Class XII Session 2026-27
Subject - Physics
Sample Question Paper - 4

Time Allowed: 3 hours **Maximum Marks: 70**

General Instructions:

1. There are 33 questions in all. All questions are compulsory.
2. This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
3. All the sections are compulsory.
4. **Section A** contains sixteen questions, twelve MCQ and four Assertion Reasoning based of 1 mark each, **Section B** contains five questions of two marks each, **Section C** contains seven questions of three marks each, **Section D** contains two case study based questions of four marks each and **Section E** contains three long answer questions of five marks each.
5. There is no overall choice. However, an internal choice has been provided in one question in Section B, one question in Section C, one question in each CBQ in Section D and all three questions in Section E. You have to attempt only one of the choices in such questions.
6. Use of calculators is not allowed.

Section A

1. Consider the following statements A and B and identify the correct choice of the given answers- **[1]**

   A: The width of the depletion layer in a $P-N$ junction diode increases in forwards bias

   B: In an intrinsic semiconductor the fermi energy level is exactly in the middle of the forbidden gap

   a) A is false and B is true
   b) A is true and B is false
   c) Both A and B are false
   d) Both A and B are true

2. The current in a wire varies with time according to the equation $i = 4 + 2t$, where i is in ampere and t is in second. Calculate the quantity of charge which has passed through a cross section of the wire during the time $t = 2\ s$ to $t = 6\ s$. **[1]**

   a) 10 C
   b) 40 C
   c) 48 C
   d) 4 C

3. When a ray of light enters a glass slab from air, **[1]**

   a) its frequency increases
   b) neither wavelength nor frequency changes

c) its wavelength increases
d) its wavelength decreases

4. Which one out of the following materials is not paramagnetic? **[1]**

a) Sodium Chloride
b) Calcium
c) Aluminium
d) Copper Chloride

5. An air capacitor is connected to a battery. The effect of filling the space between the plates with a dielectric is to increase **[1]**

a) the charge and the potential difference
b) the potential difference and the electric field
c) the charge and the capacitance
d) the electric field and the capacitance

6. A particle of mass m and charge q moves along y-axis in a region in which a uniform magnetic field $\overrightarrow{B}$ is pointing along x-axis. The Lorentz force acting on the charge will point along: **[1]**

a) x-axis
b) negative z-axis
c) z-axis
d) y-axis

7. The magnetic flux linked with a coil changes with time t as $\phi = \left(8t^2 + 5t + 7\right)$, where t is in seconds and ϕ is in Wb. The value of emf induced in the coil at $t = 4\ s$ is: **[1]**

a) 64 V
b) 32 V
c) 37 V
d) 69 V

8. A magnet of magnetic moment M is suspended in a uniform magnetic field B. The maximum value of torque acting on the magnet is **[1]**

a) zero
b) 2MB
c) MB
d) $\frac{1}{2}MB$

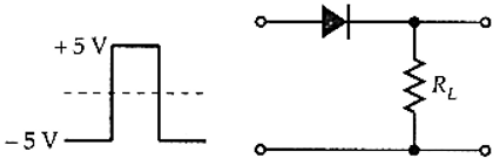
9. A plane wavefront is incident on a concave mirror of radius of curvature R. The radius of the refracted wavefront will be: **[1]**

a) $\frac{R}{4}$
b) R
c) $\frac{R}{2}$
d) 2R

10. A wire is bent into a ring of radius R is given a charge q. The magnitude of the electrical field at the centre of the ring is: **[1]**

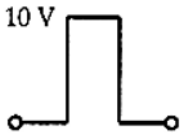
a) $\frac{1}{2}$
b) Two
c) Infinite
d) Zero

11. If in a p-n junction, a square input signal of 10 V is applied as shown, **[1]**

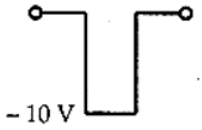


then the output across R_L will be

a) 

b) 

c) 

d) 

12. The focal lengths of the objective and the eyepiece of a compound microscope are 1 cm and 2 cm respectively. If the tube length of the microscope is 10 cm, the magnification obtained by the microscope for most suitable viewing by relaxed eye is: **[1]**

a) 250 b) 150

c) 125 d) 200

13. **Assertion (A):** In his study of photoelectric emission, Hallwachs connected a negatively charged zinc plate to an electroscope. He found that negatively charged particles were emitted from the zinc plate under the action of visible light. **[1]**
Reason (R): An uncharged zinc plate becomes positively charged when it is irradiated by visible light.

a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

14. **Assertion:** When charges are shared between two bodies, there occurs no loss of charge but there does occur a loss of energy. **[1]**
Reason: In case of sharing of charges, conservation of energy fails.

a) Assertion and reason both are correct statements and reason is correct explanation for assertion.

b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

c) Assertion is correct statement but reason is wrong statement.

d) Assertion is wrong statement but reason is correct statement.

15. **Assertion (A):** In interference all the fringes are of same width. **[1]**
Reason (R): In interference fringe width is independent of position of the fringe.

a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

16. **Assertion:** In alternating current, direction of motion of free electrons changes **[1]**

periodically.

Reason: Alternating current changes its direction after a certain time interval.

a) Assertion and reason both are correct statements and reason is correct explanation for assertion.

b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

c) Assertion is correct statement but reason is wrong statement.

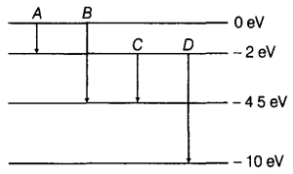
d) Assertion is wrong statement but reason is correct statement.

Section B

17. Sea water at frequency $\nu = 4 \times 10^8$ Hz has permittivity $\varepsilon \approx 80\varepsilon_0$, permeability $\mu \approx \mu_o$ and resistivity $\rho = 0.25\ \Omega$-m. Imagine a parallel plate capacitor immersed in sea water and driven by an alternating voltage source $V(t) = V_0 \sin(2\pi\nu t)$. What fraction of the conduction current density is the displacement current density? **[2]**

18. When the voltage drop across a p-n junction diode is increased from 0.70 V to 0.71 V, the change in the diode current is 10 mA. What is the dynamic resistance of the diode? **[2]**

19. i. The energy levels of an atom are as shown in figure below. Which of them will result in the transition of a photon of wavelength 275 nm? **[2]**



ii. Which transition corresponds to emission of radiation of minimum wavelength?

