SAMPLE CONTENT

Precise

PHYSICS

Vol. I

BASED ON NEW PAPER PATTERN

Std. XII Science

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Precise

PHYSICS (Vol. I)

Std. XII Sci.

Salient Features

- Written as per Latest Board Paper Pattern
- Subtopic-wise segregation for powerful concept building
- Complete coverage of Textual Exercise Questions, Intext Questions and Numericals
- Includes selective Board questions from March 2013 to February 2020
- Includes selective questions from NCERT textbook for practice
- Marks provided to the Questions as per relevant weightage as deemed necessary
- 'Solved Examples' provided to cover numerical aspect of the topic in detail.
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- 'Important Formulae' offers compilation of formulae covered in a chapter
- 'Reading Between the Lines' to elucidate concept
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- QR Code to access Reduced Syllabus as issued by the Board
- Includes Board Question Paper of March 2022 (with solution through QR code)

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PREFACE

Precise Physics Vol. I, Std. XII Sci. is intended for every Maharashtra State Board aspirant of Std. XII, Science. The scope, sequence, and level of the book are designed to match the new textbook of Maharashtra State board.

We believe that the study of Physics needs driving desire to learn and willingness to work hard. The earnestness to dive into the subject eventuates naturally when students are presented with meaningful content that is easy to read and understand rather than being mired down with facts and information. Students do much better when they grasp the nub of the subject.

While beginning with a chapter in Physics, students should study to understand the content and not merely read point blankly. They can go slowly, knowing Physics can't be read like a novel, choosing their own pace. But it is essential for students to comprehend the concepts involved, ruminate and reproduce their own versions of the same.

To quote Albert Einstein, **"If you can't explain it simply, you don't understand it yourself."**

Students should then attempt theoretical questions based on these concepts to gauge the level of understanding achieved.

Next advance after gaining command over theory would be numericals. Though Physics is communicated in English, it is expressed in Mathematics. Hence, it is essential to befriend formulae and derivations. These should be learnt and memorized. Once physical mathematics of concept is ingrained, solved numericals should be studied, starting from simple problems to difficult by escalating level of complexity gradually. Students are required to practise numericals and ascertain their command on problem solving. Calculations at this stage must be done using log table keeping in mind that calculators are not allowed in Board Exams. **When it comes to problems in Physics nothing makes students perfect like practice!**

Amongst building concepts, advancing into numbers and equations, it is essential to ponder underlying implications of subject. Students should read from references, visit authentic websites and watch relevant fascinating links.

Such a holistic preparation of subject is the key to succeed in the board examination.

After all, **"Success is no accident. It is hard work, perseverance, learning, studying, sacrifice and most of all, love of what you are doing or learning to do,"** as said by legendary football player Pele and students should bear it in mind!

Our **Precise Physics Vol. I, Std. XII Sci.** adheres to our vision and achieves several goals: **building concepts**, **developing competence to solve numericals, recapitulation and self-study** —all while encouraging students toward cognitive thinking.

Features of the book presented below will explicate more about the same!

We hope the book benefits the learner as we have envisioned.

\- Publisher

Edition: Fourth

The journey to create a complete book is strewn with triumphs, failures and near misses. If you think we've nearly missed something or want to applaud us for our triumphs, we'd love to hear from you.
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Sample Content

KEY FEATURES

Reading between the lines

Reading between the lines provides elaboration or missing fragments of concept essential for complete understanding of the concept.

QR Codes

QR code provides:
i. Access to a video/PDF in order to boost understanding of a concept or activity
ii. Access to reduced syllabus as issued by the Board.
iii. Solution to Board Question Paper of March 2022

Solved Examples

Solved Examples offer complete solution to numerical including log (as seemed required).

Important Formulae

Important Formulae includes all of the key formulae in the chapter.

Quick Review

Quick review includes tables/ flow chart to summarize the key points in chapter.

Exercise

Exercise includes subtopic-wise additional questions and problems.

Multiple Choice Questions

Multiple Choice Question includes textual as well as additional MCQs.

