H

THOOTHUKUDI DISTRICT

19

Reg.No.:

COMMON SECOND REVISION TEST - 2023

Std - XII

Time : 3.00 Hours

PHYSICS

Marks: 70

Part - I

Choose the correct answer for the following: 15 x 1 = 15

1. Electron microscope works on the principle of
   a) photoelectric effect b) particle nature of electron
   c) wave nature of moving electron d) dual nature of matter
2. The value of Bohrmagneton is Pg: 162 V-I
   a) 9.27×10^{24} Am^{-2} b) 9.27×10^{-27} Am^{2} c) 9.27×10^{27} Am^{2}
   d) 9.27×10^{-24} Am^{2}
3. The uniformly charged spherical shell produce zero electric field at points
   a) On the surface of the shell b) Inside the shell
   c) At infinite distance from the shell d) Outside the shell
4. When number of turns in galvanometer is doubled. Then current sensitivity of galvanometer
   a) Not changed b) decreased into two times
   c) increased into two times d) increased into four times
5. In an electromagnetic wave travelling in free space the rms value of the electric field is $3Vm^{-1}$. The peak value of the magnetic field is
   a) 1.414×10^{-8} T b) 1.0×10^{-8} T c) 2.828×10^{-8} T d) 2.0×10^{-8} T
6. Potential Barrier of silicon diode is
   a) 0.3V b) 0.7V c) 1.1V d) 2.2V
7. Nicol prism produces polarised light based on
   a) scattering b) selective absorption c) reflection d) double refraction
8. Two point white dots are 1 mm apart on a black paper. They are viewed by eye of pupil diameter 3mm approximately. The maximum distance at which these dots can be resolved by the eye is, [take wavelength of light, $\lambda = 500nm$)
   a) 1m b) 5m c) 3m d) 6m
9. Two radiations with photon energies 0.9eV and 3.3eV respectively are falling on a metallic surface successively. If the work function of the metal is 0.6eV, then the ratio of maximum speeds of emitted electrons in the two cases will be L-8
   a) 1:4 b) 1:3 c) 1:1 d) 1:9
10. A radioactive nucleus (initial mass number A and atomic number Z) emits two α-particles and 2 positrons. The ratio of number of neutrons to that of proton in the final nucleus will be
    a) $\frac{A-Z-4}{Z-2}$ b) $\frac{A-Z-2}{Z-6}$ c) $\frac{A-Z-4}{Z-6}$ d) $\frac{A-Z-12}{Z-6}$
11. The variation of frequency of carrier wave with respect to the amplitude of the modulating signal is called
    a) amplitude modulation b) frequency modulation c) phase modulation
    d) pulse width modulation
12. Aluminium and copper conductors of same length and same resistance, if their radii ratio is 1:3, What is ratio of their specific resistance?
    a) 1:9 b) 3:1 c) 1:3 d) 9:1
13. Which one of the following represents forward bias diode?
    a) 

    b) 

    c) 

    d) 

14. In India electricity is supplied for domestic use at 220V. It is supplied at 110V in USA. If the resistance of a 60W bulb for use in India is R, the resistance of a 60W bulb for use in USA will be
    a) R b) 2R c) R/4 d) R/2
15. The internal resistance of a 2.1V cell which gives a current of 0.2A through a resistance of 10Ω is
    a) 0.2Ω b) 0.5Ω c) 0.8Ω d) 1.0Ω

Part - II

Answer any six of the following Questions No. 24 is compulsory. **6 x 2 = 12**

16. Why are NOR and NAND gates called universal gates? 230 (L-10)
17. What is isotone? Give an example. 164 (L-9)
18. Define stopping potential. 133 (L-8)
19. State Huygen's principle. 55 (L-7)
20. Give two uses Gamma rays. 277 (L-5)
21. State Faraday's laws of electromagnetic induction. 200 (L-4)
22. Define magnetic dipole moment. 130 (L-3)
23. What is mean by superconductivity? 96 (L-2)
24. Find the heat energy produced in a resistance of 10Ω when 5A current flows through it for 5 minutes. 112 (L-2) Ex 2.27

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Part - III

Answer any six of the following Q. No. 30 is compulsory. **6 x 3 = 18**

25. Discuss the basic properties of electric field lines. 17,18,19 (L-1)
26. Write difference between Peltier effect and Joule's effect. 115,112 (L-2)
27. Two materials X and Y are magnetised whose values of intensity of magnetisation are $500Am^{-1}$ and $2000Am^{-1}$ respectively. If the magnetising field is $1000Am^{-1}$, then which one among these materials can be easily magnetized? 143 (L-3) Ex 3.10
28. Assuming that the length of the solenoid is large when compared to its diameter, find the equation for its inductance. 213, 214 (L-4)
29. List the uses of polaroids. 84 (L-7)
30. A monochromatic light is incident on an equilateral prism at an angle 30° and is emergent at an angle of 75°. What is the angle of deviation produced by the prism? 39 (L-6)
31. A proton and an electron have same de Broglie wavelength. Which of them moves faster and which possesses more kinetic energy? (L-8) Ex 8.8
32. What is half-life of a radio active nucleus? Give the expression. 175 (L-9)
33. List out the advantages and limitations of fiber optic communication. 241 (L-10)

Part - IV

Answer all the questions. **5 x 5 = 25**

34. Derive the expression for the force between two parallel, current-carrying conductors. 178,179 V-I

    (OR)

    Define Radioactive Disintegration law. Obtain the expression for number of Radioactive atoms present at particular instant of time. 173,174,175 V-II
35. Explain the determination of the internal resistance of a cell using voltmeter. **(OR)** V-I
    Discuss the diffraction at single slit and obtain the condition for n^{th} minimum. 79 V-II
36. Obtain the expression for electric field due to an infinitely long charged wire. **(OR)** 43,47
    What is dispersion? Obtain the equation for dispersive power of a medium. 41,42,43 V-II
37. Obtain Einstein's photoelectric equation with necessary explanation. 119 **(OR)** V-II
    i) What are Fraunhofer lines? How are they usseful in the identification of elements present in the Sun? 279 V-I
    ii) If the relative permeability and relative permittivity of a medium are 1.0 and 2.25 respectively, find the speed of the electromagnetic wave in this medium. $V = 2\times10^8 ms^{-1}$ 284 V-I
38. Derive an expression for phase angle between the applied voltage and current in a series RLC circuit. 244, 245 **(OR)** V-I
    Draw the circuit diagram of a half wave rectifier and explain its working. 207, 208 V-II

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THOOTHUKUDI DISTRICT
Std – XII
Physics

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Part – I

Note : i) Answer all the questions. Choose the most appropriate answer from the given four alternatives and write the option code and the corresponding answer.