20. A long bar magnet is cut into three pieces. These parts are then combined with their like poles together. Find the ratio of the time period of oscillation of the original magnet and the combination magnet in the same external magnetic field. **[2]**

OR

An iron sample having mass 8.4 kg is repeatedly taken over cycles of magnetisation and demagnetisation at a frequency of 50 cycles s^{-1}. It is found that 3.2×10^4 J of energy is dissipated as heat in the sample in 30 minutes. Find the energy dissipated per unit volume per cycle in the iron sample. Density of iron = 7200 kg m^{-3}.

21. Two parallel conducting wires carrying currents in the same direction attract each other. Why? **[2]**

OR

a. Obtain the conditions under which an electron does not suffer any deflection while passing through a magnetic field.

b. Two protons P and Q moving with the same speed pass through the magnetic fields $\vec{B}_1$ and $\vec{B}_2$ respectively, at right angles to the field directions. If

$\left|\overrightarrow{B}_2\right| > \left|\overrightarrow{B}_1\right|$, which of the two protons will describe the circular path of smaller radius? Explain.

Section C

22. a. Define resistivity of a conductor. Discuss its dependence on temperature of the conductor and draw a plot of resistivity of copper as a function of temperature. **[3]**

b. i. "A low voltage battery from which high current is required must have low internal resistance." Justify.

ii. "A high voltage battery must have a large internal resistance." Justify.

23. Ultra-violet light of wavelength 200 nm from a source is incident on a metal surface. If the stopping potential is -2.5 V, **[3]**

a. Calculate the work function of the metal, and

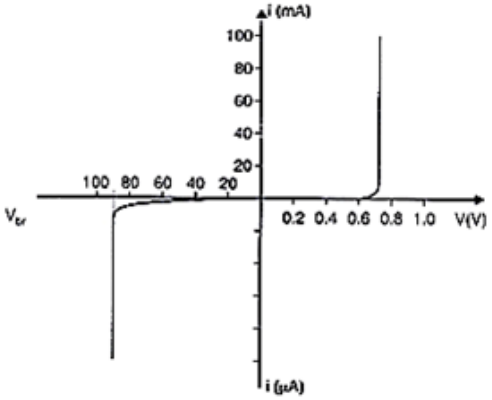
b. How would the surface respond to a high intensity red light of wavelength 6328 A produced by a laser?

24. The following figure shows the V-I characteristics of a semiconductor diode. **[3]**

i. Identify the semiconductor diode used.

ii. Draw the circuit diagram to obtain the given characteristics of this device.

iii. Briefly explain how this diode can be used as a voltage regulator.



25. a. Show the variation of binding energy per nucleon with mass number. Write the significance of the binding energy curve. **[3]**

b. Two nuclei with lower binding energy per nucleon form a nuclei with more binding energy per nucleon.

i. What type of nuclear reaction is it?

ii. Whether the total mass of nuclei increases, decreases or remains unchanged?

iii. Does the process require energy or produce energy?

26. Show that the electron revolving around the nucleus in an orbit of radius r with speed v has magnetic moment $\frac{evr}{2}$. Hence Using Bohr's postulate of angular momentum, obtain the expression for the magnetic moment of hydrogen atom in its ground state. **[3]**

27. a. A toroidal solenoid with an air core has an average radius of 0.15 m, area of cross section $12 \times 10^{-4} m^2$ and 1200 turns. Obtain the self inductance of the toroid. Ignore field variation across the cross section of the toroid. **[3]**

b. A second coil of 300 turns is wound closely on the toroid above. If the current in the primary coil is increased from zero to 2.0 A in 0.05 s, obtain the induced emf in the secondary coil.

OR

Define the term self-inductance of a solenoid. Obtain the expression for the magnetic energy stored in an inductor of self-inductance L to build up a current I through it.

28. In a diffraction pattern due to a single slit, how will the angular width of central maximum change, if **[3]**

a. Orange light is used in place of green light,

b. the screen is moved closer to the slit,

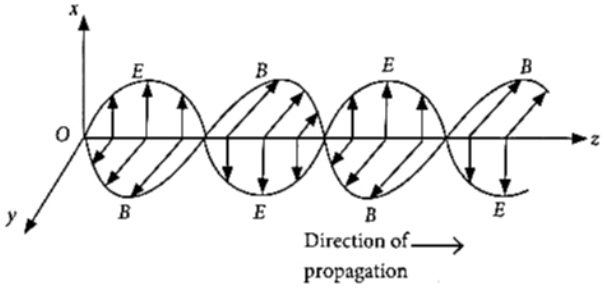
c. the slit width is decreased?

Justify your answer in each case.

Section D

29. **Read the text carefully and answer the questions:** **[4]**

A stationary charge produces only an electrostatic field while a charge in uniform motion produces a magnetic field, that does not change with time. An oscillating charge is an example of accelerating charge. It produces an oscillating magnetic field, which in turn produces an oscillating electric fields and so on. The oscillating electric and magnetic fields regenerate each other as a wave which propagates through space.



(a) Magnetic field in a plane electromagnetic wave is given by $\vec{B}$ = B_0 sin(kx + ωt)$\hat{j}$ T

Expression for corresponding electric field will be (Where c is speed of light.)

a) $\vec{E}$ = -B_0c sin (kx - ωt) $\hat{k}$ V/m

b) $\vec{E} = \frac{B_0}{c}$ sin (kx + ωt) $\hat{k}$ V/m

c) $\vec{E}$ = -B_0c sin (kx + ωt) $\hat{k}$ V/m

d) $\vec{E}$ = B_0c sin (kx + ωt) $\hat{k}$ V/m

(b) The electric field component of a monochromatic radiation is given by $\vec{E}$ = $2E_0\hat{i}$ cos kz cos ωt. Its magnetic field $\vec{B}$ is then given by

a) $\frac{2E_0}{c}$ $\hat{j}$ sin kz sin ωt

b) $\frac{2E_0}{c}$ $\hat{j}$ cos kz cos ωt

c) $-\frac{2E_0}{c}$ $\hat{j}$ sin kz sin ωt

d) $\frac{2E_0}{c}$ $\hat{j}$ sin kz cos ωt

(c) A plane em wave of frequency 25 MHz travels in a free space along x-direction. At a particular point in space and time, E = (6.3 $\hat{j}$) V/m. What is magnetic field at that time?

