons

B. protons

C. positive ions

D. negative ions

Answer: A

2. Cathode rays 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

Answer: C

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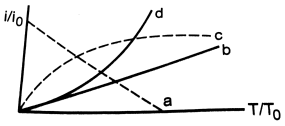
3. Let i_0 be the thermionic current from a metal surface when the absolute temperature of the surface is T_0. The temperature is slowly increased and the thermionic current is measured as a function of temperature. Which of the following plots may represent the variation in $\left(\frac{i}{i_0}\right)$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



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4. When the diode shows saturated current, dynamic plate resistance is

A. zero

B. infinity

C. indeterminate

D. different for different diodes

Answer: B

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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

Answer: A

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6. A diode, a resistor and a $50HzAC$ source are connected in series. The number of current pulses per second through the resistor is

A. 25

B. 50

C. 100

D. 200

Answer: B

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7. A triode is operated in the liner 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

Answer: C

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8. The plate current in a triode valve is maximum when the potential of the grid is

A. positve

B. zero

C. negative

D. nonpositive

Answer: A

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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

Answer: D

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Objective 2

1. Electric conduction takes place in a discharge tube due to the movement of

A. positive ions

B. negative ions

C. electrons

D. protons

Answer: A::B::C

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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

Answer: A::B::C

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3. Because of the space charge in a diode valve,

A. the plate current decreases

B. the plate voltage increase

C. the rate of emission of thermions increases

D. the saturation current increases

Answer: A

4. The saturation current in a triode valve can be changed by changing

A. the grid voltage

B. the plate voltage

C. theseparation between the grid and the cathode

D. the temperature of the cathode

Answer: D

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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.

Answer: A::B::D

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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

Answer: A::B::C::D

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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. $V_g < 0, V_p < 0$

Answer: B::C::D

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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.`

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2. A molecule of a gas, filled in a discharge tube, gets ionized when an electron is detached from it. An electric field of $5.0kVm^{-1}$ exists in the vicinity of the event. (a) Find the distance travelled by the free electron in $1\mu s$ assuming no collision. (b) If the mean free path of the electron is $1.0mm$, estimate the time of transit of the free electron between successive collisions.

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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 $0.02mm$ of mercury. Estimate the pressure at which the dark space will fill the whole tube.

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4. Two discharge tubes have identical material structure and the same gas is filled in them. The length of one tube is 10cm and that of th other tube is 20cm. Sparking starts in both the tubes when the potential difference between the cathode and the anode is $100V$. If the pressure in the shorter tube is

$1.0mm$ of mercury, what is the pressure in the longer tube?

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5. Calcuate $n(T)/n(1000K)$ for tungsten emitter at $T = 300K, 2000K \text{ and } 3000K$ where $n(T)$ represent the number of thermions emitted per secodn by the surface at temperature. T. Work function of tungsten is $4.52eV$.

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6. The saturation current from a thoriated-tungsten cathode at $2000K$ is $100mA$. 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 $60 \times 10^4 Am^{-2}K^{-2}$ for pure tungsten and $3.0 \times 10^4 Am^{-2}K^{-2}$ for thoriated tungsten. The work function of pure tungsten is $4.5eV$ and that of thoriated tungsten is $2.6eV$.

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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.

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8. If the temperature of a tungsten filament is raised from $2000K \rightarrow 2010K$, by what factor does the emission current change? Work function of tungsten is $4.5eV$.

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9. The constant A in the Richardson-Dushman equation for tungsten is $60 \times 10^4 Am^{-2}$. The work function of tungsten is $4.5eV$. A tungsten cathode having a surface area $2.0 \times 10^{-5} m^2$ is heated by a $24W$ 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 $= 6 \times 10^{-8} Wm^{-2} K^{-4}$. Assume that the thermions take only a small fraction of the heat supplied.

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10. A plate current of $10mA$ is obtained when 60 volts are applied across a diode tube. Assuming the Langmuir-Child equation $i_p \propto V_p^{\frac{3}{2}}$ to hold, find the dynamic resistance r_p in this operating condition.

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11. The plate current in a diode is $20mA$ when the plate voltage is $50V$ or $60V$. What will be the current if the plate voltage is $70V$?

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12. The power delivered in the plate circuit of a diode is $1.0W$ when the plate voltage is $36V$. Find the power delivered if the plate voltage is increased to $49V$. Assume Langmuir-Child equation to hold`.

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13. A triode valve operates at $V_p = 225V$ and $V_g = -0.5V$. The plate current remains unchanged if the plate voltage is increased to $250V$ and the grid voltage is decreased to $-2.5V$. Calculate the amplification factor.

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14. Calculate the amplification factor of a triode valve which has plate resistance of $2k\Omega$ and transconductance of 2 millimho`.

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15. The dynamic plate resistance of a triode valve is $10k\Omega$. Find the change in the plate current if the plate voltage is changed from $200V$ to $220V$.

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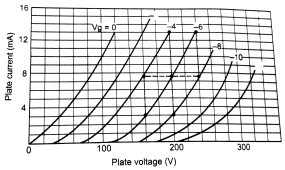
16. Find the values of r_p, μ and g_m of a triode operating at plate voltage $200V$ and grid voltage $-6V$. The plate characteristic are shown in figure.



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17. The plate resistance of a triode is $8k\Omega$ and the transconductiance is $2.5mil \lim h \odot (a)Iftheplatevo < a \geq is \in creasedby$ 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?

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18. The plate resistance and the amplification factor of a triode are $10k\Omega$ and 20. The tube is operated at plate voltage $250V$ and grid voltage $-7.5V$. The plate current is $10mA$. (a) To what value should the grid voltage be changed so as to increase the plate current to $15mA$? (b) To what value should the plate voltage be changed to take the plate current back to $10mA$?

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19. The plate current, plate voltage and grid voltage of a $6F6$ triode tube are related as

$i_p = 41\left(V_p + 7V_g\right)^{1.41}$

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

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20. The plate current in a triode can be written as

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

Show that the mutual conductance is proportional to the cube root of the plate current.

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21. A triode has mutual conductance $= 2.0$ millimho and plate resistance $= 20k\Omega$. It is desired to amplify a signal by a factor of 30. What load resistance should be added in the circuit?

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

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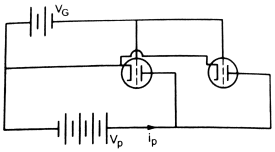
23. Figure shows two identical triode tubes connected in paralle. The anodes are connected together, the grids are connected together and the cathodes are connected together. Show that the equivalent plate resistance is half of the individual plate resistance, the equivalent mutual conductance

is double the individual mutual conductance and the equivalent amplification factor is the same as the individual amplification factor.



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