15 X 1 = 15

1) c) wave nature of moving electron
2) d) 9.27×10^{-24} Am^{-2}
3) b) inside the shell
4) c) increased into two times
5) a) 1.414×10^{-8} T
6) b) 0.7 V
7) d) double refraction
8) b) 5m
9) b) 1 : 3
10) b) $\frac{A-Z-2}{Z-6}$
11) b) frequency modulation
12) a) 1 : 9
13) a) 

14) c) R / 4
15) b) 0.5 Ω

Part – II

6 x 2 = 12

Note : Answer any six of the following Questions No. 24 is Compulsory.

16) Why are NOR and NAND gates called universal gates?

- NAND and NOR gates are known as universal gates because any other logic gate can be made from NAND or NOR gates.

17) What is isotone? Give an example.

Isotones are the atoms of different elements having same number of neutrons. ${}^{12}_{5}B$ and ${}^{13}_{6}C$ are examples of isotones with 7 neutrons each.

18) Define stopping potential.

Stopping potential is that the value of the negative (retarding) potential given to the collecting electrode *A* which is just sufficient to stop the most energetic photoelectrons emitted and make the photocurrent zero.

19) State Huygen's principle

According to Huygens principle, each point on the wavefront behaves as the source of secondary wavelets spreading out in all directions with the speed of the wave. These are called as secondary wavelets. The envelope to all these wavelets gives the position and shape of the new wavefront at a later time.

20) Give two uses of Gamma rays.

It is used in radio therapy for the treatment of cancer and tumour, in food industry to kill pathogenic microorganism.

21) State Faraday's laws of electromagnetic induction.

First law

Whenever magnetic flux linked with a closed circuit changes, an emf is induced in the circuit which lasts in the circuit as long as the magnetic flux is changing.

Second law

The magnitude of induced emf in a closed circuit is equal to the time rate of change of magnetic flux linked with the circuit.

22) Define magnetic dipole moment.

The magnetic dipole moment is defined as the product of its pole strength and magnetic length. It is a vector quantity, denoted by $\vec{p}_m$.

23) What is mean by superconductivity?

The resistance of certain materials become zero below certain temperature T_c. This temperature is known as critical temperature or transition temperature. The materials which exhibit this property are known as superconductors.

24) Find the heat energy produced in a resistance of 10 Ω when 5 A current flows through it for 5 minutes.

Solution

$R = 10\ \Omega$, $I = 5$ A, $t = 5$ minutes $= 5 \times 60$ s

$H = I^2Rt$

$= 5^2 \times 10 \times 5 \times 60$

$= 25 \times 10 \times 300$

$= 25 \times 3000$

= 75000 J (or) 75 kJ

Part – III

Answer any six of the following Q. No. 30 is compulsory. 6 x 3 = 18

25) Discuss the basic properties of electric field lines.

- The electric field lines start from a positive charge and end at negative charges or at infinity. For a positive point charge the electric field lines point radially outward and for a negative point charge, the electric field lines point radially inward.
- The electric field vector at a point in space is tangential to the electric field line at that point.
- The electric field lines are denser (more closer) in a region where the electric field has larger magnitude and less dense in a region where the electric field is of smaller magnitude. In other words, the number of lines passing through a given surface area perpendicular to the lines is proportional to the magnitude of the electric field in that region.
- No two electric field lines intersect each other. If two lines cross at a point, then there will be two different electric field vectors at the same point, As a consequence, if some charge is placed in the intersection point, then it has to move in two different directions at the same time, which is physically impossible. Hence, electric field lines do not intersect.
- The number of electric field lines that emanate from the positive charge or end at a negative charge is directly proportional to the magnitude of the charges.

26) Write difference between Peltier effect and Joule's effect.

Peltier effect

When an electric current is passed through a circuit of a thermocouple, heat is evolved at one junction and absorbed at the other junction. This is known as Peltier effect.

Joule's effect

$H = I^2Rt$ The heat developed in an electrical circuit due to the flow of current varies directly as

(i) the square of the current
(ii) the resistance of the circuit and
(iii) the time of flow.

27) Two materials X and Y are magnetised whose values of intensity of magnetisation are 500 A m^{-1} and 2000 A m^{-1} respectively. If the magnetising field is 1000 A m^{-1}, then which one among these materials can be easily magnetized?.

Solution

The susceptibility of material X is

$$\chi_{m,X} = \frac{|\vec{M}|}{|\vec{H}|} = \frac{500}{1000} = 0.5$$

The susceptibility of material Y is

$$\chi_{m,Y} = \frac{|\vec{M}|}{|\vec{H}|} = \frac{2000}{1000} = 2$$

Since, susceptibility of material Y is greater than that of material X, which implies that material Y can be easily magnetized.

28) Assuming that the length of the solenoid is large when compared to its diameter, find the equation for its inductance.

Self-inductance of a long solenoid

Consider a long solenoid of length l and cross-sectional area A. Let n be the number of turns per unit length (or turn density) of the solenoid. When an electric current i is passed through the solenoid, a magnetic field produced inside is almost uniform and is directed along the axis of the solenoid as shown in Figure 4.20. The magnetic field at any point inside the solenoid is given by

$$\boldsymbol{B = \mu_0 ni}$$

As this magnetic field passes through the solenoid, the windings of the solenoid are linked by the field lines. The magnetic flux passing through each turn is

$$\Phi_B = \int_A \vec{B}.d\vec{A} = BA\cos\theta$$
$$= BA \qquad \text{since } \theta = 0°$$
$$= (\mu_0 ni)A$$

The total magnetic flux linked or flux linkage of the solenoid with N turns (the total number of turns N is given by $N = n\,l$) is

$$N\Phi_B = (nl)(\mu_0 ni)A$$
$$N\Phi_B = (\mu_0 n^2 Al)\, i$$

We know that

$$N\Phi_B = Li$$

Comparing the above equations, we get

$$L = \mu_o n^2 Al$$

From the above equation, it is clear that inductance depends on the geometry of the solenoid (turn density n, cross-sectional area A, length l) and the medium present inside the solenoid. If the solenoid is filled with a dielectric medium of relative permeability μ_r, then

$$L = \mu n^2 Al \quad or \quad L = \mu_o \mu_r n^2 Al$$

29) List the uses of polaroids.