a) 0.095 μT

b) 0.124 μT

c) 0.021 μT

d) 0.089 μT

(d) A plane electromagnetic wave travelling along the x-direction has a wavelength of 3 mm. The variation in the electric field occurs in the y-direction with an amplitude 66 V m^{-1}. The equations for the electric and magnetic fields as a function of x and t are respectively

a) $E_y = 11 \cos 2\pi \times 10^{11} \left(t - \frac{x}{c}\right)$, $B_y = 11 \times 10^{-7} \cos 2\pi \times 10^{11} \left(t - \frac{x}{c}\right)$

b) $E_x = 33 \cos \pi \times 10^{11} \left(t - \frac{x}{c}\right)$, $B_x = 11 \times 10^{-7} \cos \pi \times 10^{11} \left(t - \frac{x}{c}\right)$

c) $E_y = 33 \cos \pi \times 10^{11} \left(t - \frac{x}{c}\right)$, $B_z = 1.1 \times 10^{-7} \cos \pi \times 10^{11} \left(t - \frac{x}{c}\right)$

d) $E_y = 66 \cos 2\pi \times 10^{11} \left(t - \frac{x}{c}\right)$, $B_z = 2.2 \times 10^{-7} \cos 2\pi \times 10^{11} \left(t - \frac{x}{c}\right)$

30. Dipoles, whether electric or magnetic, are characterised by their dipole moments, which are vector quantities. Two equal and opposite charges separated by a small distance constitute an electric dipole, while a current carrying loop behaves as a magnetic dipole. Electric dipoles create electric fields around them. Electric dipoles experience a torque when placed in an external electric field. (4 × 1 = 4) **[4]**

i. Two identical electric dipoles, each consisting of charges -q and +q separated by distance d, are arranged in $x - y$ plane such that their negative charges lie at the origin O and positive charges lie at points $(d, 0)$ and $(0,\ d)$ respectively. The net dipole moment of the system is:

(A) $-qd(\hat{i} + \hat{j})$

(B) $qd(\hat{i} + \hat{j})$

(C) $\mathrm{qd}(\hat{i} - \hat{j})$

(D) $\mathrm{qd}(\hat{j} - \hat{i})$

ii. E_1 and E_2 are magnitudes of electric field due to a dipole, consisting of charges -q and +q separated by distance 2a, at points $r(\gg a)$ (1) on its axis, and (2) on equatorial plane, respectively. Then $\left(\frac{E_1}{E_2}\right)$ is:

(A) $\frac{1}{4}$

(B) $\frac{1}{2}$

(C) 2

(D) 4

iii. An electric dipole of dipole moment $5.0 \times 10^{-8} Cm$ is placed in a region where an electric field of magnitude $1.0 \times 10^{3}\ N/C$ acts at a given instant. At that instant the electric field $\vec{E}$ is inclined at an angle of 30° to dipole moment $\vec{P}$. The magnitude of torque acting on the dipole, at that instant is:

(A) $2.5 \times 10^{-5} Nm$

(B) $5.0 \times 10^{-5} Nm$

(C) $1.0 \times 10^{-4} Nm$

(D) $2.0 \times 10^{-6} Nm$

iv. a. An electron is revolving with speed v around the proton in a hydrogen atom, in a circular orbit of radius r. The magnitude of magnetic dipole moment of the electron is:

(A) 4 evr

(B) 2 evr

(C) $\frac{1}{2}evr$

(D) $\frac{1}{4}evr$

OR

b. A square loop of side 5.0 cm carries a current of 2.0 A. The magnitude of magnetic dipole moment associated with the loop is:

(A) $1.0 \times 10^{-3} Am^2$

(B) $5.0 \times 10^{-3} Am^2$

(C) $1.0 \times 10^{-2} Am^2$

(D) $5.0 \times 10^{-2} Am^2$

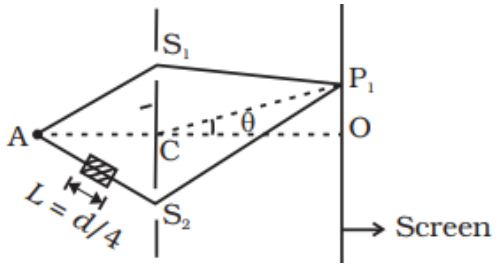
Section E

31. i. Draw a labelled ray diagram showing the image formation by a refracting telescope. Define its magnifying power. Write two limitations of a refracting telescope over a reflecting telescope. **[5]**

ii. The focal lengths of the objective and the eye-piece of a compound microscope are 1.0 cm and 2.5 cm respectively. Find the tube length of the microscope for obtaining a magnification of 300.

OR

A small transparent slab containing material of μ = 1.5 is placed along AS_2 (Figure). What will be the distance from O of the principal maxima and of the first minima on either side of the principal maxima obtained in the absence of the glass slab?



$AC = CO = D$, $S_1C = S_2C = d << D$

32. Calculate potential on the axis of a disc of radius R due to a charge Q uniformly distributed on its surface. **[5]**

OR

a. Describe briefly the process of transferring the charge between the two plates of a parallel plate capacitor when connected to a battery. Derive an expression for the energy stored in a capacitor.

b. A parallel plate capacitor is charged by a battery to a potential difference V. It is disconnected from the battery and then connected to another uncharged capacitor of the same capacitance. Calculate the ratio of the energy stored in the combination to the initial energy on the single capacitor.

33. i. Draw a labelled diagram of a step-up transformer and describe its working principle. Explain any three causes for energy losses in a real transformer. **[5]**

ii. A step-up transformer converts a low voltage into high voltage. Does it violate the principle of conservation of energy? Explain.

iii. A step-up transformer has 200 and 3000 turns in its primary and secondary coils respectively. The input voltage given to the primary coil is 90 V. Calculate:

1. The output voltage across the secondary coil
2. The current in the primary coil if the current in the secondary coil is 2.0 A.

OR

An emf $\varepsilon = 100 \sin 314\ t$ is applied across a pure capacitor of 637 μF. Find

i. the instantaneous current I

ii. instantaneous power P

iii. the frequency of power and

iv. the maximum energy stored in the capacitor.