Sample Content

PAPER PATTERN

- There will be single question paper of 70 Marks and practical examination of 30 Marks in Physics.
- Duration of the paper will be 3 hours.

Section A: **(18 Marks)**

This section will contain Multiple Choice Questions and Very Short Answer (VSA) type of questions.
There will be 10 MCQs and 8 VSA type of questions, each carrying one mark.
Students will have to attempt all these questions.

Section B: **(16 Marks)**

This section will contain 12 Short Answer (SA-I) type of questions, each carrying 2 marks.
Students will have to attempt any 8 questions.

Section C: **(24 Marks)**

This section will contain 12 Short Answer (SA-II) type of questions, each carrying 3 marks.
Students will have to attempt any 8 questions.

Section D: **(12 Marks)**

This section will contain 5 Long Answer (LA) type of questions, each carrying 4 marks.
Students will have to attempt any 3 questions.

Distribution of Marks According to the Type of Questions

Type of Questions		
MCQ	1 Mark each	10 Marks
VSA	1 Mark each	8 Marks
SA - I	2 Marks each	16 Marks
SA - II	3 Marks each	24 Marks
LA	4 Marks each	12 Marks

Percentage wise distribution of marks	
Theory	63%
Numerical	37%

Sample Content

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[Reference: Maharashtra State Board of Secondary and Higher Secondary Education, Pune - 04**]**

Note:
1. * mark represents Textual question.
2. # mark represents Intext question.
3. + mark represents Textual examples.
4. symbol represents textual questions that need external reference for an answer.
5. This Reference Book is based on the Entire Textbook (Complete Syllabus) of Physics Prescribed by Maharashtra State Board. R symbol represents the content that belongs to the Reduced Syllabus as issued by State Board.
6. Chapters 8 to 16 are a part of Std. XII: Precise Physics (Vol. II).

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3 Kinetic Theory of Gases and Radiation

Contents and Concepts

3.1 Introduction

Q.1. Using the gas laws, prove that PV = Nk_BT. Also state the significance of terms involved.

OR

Can you recall? *(Textbook page no. 56)*

How do you get ideal gas equation from the gas laws? **[3 Marks]**

Ans:

i. The three gas laws applied to a fixed mass m of an enclosed gas are,

a. Boyle's law: $V \propto \frac{1}{P}$ at constant T.

b. Charles' law: $V \propto T$ at constant P.

c. Gay-Lussac's law: $P \propto T$ at constant V.

ii. Combining the three laws,

$PV \propto T$ i.e., $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

iii. In terms of number of moles (n) of the gas,

$PV \propto nT$

$\therefore$ $PV = nRT$ ….(1)

Where, R = proportionality constant = Universal gas constant.

iv. But, number of moles (n)

$= \frac{\text{mass of the gas}(m)}{\text{molar mass}(M_0)} = \frac{N}{N_A}$ ….(2)

Where, N = number of molecules,

M_0 = mass of 1 mole of gas

N_A = Avogadro's number

v. The universal gas constant can also be expressed in terms of Boltzmann constant (k_B) as,

$R = N_Ak_B$ ….(3)

Substituting equations (2) and (3) in equation (1), we get,

$\therefore$ $PV = \frac{N}{N_A} \times N_Ak_BT = Nk_BT$

Q.2. Why does an ideal gas equation is known as equation of state? [1 Mark]

Ans: For a gas, its state is specified by a number of physical quantities such as pressure P, temperature T, volume V, internal energy E, etc. Hence, the equation relating these quantities i.e., ideal gas equation is known as the equation of state.

***Q.3. Write ideal gas equation for a mass of 7 g of nitrogen gas. [1 Mark]**

Ans: Ideal gas equation for 7 g of nitrogen gas is,

$PV = \frac{RT}{4}$.

Reading between the lines

Ideal gas equation, PV = nRT

Here, $n = \frac{m}{M_0}$

$m = 7$ g, $(M_0)_{N_2} = 28$ g/mol

$\therefore$ $n = \frac{7}{28} = \frac{1}{4}$

$\therefore$ $PV = \frac{1}{4} \times RT = \frac{RT}{4}$

Sample Content

Page no. **83** to **88** are purposely left blank.