1. Polaroids are used in goggles and cameras to avoid glare of light.
2. Polaroids are used to take 3D pictures i.e., holography.
3. Polaroids are used to improve contrast in old oil paintings.
4. Polaroids are used in optical stress analysis.
5. Polaroids are used as window glasses to control the intensity of incoming light.
6. Polarised laser beam acts as needle to read/write in compact discs (CDs).
7. Polarised light is used in liquid crystal display (LCD).

30) A monochromatic light is incident on an equilateral prism at an angle 30^0 and is emergent at an angle of 75^0 What is the angle of deviation produced by the prism?

Solution

Since, the prism is equilateral, $A = 60^0$;

Given, $i_1 = 30^0$; $i_2 = 75^0$

Equation for angle of deviation, $d = i_1 + i_2 - A$

Substituting the values, $d = 30° + 75° - 60° = 45°$

The angle of deviation produced, $d = 45°$

31) A proton and an electron have same de Broglie wavelength. Which of them moves faster and which possesses more kinetic energy?

Solution

We know that $\lambda = \frac{h}{\sqrt{2mK}}$

Since proton and electron have same de Broglie wavelength, we get

$$\frac{h}{\sqrt{2m_pK_p}} = \frac{h}{\sqrt{2m_eK_e}} \quad \text{(or)} \quad \frac{K_p}{K_e} = \frac{m_e}{m_p}$$

Since $m_e < m_p$, $K_p < K_e$, the electron has more kinetic energy than the proton.

$$\frac{K_p}{K_e} = \frac{\frac{1}{2}m_p v_p^2}{\frac{1}{2}m_e v_e^2} \quad \text{(or)} \quad \frac{v_p}{v_e} = \sqrt{\frac{K_p m_e}{K_e m_p}}$$

$$\frac{v_p}{v_e} = \sqrt{\frac{m_e^2}{m_p^2}} = \frac{m_e}{m_p} \quad \text{since} \quad \frac{K_p}{K_e} = \frac{m_e}{m_p}$$

Since $m_e < m_p$, $v_p < v_e$, the electron moves faster than the proton.

32) What is half – life of a radioactive nucleus? Give the expression.

We can define the half-life $T_{1/2}$ as the time required for the number of atoms initially present to reduce to one half of the initial amount.

The half-life is the important characteristic of every radioactive sample. Some radioactive nuclei are known to have half-life as long as 10^{14} years and some nuclei have very shorter half-life time (10^{-14}s).

We can express half-life in terms of the decay constant. At $t = T_{1/2}$, the number of undecayed nuclei $N = N_0 / 2$.

By substituting this value in to the equation $N = N_0\, e^{-\lambda t}$, we get

$$N_0 / 2 = N_0\, e^{-\lambda T_{1/2}}$$

$$½ = e^{-\lambda T_{1/2}} \text{ or } e^{\lambda T_{1/2}} = 2$$

Taking logarithm on both sides and rearranging the terms,

$$T_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.6931}{\lambda}$$

33) List out the advantages and limitations of fiber optic communication.

Merits

i) Fiber cables are very thin and weigh less than copper cables.

ii) This system has much larger band width. This means that its information carrying capacity is larger.

iii) Fiber optic system is immune to electrical interferences.

iv) Fiber optic cables are cheaper than copper cables.

Demerits

i) Fiber optic cables are more fragile when compared to copper wires.

ii) It is an expensive technology.

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Part – IV

Answer all the questions. **5 x 5 = 25**

34) a) Derive the expression for the force between two parallel, current-carrying conductors.

For equilibrium of the rod,

$$mg\sin 45^\circ = IBl\cos 45^\circ$$

$$\Rightarrow I = \frac{1}{B}\frac{m}{l}g\tan 45^\circ$$

$$= \frac{0.25\,\text{kg m}^{-1}}{0.25\,T}\times 1\times 9.8\ \text{m s}^{-2}$$

$$\Rightarrow I = 9.8\,\text{A}$$

So, we need to supply current of 9.8 A to keep the metallic rod stationary.

3.10.6 Force between two long parallel current carrying conductors

Let two long straight parallel current carrying conductors separated by a distance r be kept in air medium as shown in Figure 3.53. Let I_1 and I_2 be the electric currents passing through the conductors A and B in same direction (i.e. along z - direction) respectively. The net magnetic field at a distance r due to current I_1 in conductor A is

$$\vec{B}_1 = \frac{\mu_\circ I_1}{2\pi r}(-\hat{i}) = -\frac{\mu_\circ I_1}{2\pi r}\hat{i}$$

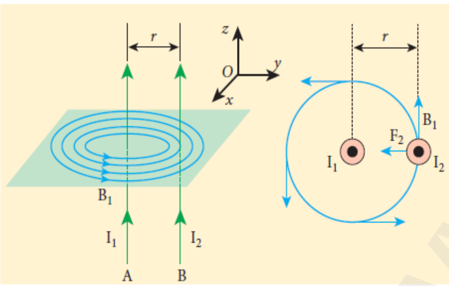


Figure 3.53 Two long straight parallel wires

From thumb rule, the direction of magnetic field is perpendicular to the plane of the paper and inwards (arrow into the page ⊗) i.e. along negative $\hat{i}$ direction.