Solution

Section A

1. **(a)** A is false and B is true
   Explanation:
   Statement A is false because, in forward bias, the width of the depletion layer in a P-N junction diode actually decreases, not increases. This is due to the applied voltage reducing the barrier for charge carriers to move across the junction. Statement B is true because, in an intrinsic semiconductor, the Fermi energy level is positioned exactly in the middle of the forbidden energy gap, indicating equal probabilities for electron and hole generation. Thus, the solution correctly identifies that A is false and B is true.

2. **(c)** 48 C
   Explanation:
   To find the quantity of charge that has passed through a cross-section of the wire, we need to calculate the integral of the current over the time interval from $t = 2$ s to $t = 6$ s. The current is given by the equation $i = 4 + 2t$.
   The charge Q can be calculated using the formula: $Q = \int_{t_1}^{t_2} i \, dt$
   Substituting the limits $t_1 = 2$ s and $t_2 = 6$ s, we have: $Q = \int_2^6 (4 + 2t) \, dt$
   Calculating the integral:
   i. The integral of 4 with respect to t is $4t$.
   ii. The integral of $2t$ with respect to t is t^2. Thus, the integral becomes: $Q = \left[4t + t^2\right]_2^6$
   Now, we evaluate this from $t = 2$ to $t = 6$:
   i. At $t = 6$: $4(6) + (6)^2 = 24 + 36 = 60$
   ii. At $t = 2$: $4(2) + (2)^2 = 8 + 4 = 12$
   Now, subtract the two results: $Q = 60 - 12 = 48\,\text{C}$
   Thus, the total charge that has passed through the wire during the specified time interval is 48 C.

3. **(d)** its wavelength decreases
   Explanation:
   The energy of the light is related to the frequency. When the light enters the medium, the apparent speed of light changes. If the frequency changed, the energy would not be conserved. The wavelength changes to balance the change in speed. When light enters from air to glass (from rarer to denser medium), its speed decreases as a consequence its wavelength also decreases.

4. **(a)** Sodium Chloride
   Explanation:
   Sodium Chloride

5. **(c)** the charge and the capacitance
   Explanation:
   Filling the space between the plates of a capacitor with a dielectric increases the capacitance because the dielectric material reduces the electric field between the plates. This allows the capacitor to store more charge for the same potential difference. Since the capacitor is

connected to a battery, the potential difference remains constant, leading to an increase in the charge stored.
Thus, the correct answer is that the charge and the capacitance increase.

6.

(b) negative z-axis
Explanation:
Negative Z- axis

7.

(d) 69 V
Explanation:
69 V

8.

(c) MB
Explanation:
$\tau = MBsin\theta$
$\tau_{max} = MBsin90^o = MB$

9.

(c) $\frac{R}{2}$
Explanation:
$\frac{R}{2}$

10.

(d) Zero
Explanation:
By the symmetry, electric field at center due to each elements will cancel out each other and hence net electric field at center will be zero.

11.

(c)



Explanation:
When the input level is -5 V, the diode gets reverse biased. No output is obtained across R_L.

When the input level becomes +5 V, the diode gets forward biased and the current flows through R_L. The diode is ideal, the output across R_L will be exactly 5V.

12.

(c) 125
Explanation:
125

13.

(d) A is false but R is true.
Explanation:

A is false but R is true.

14.

(c) Assertion is correct statement but reason is wrong statement.
Explanation:
Assertion is correct statement but reason is wrong statement.

15. **(a)** Both A and R are true and R is the correct explanation of A.
Explanation:
As given in the expression $\beta = \frac{D\lambda}{d}$, fringe width β is independent of n (position of fringe), hence all the fringes are of same width.

16. **(a)** Assertion and reason both are correct statements and reason is correct explanation for assertion.
Explanation:
Assertion and reason both are correct statements and reason is correct explanation for assertion.

Section B

17. Let the separation between the plates of capacitor immersed in sea water plates is d and applied voltage across the plates is V(t) = V_0 sin ($2\pi\nu$t)

Now using Ohm's law, the conduction current density $J^c = \frac{E}{\rho} = \frac{1}{\rho}\frac{V_0}{d}$ sin ($2\pi\nu$t)

$\Rightarrow J^c = \frac{V_0}{\rho d}$ sin ($2\pi\nu$t) = J_0^c sin ($2\pi\nu$t)

Hence, $J_0^c = \frac{V_0}{\rho d}$

The displacement current density is given as

$J^d = \varepsilon\frac{dE}{dt} = \varepsilon\frac{d}{dt}\left[\frac{V_0}{d}\sin(2\pi\nu t)\right]$

$= \frac{\varepsilon 2\pi\upsilon V_0}{d}\cos(2\pi\nu t)$

$\Rightarrow J^d = J_0^d\cos(2\pi\nu t)$

where, $J_0^d = \frac{2\pi\nu\varepsilon V_0}{d}$

$\Rightarrow \quad \frac{J_0^d}{J_0^c} = \frac{\frac{2\pi\nu\varepsilon V_0}{d}}{\frac{V_0}{\rho d}} = 2\pi\nu\varepsilon\rho$

$= 2\pi \times 80\varepsilon_0\nu \times 0.25 \ = 4\pi\varepsilon_0\nu \times 10$

$\Rightarrow \frac{J_0^d}{J_0^c} = \frac{10\times 4\times 10^8}{9\times 10^9} = \frac{4}{9}$,this is required result.

18. For a p-n junction diode, the dynamic resistance is given by:
r = $\frac{\Delta V}{\Delta I}$
Given that:
ΔV = 0.71 - 0.70 = 0.01 V = 10^{-2} V
ΔI = 10^{-3} × 10A = 10^{-2} A
$\therefore$ r = $\frac{10^{-2}}{10^{-2}}$ = 1Ω

19. i. Given, wavelength of the photon, $\lambda = 275nm$
Energy of photon is given by,
$E = h\nu$
$E = \frac{hc}{\lambda}$
$E = \frac{1242 \text{ eV}}{\lambda(\text{in nm})} = 4.5\text{eV}$

From fig. this transition corresponds to B since for transition B.
E = 0 - (- 4.5eV) = 4.5eV

ii. Energy of Photon Emitted, E = hc/$\lambda \propto 1/\lambda$
For minimum wavelength of emission, the energy is maximum.
Transition D, for which the energy emission is maximum, corresponds to the emission of radiation of minimum wavelength.