Let us consider a small elemental length dl in conductor B at which the magnetic field $\vec{B}_1$ is present. From equation 3.66, Lorentz force on the element dl of conductor B is

$$d\vec{F} = \left(I_2 d\vec{l}\times\vec{B}_1\right) = -I_2 dl\frac{\mu_\circ I_1}{2\pi r}(\hat{k}\times\hat{i})$$

$$= -\frac{\mu_\circ I_1 I_2 dl}{2\pi r}\hat{j}$$

Therefore the force on dl of the wire B is directed towards the conductor A. So the element of length dl in B is attracted towards the conductor A. Hence the force per unit length of the conductor B due to current in the conductor A is

$$\frac{\vec{F}}{l} = -\frac{\mu_\circ I_1 I_2}{2\pi r}\hat{j}$$

Similarly, the net magnetic induction due to current I_2 (in conductor B) at a distance r in the elemental length dl of conductor A is

$$\vec{B}_2 = \frac{\mu_\circ I_2}{2\pi r}\hat{i}$$

From the thumb rule, direction of magnetic field is perpendicular to the plane of the paper and outwards (arrow out of the page ⊙) i.e., along positive $\hat{i}$ direction. Hence, the magnetic force acting on element dl of the conductor A is

$$d\vec{F} = \left(I_1 d\vec{l}\times\vec{B}_2\right) = I_1 dl\frac{\mu_\circ I_2}{2\pi r}(\hat{k}\times\hat{i})$$

$$= \frac{\mu_\circ I_1 I_2 dl}{2\pi r}\hat{j} \qquad (3.68)$$

Therefore the force on dl of conductor A is directed towards the conductor B. So the length dl is attracted towards the conductor B as shown in Figure (3.54).

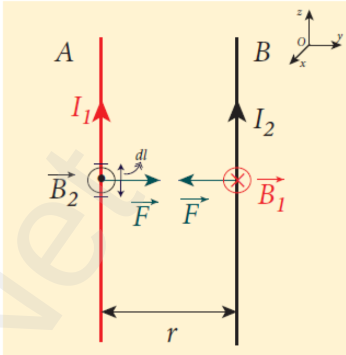


Figure 3.54 Current in both the conductors are in the same direction - attracts each other

The force acting per unit length of the conductor A due to the current in conductor B is

$$\frac{\vec{F}}{l} = \frac{\mu_\circ I_1 I_2}{2\pi r}\hat{j}$$

Thus the force between two parallel current carrying conductors is attractive if they carry current in the same direction. (Figure 3.55)

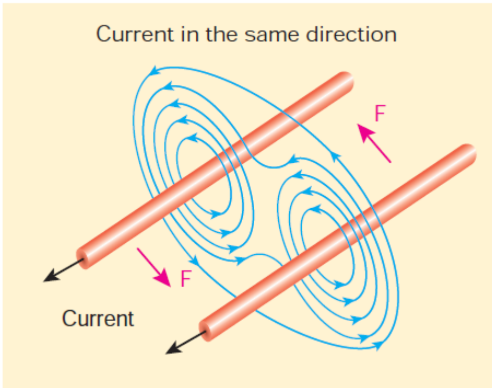


Figure 3.55 Two parallel conductors carrying current in same direction experience an attractive force

The force between two parallel current carrying conductors is repulsive if they carry current in opposite directions

34) b) Define Radioactive Disintegration law. Obtain the expression for number of Radioactive atoms present at particular instant of time.

Law of radioactive decay

we have bulk material of radioactive sample which contains a vast number of the radioactive nuclei and not all the radioactive nucleus in a sample decay at the time.

decay at the same time. It decays over a period of time and this decay is basically a random process. It implies that we cannot predict which nucleus is going to decay or rather we can determine like probabilistic basis (like tossing a coin). We can calculate approximately how many nuclei in a sample are decayed over a period of time.

At any instant t, the number of decays per unit time, called rate of decay $\left(\frac{dN}{dt}\right)$ is proportional to the number of nuclei (N) at the same instant.

$$\frac{dN}{dt} \propto N$$

By introducing a proportionality constant, the relation can be written as

$$\frac{dN}{dt} = -\lambda N \qquad (9.32)$$

Here proportionality constant λ is called decay constant which is different for different radioactive sample and the negative sign in the equation implies that N is decreasing with time.

By rewriting the equation (9.32), we get

$$dN = -\lambda N dt \qquad (9.33)$$

Here dN represents the number of nuclei decaying in the time interval dt.

Let us assume that at time $t = 0$ s, the number of nuclei present in the radioactive sample be N_0. By integrating the equation (9.33), we can calculate the number of undecayed nuclei N present at any time t.

From equation (9.33), we get

$$\frac{dN}{N} = -\lambda dt \qquad (9.34)$$

$$\int_{N_0}^{N} \frac{dN}{N} = -\int_0^t \lambda dt$$

$$[\ln N]_{N_0}^{N} = -\lambda t$$

$$\ln\left[\frac{N}{N_0}\right] = -\lambda t$$

Taking exponentials on both sides, we get

$$N = N_0 e^{-\lambda t} \qquad (9.35)$$

[Note: $e^{\ln x} = e^y \Rightarrow x = e^y$]

Equation (9.35) is called the law of radioactive decay. Here N denotes the number of undecayed nuclei present at any time t and N_0 denotes the number of nuclei present initially time t=0. Note that the number of atoms is decreasing exponentially over the length of time. This implies that the time taken for all the radioactive nuclei to decay will be infinite. Equation (9.35) is plotted in Figure 9.26.

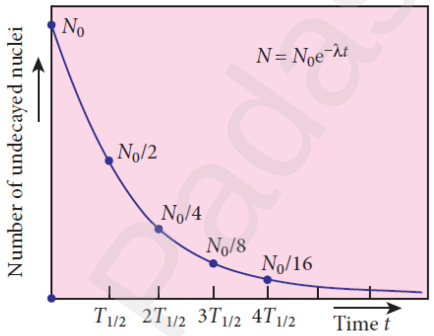


Figure 9.26 Law of radioactive decay

We can also define another useful quantity called activity (R) or decay rate which is the number of nuclei decayed per second and it is denoted as $R = \left|\frac{dN}{dt}\right|$. Note that activity R is a positive quantity.

From equation (9.35), we get

$$R = \left|\frac{dN}{dt}\right| = \lambda N_0 e^{-\lambda t} \qquad (9.36)$$

$$R = R_0 e^{-\lambda t} \qquad (9.37)$$

where $R_0 = \lambda N_0$

The equation (9.37) is also equivalent to radioactive law of decay. Here R_0 is the activity of the sample at t=0 and R is the activity of the sample at any time t. From equation (9.37), activity also shows exponential decay behavior. The activity R also can be expressed in terms of number of undecayed atoms present at any time t.

From equation (9.37), since $N = N_0 e^{-\lambda t}$, we write

$$R = \lambda N \qquad (9.38)$$

Equation (9.38) implies that the activity at any time t is equal to the product of decay constant and number of undecayed nuclei present at that time t. Since N decreases with time, R also decreases.

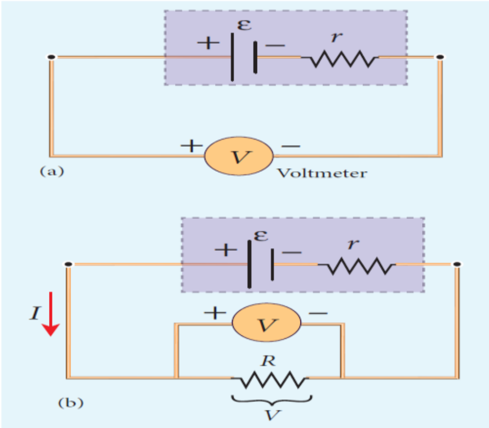
The SI unit of activity R is Becquerel and one Becquerel (Bq) is equal to one decay per second. There is also another standard unit for the activity called Curie(Ci).

1 Curie = 1 Ci = 3.7×10^{10} decays per second

1 Ci = 3.7×10^{10} Bq

35) a) Explain the determination of the internal resistance of a cell using voltmeter.

Determination of internal resistance



The emf of cell ε is measured by connecting a high resistance voltmeter across it without connecting the external resistance *R* as shown in Figure 2.20(a). Since the voltmeter draws very little current for deflection, the circuit may be considered as open. Hence the voltmeter reading gives the emf of the cell. Then, external resistance *R* is included in the circuit and current *I* is established in the circuit. The potential difference across R is equal to the potential difference across the cell (V).

The potential drop across the resistor *R* is

$V = IR$--------------- (1)

Due to internal resistance *r* of the cell, the voltmeter reads a value *V*, which is less than the emf of cell ε. It is because, certain amount of voltage (*Ir*) has dropped across the internal resistance *r*.

Then $V = \varepsilon - Ir$

$Ir = \varepsilon - V$---------- (2)

Dividing equation (2) by equation (1), we get

$$\frac{Ir}{IR} = \frac{\varepsilon - V}{V}$$

$$R = \left[\frac{\varepsilon - V}{V}\right]R \text{ ----------(3)}$$

Since ε, *V* and *R* are known, internal resistance *r* can be determined. We can also find the total current that flows in the circuit.

Due to this internal resistance, the power delivered to the circuit is not equal to power rating mentioned in the battery. For a battery of emf ε, with an internal resistance *r*, the power delivered to the circuit of resistance *R* is given by

$P = I\varepsilon = I\,(V + Ir)$ (from equation 2)

Here *V* is the voltage drop across the resistance *R* and it is equal to *IR*.

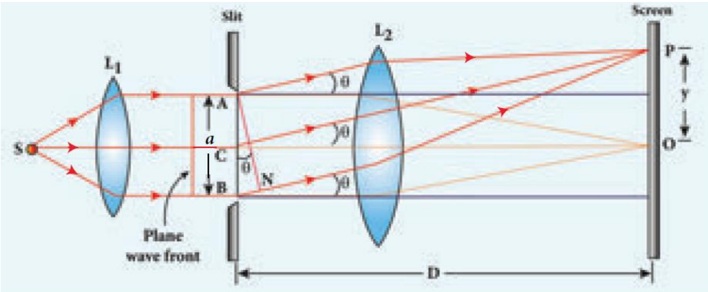
Therefore, $P = I\,(IR + Ir)$

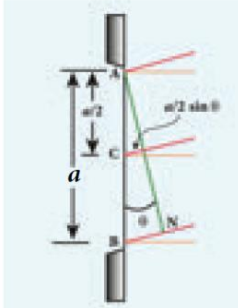
$P = I^2 R + I^2 r$ -------------(4)

Here I^2r is the power delivered to the internal resistance and I^2R is the power delivered to the electrical device (here it is the resistance *R*). For a good battery, the internal resistance *r* is very small, then $I^2r << I^2R$ and almost entire power is delivered to the external resistance.

35) b) Discuss the diffraction at single slit and obtain the condition for nth minimum.

Diffraction in single slit





Let a parallel beam of light (plane wavefront) fall normally on a single slit AB of width a as shown in Figure 7.17. The diffracted beam falls on a screen kept at a distance D from the slit. The center of the slit is C. A straight line through C perpendicular to the plane of slit meets the center of the screen at O. Consider any point P on the screen. All the light reaching the point P from different points on the slit make an angle θ with the normal CO.

All the light waves coming from different points on the slit interfere at point P (and other points) on the screen to give the resultant intensities. The point P is in the geometrically shadowed region, up to which the central maximum is spread due to diffraction. We need to give the condition for the point P to be of various minima.

The basic idea is to divide the slit into even number of smaller parts. Then, add their contributions at P with the proper path difference to show that destructive interference takes place at that point to make it minimum. To explain maximum, the slit is divided into odd number of parts.

Condition for P to be nth minimum

Dividing the slit into $2n$ number of (even number of) equal parts makes the light produced by one of the corresponding points to be cancelled by its counterpart. Thus, the condition for n^{th} minimum is,

$$\frac{a}{2n} = \frac{\lambda}{2}$$

$$a \sin\theta = n\lambda$$

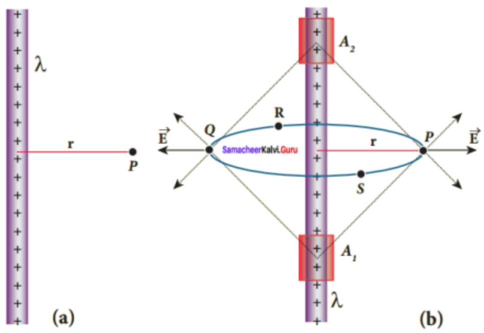
Where, $n = 1, 2, 3$ ... is the order of diffraction minimum.

36) a) Obtain the expression for electric field due to an infinitely long charged wire.

(i) Electric field due to an infinitely long charged wire

Consider an infinitely long straight wire having uniform linear charge density λ(charge per unit length). Let P be a point located at a perpendicular distance r from the wire. The electric field at the point P can be found using Gauss law.

We choose two small charge elements A_1 and A_2 on the wire which are at equal distances from the point P. The resultant electric field due to these two charge elements points radially away from the charged wire and the magnitude of electric field is same at all points on the circle of radius r. Since the charged wire possesses a cylindrical symmetry, let us choose a cylindrical Gaussian surface of radius r and length L.