20. Time period of original magnet = $T_1 = 2\pi\sqrt{\frac{I_1}{M_1 B}}$

Time period of combination magnet = T_2

$= 2\pi\sqrt{\frac{I_2}{M_2 B}}$

$I_1 = \frac{ml^2}{12}$

$I_2 = \frac{1}{12} \times \frac{m}{3} \times \left(\frac{l}{3}\right)^2 \times 3 = \frac{I_1}{9}$

$M_2 = \frac{M_1}{3} \times 3 = M_1$

Putting in equation

$\frac{T_2}{T_1} = \sqrt{\frac{I_2}{I_1}} = 1:3$

OR

Here W = 3.2×10^4 J, v = 50 cycle s^{-1}, t = 30 min = 1800 s

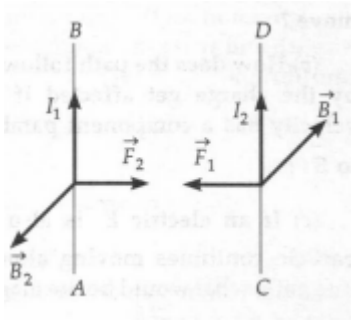
Volume, V = $\frac{\text{Mass}}{\text{Density}} = \frac{8.4}{7200}$ = kg m^{-3}

Energy dissipated per unit volume per cycle,

Q = $\frac{W}{V \times v \times t} = \frac{3.2 \times 10^4 \times 7200}{8.4 \times 50 \times 1800}$

= 304.8 Jm^{-3} $cycle^{-1}$

21. Each current-carrying conductor produces a magnetic field around it. So each conductor experiences a force due to the magnetic field of the other. According to Fleming's left hand rule, the direction of the force is perpendicular to the two wires and is inwards. Hence the two wires attract each other, as shown in Fig.



OR

a. No deflection if electron moves parallel or anti parallel to the magnetic field

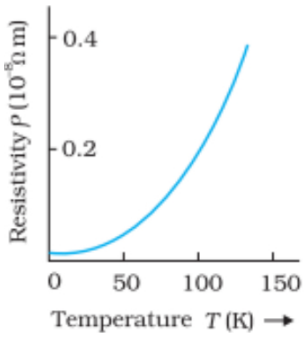
b. The radius of circular path $r = \frac{mv}{Bq}$

$\frac{r_1}{r_2} = \frac{B_2}{B_1}$

As $B_1 < B_2$ $r_2 < r_1$

Section C

22. a. Resistivity is the resistance of a material of unit length having unit area of cross-section.
On increasing the temperature of a conductor, the resistivity increases.



b. i. A low internal resistance allows large current to be drawn even at a low voltage.
ii. To limit the current.

23. a. λ = 200 nm, stopping potential = -2.5 V

K.E. = $2.5 \times 1.6 \times 10^{-19}$ J = 4×10^{-19} J

$E = hv = h\frac{c}{\lambda}$

$= \frac{6.63\times10^{-34}\times3\times10^{8}}{200\times10^{-9}}$

$= 9.945 \times 10^{-19}$ J

Work function = E - eV

$= (9.945 \times 10^{-19} - 4 \times 10^{-19})$J

$= 5.595 \times 10^{-19}$ J

b. Wavelength of red light = 6328 $\overset{\circ}{A}$

$E = hv = h\frac{c}{\lambda}$

$= \frac{6.63\times10^{-34}\times3\times10^{8}}{6328\times10^{-10}}$

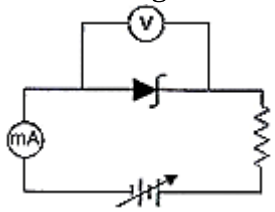
$= 0.00314 \times 10^{-16}$ J

$= 3.14 \times 10^{-19}$ J

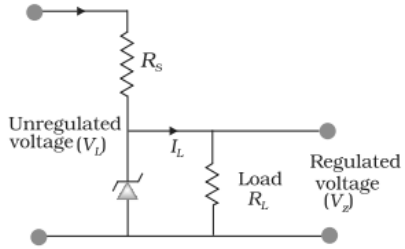
Energy of red light < work function of metal surface

$\therefore$ No emission of photoelectrons takes place.

24. i. The semiconductor diode whose V-I characteristic is shown in figure is Zener diode.
ii. Circuit diagram to obtain the given characteristic is shown in figure.



iii. The circuit of Zener diode used as voltage regulator is shown in figure.

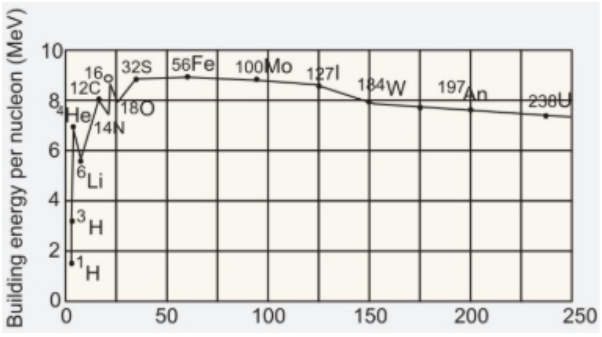


The unregulated dc voltage (filtered output of a rectifier) is connected to the Zener diode through a series resistance R_S such that the Zener diode is reverse biased.

If the input voltage increases, the current through R_S and Zener diode also increases. This increases the voltage drop across R_S without any change in the voltage across the Zener diode. This is because in the breakdown region, Zener voltage remains constant even though the current through the Zener diode changes. Similarly, if the input voltage decreases, the

current through R_s and Zener diode also decreases. The voltage drop across R_s decreases without any change in the voltage across the Zener diode. Thus any increase/decrease in the input voltage results in, increase/decrease of the voltage drop across R_s without any change in voltage across the Zener diode. Thus the Zener diode acts as a voltage regulator.

25. a.



Significance of the binding energy curve-

- Why lighter nuclei undergo fusion and heavier nuclei undergo fission.
- Nuclear forces are short ranged.
- Energy is released in both nuclear fission and nuclear fusion.

b. i. Nuclear fusion
ii. Decreases
iii. Energy is produced

26. Magnetic momentum,

$\mu = -\left(\frac{e}{2m}\right) L$

where (-) indicates μ direction is opposite to L.