Electric field due to infinite long charged wire

The total electric flux through this closed surface is calculated as follows.

$$\Phi_E = \oint \vec{E}\cdot d\vec{A}$$
$$= \int\limits_{\substack{Curved \\ surface}} \vec{E}\cdot d\vec{A} + \int\limits_{\substack{top \\ surface}} \vec{E}\cdot d\vec{A} + \int\limits_{\substack{bottom \\ surface}} \vec{E}\cdot d\vec{A} \quad (1.63)$$

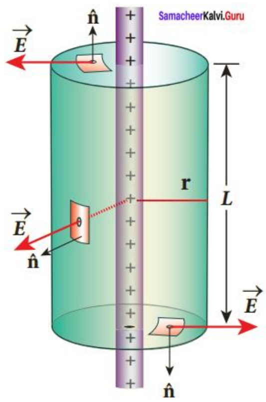
It is that for the curved surface, $\vec{E}$ is parallel to $\vec{A}$ and $\vec{E}\,.d\vec{A} = E\,dA$. For the top and bottom surfaces, $\vec{E}$ is perpendicular to $\vec{A}$ and $\vec{E}\,.\,d\vec{A} = 0$

Substituting these values in the equation (1) and applying Gauss law to the cylindrical surface, we have

$$\Phi_E = \int\limits_{\substack{Curved \\ surface}} E\,dA = \frac{Q_{encl}}{\epsilon_\circ} \quad (1.64)$$

Since the magnitude of the electric field for the entire curved surface is constant, E is taken out of the integration and Q_{encl} is given by $Q_{encl} = \lambda L$, where λ is the linear charge density (charge present per unit length)

$$E \int\limits_{\substack{Curved \\ surface}} dA = \frac{\lambda L}{\epsilon_\circ} \quad (1.65)$$



Cylindrical Gaussian surface

Here $\int dA$ = total area of the curved surface = $2\pi rL$. Substituting this in equation (3), we get

$$E\cdot 2\pi rL = \frac{\lambda L}{\epsilon_\circ}$$
$$E = \frac{1}{2\pi\epsilon_\circ}\frac{\lambda}{r} \quad (1.66)$$

In vector form,

$$\vec{E} = \frac{1}{2\pi\epsilon_\circ}\frac{\lambda}{r}\hat{r} \quad (1.67)$$

The electric field due to the infinite charged wire depends on $1/r$ rather than $1/r^2$ which is for a point charge.

Equation (1.67) indicates that the electric field is always along the perpendicular direction ($\hat{r}$) to wire. In fact, if $\lambda > 0$ then $\vec{E}$ points perpendicularly outward ($\hat{r}$) from the wire and if $\lambda < 0$, then $\vec{E}$ points perpendicularly inward ($-\hat{r}$).

The equation (1.67) is true only for an infinitely long charged wire. For a charged wire of finite length, the electric field need not be radial at all points. However, equation (1.67) for such a wire is taken approximately true around the mid-point of the wire and far away from the both ends of the wire.

36) b) What is dispersion? Obtain the equation with necessary explanation.

The angle of deviation produced by a prism is so far discussed only for monochromatic light (i.e. light of single colour). When white light enter in to a prism, an effect called *dispersion* takes place. **Dispersion is splitting of white light into its constituent colours. This band of colours of light is called its *spectrum*.**

Dispersive Power

Consider a beam of white light passing through a prism. It gets dispersed into its constituent colours.

If the angle of prism is small of the order of 10o, the prism is said to be a small angle prism. When rays of light pass through such prisms, the angle of minimum deviation also becomes small. Let A be the angle of a small angle prism and δ be its angle of minimum deviation, then equation (6.89) becomes,

$$n = \frac{\sin\left(\frac{A+\delta}{2}\right)}{\sin\left(\frac{A}{2}\right)} \qquad (6.90)$$

For small angles of A and δ,

$$\sin\left(\frac{A+\delta}{2}\right) \approx \left(\frac{A+\delta}{2}\right)$$

$$\sin\left(\frac{A}{2}\right) \approx \left(\frac{A}{2}\right)$$

$$\therefore n = \frac{\left(\frac{A+\delta}{2}\right)}{\left(\frac{A}{2}\right)} = \frac{A+\delta}{A} = 1 + \frac{\delta}{A}$$

On further simplifying, $\frac{\delta}{A} = n - 1$

$$\delta = (n-1)A \qquad (6.91)$$

When white light enters the prism, the deviation is different for different colours. Thus, the refractive index is also different for different colours.

Let δ_V, δ_R are the angles of minimum deviation for violet and red colour. Let n_V and n_R be the refractive indices for the violet and red colour respectively.

For Violet colour, $\delta_V = (n_V - 1)A \qquad (6.92)$

For Red colour, $\delta_R = (n_R - 1)A \qquad (6.93)$

As, angle of minimum deviation for violet colour δ_V is greater than angle of minimum deviation for red colour δ_R, the refractive index for violet colour n_V is greater than the refractive index for red colour n_R.

Subtracting δ_R from δ_V we get,

$$\delta_V - \delta_R = (n_V - n_R)A \qquad (6.94)$$

The angular separation between the two extreme colours (violet and red) in the spectrum ($\delta_V - \delta_R$) is called the *angular dispersion*.

If we take δ as the angle of minimum deviation for any mean colour (green or yellow) and n the corresponding refractive index. Then,

$$\delta = (n - 1)A \qquad (6.95)$$

Dispersive power ω is defined as the ratio of the angular dispersion for the extreme colours to the deviation for any middle colour. Dispersive power is the ability of the material of the prism to produce dispersion.

$$\omega = \frac{\text{angular dispersion}}{\text{middle deviation}} = \frac{\delta_V - \delta_R}{\delta} \qquad (6.96)$$

Substituting for $(\delta_V - \delta_R)$ and (δ),

$$\omega = \frac{(n_V - n_R)}{(n-1)} \qquad (6.97)$$

The dispersive power is a dimensionless and unitless quantity. The dispersive power is always positive. The dispersive power of a prism depends only on the nature of material of the prism and it is independent of the angle of the prism.

EXAMPLE 6.22

Find the dispersive power of a prism if the refractive indices of flint glass for red, green and violet colours are 1.613, 1.620 and 1.632 respectively.