As Bohr's atomic model

L = mvr

$\therefore \mu = -\left(\frac{e}{2m}\right) \times mvr$

$\mu = \frac{evr}{2}$

Energy levels of hydrogen atom

$E_n = -\frac{2\pi^2 m\, K^2 e^4}{n^2 h^2}$

For lowest energy level, n = 1

$E_1 = -\frac{2\pi^2 mK^2 e^4}{n^2 h^2}$

$E_1 = -\frac{2\pi^2 mK^2 e^4}{h^2}$

$E_1 = -\left(\frac{4\pi^2 m\, Ke^2}{h^2}\right) \frac{Ke^2}{2}$

while $r = -\frac{h^2}{4\pi^2 Kme^2}$

$E_n = -\frac{Ke^2}{2r} = \frac{-13.6}{n^2} e\ V$

$\because \mu = \frac{evr}{2}$

$E_1 = -\frac{Kev.er}{2vr^2}$ = -13.6

$\frac{K\mu}{vr^2}$ = -13.6

$\mu = 13.6\left(\frac{vr^2}{Ke}\right)$

27. a. $B = \mu_0 n_1 I = \frac{\mu_0 N_1 I}{l} = \frac{\mu_0 N_1 I}{2\pi r}$

Total magnetic flux, $\phi_B = N_1 BA = \frac{\mu_0 N_1^2 IA}{2\pi r}$

But $\phi_B = LI$

$\therefore L = \frac{\mu_0 N_1^2 A}{2\pi r}$

Or $L = \frac{4\pi \times 10^{-7} \times 1200 \times 1200 \times 12 \times 10^{-4}}{2\pi \times 0.15}$

$= 2.3 \times 10^{-3} H$ = 2.3 mH

b. $|E| = \frac{d}{dt}(\phi_2)$ where ϕ_2 is the total magnetic flux linked with the second coil.

$|E| = \frac{d}{dt}(N_2 BA) = \frac{d}{dt}\left[N_2 \frac{\mu_0 N_1 I}{2\pi r} A\right]$

$|E| = \frac{\mu_0 N_1 N_2 A}{2\pi r} \frac{dI}{dt}$

$|E| = \frac{4\pi \times 10^{-7} \times 1200 \times 300 \times 12 \times 10^{-4} \times 2}{2\pi \times 0.15 \times 0.05}$ = 0.023 V

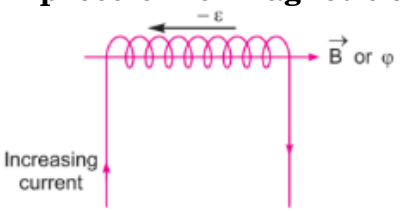
OR

Using formula, $|-\varepsilon| = L\frac{dI}{dt}$

If $\frac{dI}{dt} = 1$ A/s, then L = $|-\varepsilon|$

Self inductance of the coil is equal to the magnitude of induced emf produced in the coil itself when the current varies at rate 1 A/s.

Expression for magnetic energy:



When a time varying current flows through the coil, back emf $(-\varepsilon)$ produces, which opposes the growth of the current flow. It means some work needs to be done against induced emf in establishing a current I. This work done will be stored as magnetic potential energy.

For the current I at any instant, the rate of work done is

$\frac{dW}{dt} = (-\varepsilon)I$

Only for inductive effect of the coil $|-\varepsilon| = L\frac{dI}{dt}$

$\therefore \quad \frac{dW}{dt} = L\left(\frac{dI}{dt}\right) I \quad \Rightarrow dW = LIdI$

From work-energy theorem,

dU = LIdI

$\therefore U = \int_0^I LIdI = \frac{1}{2}LI^2$

28. angular width of central maxima of a single slit diffraction is given as $2\theta = \frac{2\lambda}{a}$

a. As λ increases (orange light has greater wave length) diffraction angle 2θ will also increase.

b. Increasing or decreasing closeness of screen and slit does not affect angular width.

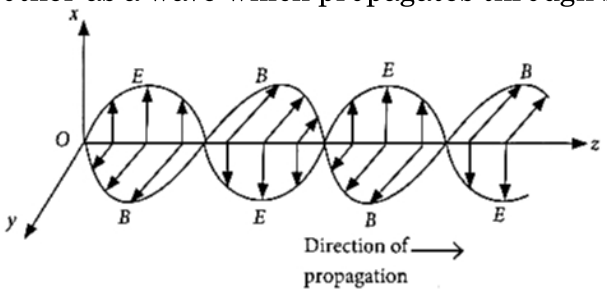
c. If a (slit width) decreases, 2θ will increase as $2\theta \propto \frac{1}{a}$

Section D

29. **Read the text carefully and answer the questions:**

A stationary charge produces only an electrostatic field while a charge in uniform motion produces a magnetic field, that does not change with time. An oscillating charge is an example of accelerating charge. It produces an oscillating magnetic field, which in turn produces an oscillating electric fields and so on. The oscillating electric and magnetic fields regenerate each

other as a wave which propagates through space.



(a) **(d)** $\vec{E}$ = B_0c sin (kx + ωt) $\hat{k}$ V/m

Explanation:

Given : $\vec{B}$ = B_0 sin (kx + ωt)$\hat{j}$T

The relation between electric and magnetic field is, c = $\frac{E}{B}$ or E = cB

The electric field component is perpendicular to the direction of propagation and the direction of magnetic field. Therefore, the electric field component along z-axis is obtained as $\vec{E}$ = cB_0 sin (kx + ωt) $\hat{k}$ V/m

(b) **(a)** $\frac{2E_0}{c}$ $\hat{j}$ sin kz sin ωt

Explanation:

$\frac{dE}{dz} = -\frac{dB}{dt}$

$\frac{dE}{dz}$ = -2 E_0k sin kz cos ωt = $-\frac{dB}{dt}$

dB = +2 E_0k sin kz cos ωt dt

B = +2 E_0k sin kz $\int$ cos ωt dt = +2 E_0 $\frac{k}{\omega}$ sin kz sin ωt

$\frac{E_0}{B_0} = \frac{\omega}{k} = c$

B = $\frac{2E_0}{c}$ sin kz sin ωt $\therefore$ $\vec{B}$ = $\frac{2E_0}{c}$ sin kz sin ωt $\hat{j}$

E is along y-direction and the wave propagates along x-axis.

$\therefore$ B should be in a direction perpendicular to both x-and y-axis.