Solution

Given, n_V=1.632; n_R=1.613; n_G=1.620

Equation for dispersive power is,

$$\omega = \frac{(n_V - n_R)}{(n_G - 1)}$$

Substituting the values,

$$\omega = \frac{1.632 - 1.613}{1.620 - 1} = \frac{0.019}{0.620} = 0.0306$$

The dispersive power of the prism is, $\omega = 0.0306$

37) a) Obtain Einstein's photoelectric equation with necessary explanation.

Einstein's explanation of photoelectric equation

When a photon of energy $h\nu$ is incident on a metal surface, it is completely absorbed by a single electron and the electron is ejected. In this process, a part of the photon energy is used in overcoming the potential barrier of the metal surface (photoelectric work function ϕ_0)and the remaining energy as the kinetic energy of the ejected electron. From the law of conservation of energy,

$$h\nu = \phi_0 + \frac{1}{2}mv^2 \qquad (8.6)$$

where m is the mass of the electron and v its velocity. This is shown in Figure 8.13(a).

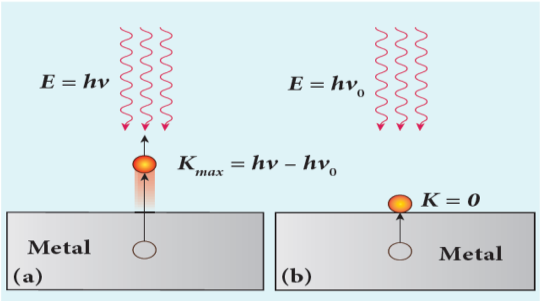


Figure 8.13 Emission of photoelectrons

If we reduce the frequency of the incident light, the speed or kinetic energy of photo electrons is also reduced. At some frequency ν_0 of incident radiation, the photo electrons are just ejected with almost zero kinetic energy (Figure 8.13(b)). Then the equation (8.6) becomes

$$h\nu_0 = \phi_0$$

where ν_0 is the threshold frequency. By rewriting the equation (8.6), we get

$$h\nu = h\nu_0 + \frac{1}{2}mv^2 \qquad (8.7)$$

The equation (8.7) is known as **Einstein's photoelectric equation**.

If the electron does not lose energy by internal collisions, then it is emitted with maximum kinetic energy K_{max}. Then

$$K_{max} = \frac{1}{2}mv^2_{max}$$

where v_{max} is the maximum velocity of the electron ejected. The equation (8.6) is rearranged as follows:

$$K_{max} = h\nu - \phi_0 \qquad (8.8)$$

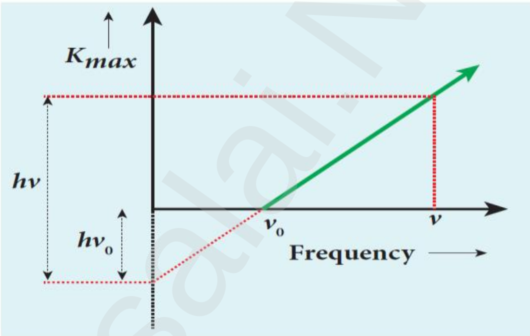


Figure 8.14 K_{max} vs ν graph

A graph between maximum kinetic energy K_{max} of the photoelectron and frequency ν of the incident light is a straight line as shown in Figure 8.14. The slope of the line is h and its y-intercept is $-\phi_0$.

Einstein's equation was experimentally verified by R.A. Millikan. He drew K_{max} versus ν graph for many metals (cesium, potassium, sodium and lithium) as shown in Figure 8.15 and found that the slope is independent of the metals.

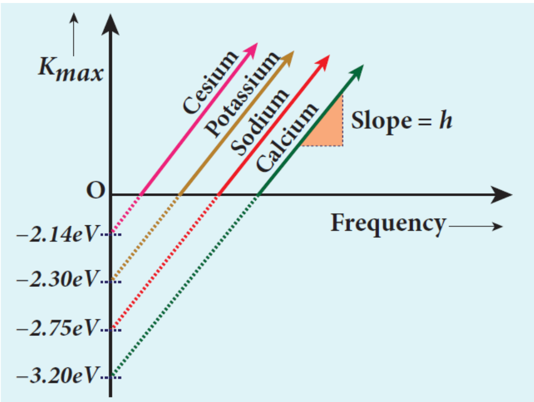


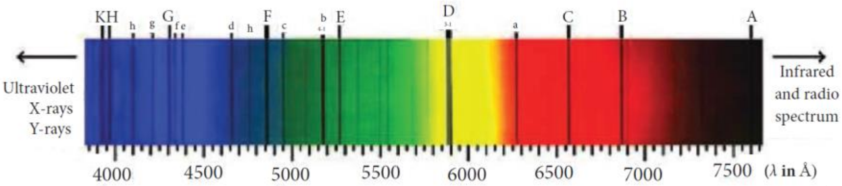
Figure 8.15 K_{max} vs ν graph for different metals

Millikan also calculated the value of Planck's constant (h = 6.626 × 10^{-34} Js) and work function of many metals (Cs, K, Na, Ca); these values are in agreement with the theoretical prediction.

37) b) i) What are Fraunhofer lines? How are they useful in the identification of elements present in the Sun?

Fraunhofer lines

When the spectrum obtained from the Sun is examined, it consists of large number of dark lines (line absorption spectrum). These dark lines in the solar spectrum are known as Fraunhofer lines. The absorption spectra for various materials are compared with the Fraunhofer lines in the solar spectrum, which helps in identifying elements present in the Sun's atmosphere.



ii) If the relative permeability and relative permittivity of a medium are 1.0 and 2.25 respectively. Find the speed of the electromagnetic wave in this medium.

Solution:

Relative permeability of the medium, $\mu_r = 1$

Relative permittivity of the medium, $\varepsilon_r = 2.25$

$$\left(\varepsilon_r = \frac{\varepsilon}{\varepsilon_0} \;\&\; \mu_r = \frac{\mu}{\mu_0}\right)$$

Speed of electromagnetic wave, v = 1με√

$$= \frac{1}{\sqrt{\mu_r \mu_o \varepsilon_r \varepsilon_o}} = \frac{C}{\sqrt{\mu_r \varepsilon_r}} \qquad \left[\text{Where, } C = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}\right]$$

$$= \frac{3\times10^8}{\sqrt{1\times2.25}} = \frac{3\times10^8}{1.5}$$

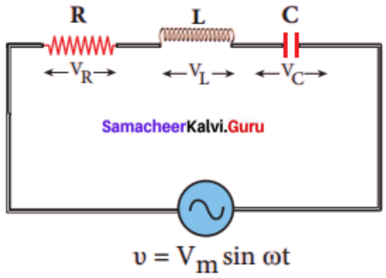
$$v = 2 \times 10^8 \text{ ms}^{-1}$$

38) a) Derive an expression for phase angle between the applied voltage and current in a series RLC circuit.