(c) **(c)** 0.021 μT

Explanation:

Here, E = 6.3 $\hat{j}$; c = 3×10^8 m/s

The magnitude of B is

$B_z = \frac{E}{c} = \frac{6.3}{3\times10^8} = 2.1 \times 10^{-8}$ T = 0.021 μ T

(d) **(d)** $E_y = 66 \cos 2\pi \times 10^{11} \left(t - \frac{x}{c}\right)$, $B_z = 2.2 \times 10^{-7} \cos 2\pi \times 10^{11} \left(t - \frac{x}{c}\right)$

Explanation:

Here : E_0 = 66 V m^{-1}, E_y = 66 cos $\omega\left(t - \frac{x}{c}\right)$,

λ = 3 mm = 3×10^{-3} m, k = $\frac{2\pi}{\lambda}$

$\frac{\omega}{k}$ = c $\Rightarrow$ ω = ck = $3 \times 10^8 \times \frac{2\pi}{3\times10^{-3}}$

or $\omega = 2\pi \times 10^{11}$

$\therefore$ E_y = 66 cos $2\pi \times 10^{11}\left(t - \frac{x}{c}\right)$

$B_z = \frac{E_y}{c} = \left(\frac{66}{3\times10^8}\right) \cos 2\pi \times 10^{11} \left(t - \frac{x}{c}\right)$

= $2.2 \times 10^{-7} \cos 2\pi \times 10^{11}\left(t - \frac{x}{c}\right)$

30. i. (B) $qd(\hat{i} + \hat{j})$

ii. (C) 2

iii. (A) $2.5 \times 10^{-5} Nm$

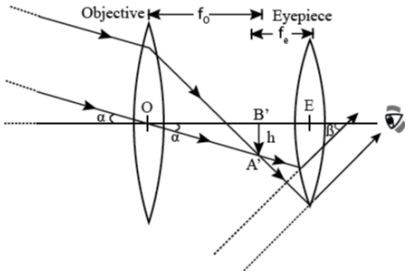
iv. (C) $\frac{1}{2}evr$

OR

v. (B) $5.0 \times 10^{-3} Am^2$

Section E

31. i.



Magnifying power of a telescope – It is defined as the ratio the angle subtended at the eye by the final image to the angle subtended by the object at the lens.

The two limitations of a refracting telescope over a reflecting telescope are following

Less resolving power and

Difficult mechanical support.

ii. f_o = 1.0 cm, f_e = 2.5 cm, m = 300, D = 25 cm, L = ?

$|m| = \frac{L}{f_0} \cdot \frac{D}{f_e}$

$300 = \frac{L}{1.0} \cdot \frac{25}{2.5}$

L = 30 cm

hence the required tube length of the microscope = 30 cm

OR

As is clear from figure and difference between waves reaching P_1 from A is

$= 2d \sin\theta + (u-1)l$

For principal maximum, path difference = 0

i.e., $2d \sin\theta + (\mu - 1)l = 0$

$2d = \sin\theta + (1.5-1)\frac{d}{4} = 0, \sin\theta = \frac{-1}{16}$

$\therefore OP_1 = (CO)\tan\theta \cong D\left(-\frac{1}{16}\right)$

For the first minimum, an angle θ_1, say,

path difference $= 2d \sin\theta_1 + 0.5l = \pm\lambda/2$

$\sin\theta_1 = \frac{\pm\lambda/2 - 0.5l}{2d}$

As diffraction occurs when d = λ,

$\therefore \sin\theta_1 = \frac{\pm\lambda/2 - \lambda/8}{2\lambda} = \pm\frac{1}{4} - \frac{1}{16}$

on the positive side, $\sin\theta_1 = +\frac{1}{4} - \frac{1}{16} = \frac{3}{16}$, on the negative side,

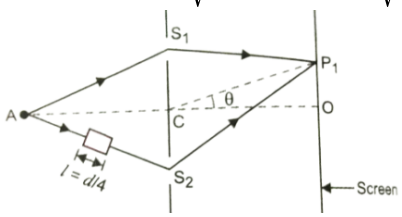
$\sin\theta_1' = -\frac{1}{4} - \frac{1}{16} = \frac{-5}{16}$

The first principal maximum on the positive side is at distance (above O)

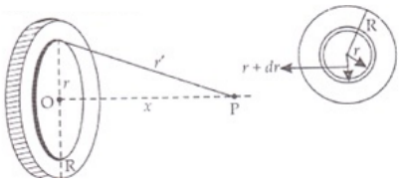
= D than $\theta_1 = D\frac{\sin\theta_1}{\sqrt{1-\sin^2\theta_1}} = \frac{D.3/16}{\sqrt{1}-9/256} = \frac{3D}{\sqrt{16^2-3^2}}$

On the negative side, the distance of first principal maximum (below O) will be

$= D\theta_1' = D\frac{\sin\theta_1'}{\sqrt{1-\sin^2\theta_1}} = \frac{D(-5/16)}{\sqrt{1-(5/16)^2}} = \frac{-5D}{\sqrt{16^2-5^2}}$



32. Consider a point P on the axis perpendicular to the plane of disc and at distance x from the center O of the disc as shown in the figure.



Now consider a ring of radius r of thickness dr on a disc of radius R, as shown in the figure, Let us consider disc is divided into a large number of rings, Again let the charge on the ring is dq then potential dV due to ring at P, will be

$dV = \frac{kdq}{r'}\left[\because r' = \sqrt{r^2 + x^2}\right]$

dq is the charge on the ring = σ area of ring

$= \sigma \cdot \left[\pi(r + dr)^2 - \pi r^2\right]$

$dq = \sigma \cdot \pi\left[r^2 + dr^2 + 2rdr - r^2\right]$

Because dr is small, therefore, dr_2 is negligible.

$\therefore$ dq $= \sigma\pi(2rdr) = 2\pi r\sigma \cdot dr$

$\therefore$ dV $= \frac{k.2\pi r\sigma dr}{\sqrt{(r^2+x^2)}}$

So the potential due to charged disc

$\int_0^V dV = \int_0^R \frac{k.2\pi\sigma dr}{\sqrt{r^2+x^2}}$

$V = k.2\pi\sigma \cdot \int_0^R \frac{rdr}{(r^2+x^2)^{12}} = k.\,\pi\sigma \int_0^R r \cdot \left(r^2 + x^2\right)^{-1/2} 2dr = \frac{k\pi\sigma[\sqrt{r^2+x^2}]_0^R}{1/2}$

$= 2\pi k\sigma\left[\left(R^2 + x^2\right)^{1/2} - x\right] = \frac{2\pi\sigma}{4\pi\varepsilon_0}\left[\left(R^2 + x^2\right)^{1/2} - x\right]$

[$\because$ $\pi R^2\sigma$ = Q(charge on disc) $\sigma = \frac{Q}{\pi R^2}$

$= \frac{\pi 2R^2\sigma}{4\pi\varepsilon_0 R^2}[\sqrt{R^2 + x^2} - x]$ thus the potential due to a disc is given by,

$V = \frac{2Q}{4\pi\varepsilon_0 R^2}[\sqrt{R^2 + x^2} - x]$

OR

a. Consider a parallel plate capacitor which is connected across a battery. The electrons are transferred from the negative terminal of the battery to the metallic plate connected to the negative terminal and acquires a negative charge. Similarly, the electrons move from the second plate to the positive terminal of the battery and acquire a positive charge. This process continues until the potential difference between the two plates becomes equal to the potential difference between the terminals of the battery. Thus, the charge is developed on the capacitor.

Let 'dW' be the work done by the battery in increasing the charge on the capacitor is given by, having the charge q and potential V is:

dW = V dq

where V = $\frac{q}{C}$

$\therefore$ dW = $\frac{q}{C}$dq

Total work done in charging up the capacitor is given by,

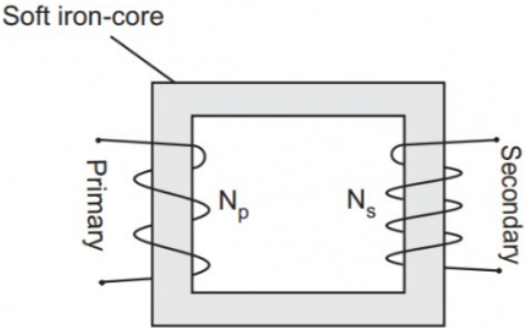
W = $\int$ dW = $\int_0^Q \frac{q}{c}$dq

$\therefore$ W = $\frac{Q^2}{2C}$

Hence total energy stored in the plates of the capacitor is given by, W = $\frac{Q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$

b. Charge on the plates of the capacitor is given by q = CV
When uncharged capacitor of same capacitance is connected to the charged capacitor, sharing of charges takes place between the two capacitors till both the capacitors acquire same potential $\frac{V}{2}$
Energy stored in the combination of capacitors is given by,
$U_2 = \frac{1}{2}C(\frac{V}{2})^2 + \frac{1}{2}C(\frac{V}{2})^2 = \frac{CV^2}{4}$
Energy stored by a single capacitor before connecting is given by, $U_1 = \frac{1}{2}CV^2$
Ratio of energy stored in the combination to that in the single capacitor is given by,
$\frac{U_2}{U_1} = \frac{CV^2/4}{CV^2/2} = 1:2$, Hence these are required results.

33. i.



The working principle of transformer is mutual induction.
When an alternating voltage is applied to the primary, the resulting current produces an alternating magnetic flux which links the secondary and induces an emf in it.
Causes of energy losses

a. **Copper Losses (I^2R Losses):**
Explanation: These losses occur due to the resistance of the wire in the coils. When current flows through the wire, some energy is dissipated as heat due to the resistance.
Mitigation: Using thicker wires with lower resistance and cooling mechanisms can help reduce these losses.

b. **Core Losses (Iron Losses):**
Explanation: Core losses include hysteresis loss and eddy current loss. Hysteresis loss occurs due to the lagging of magnetic domains behind the changing magnetic field. Eddy current loss is caused by circulating currents induced within the core material due to the changing magnetic field.
Mitigation: Using laminated silicon steel cores reduces eddy currents, and using materials with low hysteresis loss minimizes core losses.

c. **Leakage Flux:**
Explanation: Not all magnetic flux produced by the primary coil links with the secondary coil. Some flux "leaks" and does not contribute to energy transfer between coils, leading to inefficiency.
Mitigation: Improving core design and using better core materials can help reduce leakage flux.

ii. A step-up transformer does not violate the conservation of energy. It increases voltage by decreasing current proportionally. The power input (low voltage, high current) equals the power output (high voltage, low current), ensuring energy conservation. The transformer merely transfers energy, with losses typically due to inefficiencies.

iii. 1. $\frac{V_s}{V_P} = \frac{N_s}{N_P}$
$V_s = \frac{N_s}{N_P} \times V_P = \frac{3000}{200} \times 90$
$V_s = 1350$ V

2. $\frac{I_P}{I_s} = \frac{N_s}{N_P}$

$I_P = \frac{3000}{200} \times 2 = 30$ A

OR

i. Given ε = 100 sin 314 t volt

As the current in a capacitor leads the voltage by 90°, so the instantaneous current is given by

I = $I_0 \sin(314t + 90^\circ) = I_0 \cos 314t$

where $I_0 = \frac{\varepsilon_0}{X_C} = \frac{\varepsilon_0}{1/\omega C} = \varepsilon_0 \omega C$

But ε_0 = 100 V, $\omega = 314$ rads^{-1}, C = 637×10^{-6} F

$\therefore I_0 = 100 \times 314 \times 637 \times 10^{-6} = 20$ A

Where $I_0 = \frac{\varepsilon_0}{X_C} = \frac{\varepsilon_0}{1/\omega C} = \varepsilon_0 \omega C$

But ε_0 = 100 V, $\omega = 314$ rad s^{-1}, $C = 637 \times 10^{-6}$ F

$\therefore I_0 = 100 \times 314 \times 637 \times 10^{-6} = 20$ A

Hence I = 20 cos 314 t ampere

ii. Instantaneous power,

P = $\varepsilon I = 100 \sin 314t \times 20 \cos 314t$

= 1000 sin 628 t watt

iii. Angular frequency of power, $\omega_p = 628$ rads^{-1}

$\therefore$ Frequency of power, $f_p = \frac{\omega_p}{2\pi} = \frac{628}{2\pi} = 100$ Hz

iv. The maximum energy stored in the capacitor is

$U_0 = \frac{1}{2} C E_0^2 = \frac{1}{2} \times 637 \times 10^{-6} \times (100)^2$ = 3.185 J