AC circuit containing a resistor, an inductor, and a capacitor in series – Series RLC circuit:

Consider a circuit containing a resistor of resistance R, an inductor of inductance L, and a capacitor of capacitance C connected across an alternating voltage source. The applied alternating voltage is given by the equation.

$$\upsilon = V_m \sin \omega t \;\ldots\ldots\; (1)$$



AC circuit containing *R*, *L* and *C*

Let i be the resulting circuit current in the circuit at that instant. As a result, the voltage is developed across R, L and C.

We know that voltage across R (V_R) is in phase with i, voltage across L (V_L) leads i by π/2 and voltage across C (V_C) lags i by π/2.

The phasor diagram is drawn with current as the reference phasor. The current is represented by the phasor

$\vec{OI}$, V_R by $\vec{OA}$; V_L by $\vec{OB}$ and V_C by $\vec{OB}$.

The length of these phasors are

$OI = I_m$, $OA = I_mR$, $OB = I_m, X_L$; $OC = I_mX_c$

The circuit is cither effectively inductive or capacitive or resistive that depends on the value of V_1 or V_c Let us assume that $V_L > V_C$. so that net voltage drop across L – C combination is $V_L < V_C$ which is represented by a phasor $\vec{AD}$.

By parallelogram law, the diagonal $\vec{OE}$ gives the resultant voltage u of VR and ($V_L - V_C$) and its length OE is equal to V_m. Therefore,

$$V_m^2 = V_R^2 + (V_L - V_C)^2 \quad ...(1)$$

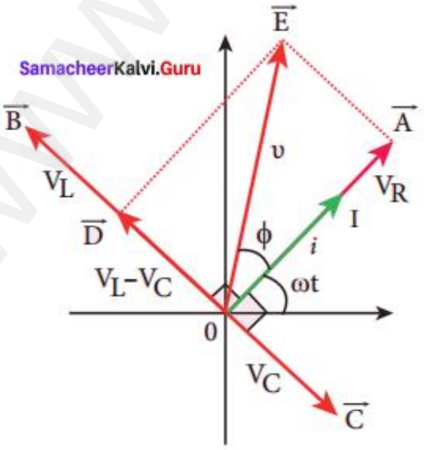
$$= \sqrt{(I_mR)^2 + (I_mX_L - I_mX_C)^2} = I_m\sqrt{R^2 + (X_L - X_C)^2}$$

or $$I_m = \frac{V_m}{\sqrt{R^2 + (X_L - X_C)^2}} \quad ...(2)$$

or $$I_m = \frac{V_m}{Z}$$

Where $$Z = \sqrt{R^2 + (X_L - X_C)^2} \quad ...(3)$$

Z is called impedance of the circuit which refers to the effective opposition to the circuit current by the series RLC circuit. The voltage triangle and impedance triangle are given in the graphical figure.



$$\tan\phi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{V_R}$$

From phasor diagram, the phase angle between n and i is found out from the following relation

Special cases Figure: Phasor diagram for a series

(i) If $X_L > X_C$, $(X_L - X_C)$ is positive and phase angle φ is also positive. It means that the applied voltage leads the current by φ (or current lags behind voltage by φ). The circuit is inductive.

$\therefore \upsilon = V_m \sin \omega t; \; i = I_m \sin(\omega t + \varphi)$

(ii) If $X_L < X_C$, $(X_L - X_C)$ is negative and φ is also negative. Therefore current leads voltage by φ and the circuit is capacitive.

$\therefore \upsilon = Vm \sin \omega t; \; i = Im \sin(\omega t + \varphi)$

(iii) If $X_L = X_C$, φ is zero. Therefore current and voltage are in the same phase and the circuit is resistive.

$\therefore \upsilon = V_m \sin \omega t; \; i = I_m \sin \omega t$

38) b) Draw the circuit diagram of a half wave rectifier and explain its working.

Half wave rectifier circuit

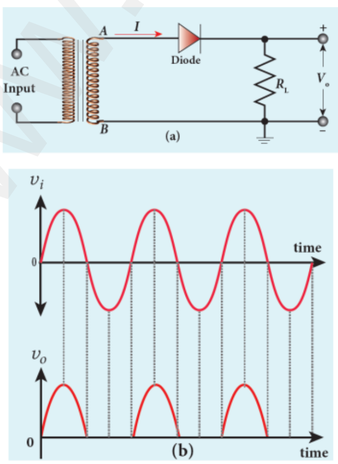
The half wave rectifier circuit consists of a transformer, a *p-n* junction diode and a resistor. In a half wave rectifier circuit, either a positive half or the negative half of the AC input is passed through by the diode while the other half is blocked. Only one half of the input wave is rectified. Therefore, it is called half wave rectifier. Here, a *p-n* junction diode acts as a rectifier diode.

During the positive half cycle

When the positive half cycle of the AC input signal passes through the circuit, terminal *A* becomes positive with respect to terminal *B*. The diode is forward biased and hence it conducts. The current flows through the load resistor R_L and the AC voltage developed across R_L constitutes the output voltage V_0 and the waveform of the output voltage.

During the negative half cycle

When the negative half cycle of the AC input signal passes through the circuit, terminal *A* is negative with respect to terminal *B*. Now the diode is reverse biased and does not conduct. Hence no current passes through R_L. The reverse saturation current in a diode is negligible. Since there is no voltage drop across R_L, the negative half cycle of AC supply is suppressed at the output.



The output of the half wave rectifier is not a steady DC voltage but a pulsating wave. This pulsating voltage cannot be used for electronic equipments. A constant or a steady voltage is required which can be obtained with the help of filter circuits and voltage regulator circuits.

Efficiency (η) is the ratio of the output DC power to the AC input power supplied to the circuit. Its value for half wave rectifier is 40.6 %.

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