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Sample Content

Also, $v_{rms} \propto \sqrt{T}$

$$\therefore \quad \left(\frac{v_2}{v_1}\right)_{rms} = \sqrt{\frac{T_2}{T_1}}$$

$$\therefore \quad (v_2)_{rms} = \sqrt{\frac{T_2}{T_1}} \times (v_1)_{rms}$$

$$= \sqrt{\frac{400}{273}} \times 1378$$

$$\therefore \quad (v_2)_{rms} = \mathbf{1668\ m/s}$$

Ans: The r.m.s velocity of the gas at 127 °C is **1668 m/s**.

3.7 Interpretation of Temperature in Kinetic Theory

Q.29. How is the kinetic energy of a gas molecule is related with the temperature? Derive the relation using kinetic theory of gases. [3 Marks]

Ans:

i. From kinetic theory of gases pressure of the gas is given as, $P = \frac{1}{3}\frac{N}{V}m\overline{v^2}$

$\therefore$ $PV = \frac{1}{3}\frac{N}{V}m\overline{v^2}$

$\therefore$ $PV = \frac{2}{3}N\left(\frac{1}{2}m\overline{v^2}\right)$ ….(1)

ii. The quantity $\frac{1}{2}m\overline{v^2}$ represents the average translational kinetic energy of an ideal gas molecule.

iii. Therefore, the total energy of the gas is,

$E = N\left(\frac{1}{2}m\overline{v^2}\right)$

iv. Substituting in equation (1),

$PV = \frac{2}{3}E$

v. From ideal gas equation,

$PV = Nk_BT = \frac{2}{3}E$ ….(2)

$\therefore$ $E = \frac{3}{2}Nk_BT$ ….(3)

vi. From equation (3), it can be concluded that the average energy per molecule is directly proportional to absolute temperature of the gas.

Reading between the lines

In an ideal gas, the molecules are noninteracting, and hence there is no potential energy term. Thus, the internal energy of an ideal gas is purely kinetic.

***Q.30. Explain, on the basis of kinetic theory, how the pressure of gas changes if its volume is reduced at constant temperature. [2 Marks]**

Ans:

i. Suppose, P = pressure exerted by the gas
V = volume of the gas
N = number of molecules of the gas
m = mass of each molecule of the gas

$\therefore$ Total mass of the gas, M = mN

ii. From kinetic theory of gases, $P = \frac{1}{3}\frac{mN}{V}\overline{v^2}$

$\therefore$ Pressure exerted by a gas in an enclosed vessel,

$P = \frac{2}{3}\frac{N}{V}\left(\frac{1}{2}m\overline{v^2}\right)$

iii. But, $\frac{1}{2}m\overline{v^2}$ = K.E = constant for all the gases at a given temperature.
N = number of molecules which is constant for a given mass of the gas.

$\therefore$ $P = \frac{\text{constant}}{V}$

$\therefore$ $P \propto \frac{1}{V}$

Hence, at constant temperature, pressure of the gas is increased if its volume is reduced.

Solved Examples

***Q.31. Find kinetic energy of 5000 cc of a gas at S.T.P. Given standard pressure is 1.013×10^5 N/m². [2 Marks]**

Solution:

Given: $V = 5000\ cc = 5 \times 10^{-3}\ m^3$
$P = 1.013 \times 10^5\ N/m^2$, $T = 273\ K$

To find: Kinetic energy of the gas (K.E.)

Formula: $K.E. = \frac{3}{2}PV$

Calculation: From formula,

$K.E. = \frac{3}{2} \times 1.013 \times 10^5 \times 5 \times 10^{-3}$

$= \mathbf{7.5975 \times 10^2\ J}$

Ans: The kinetic energy of the gas is **7.5975×10^2 J.**

***Q.32. Calculate the average molecular kinetic energy**
i. per kmol ii. per kg
iii. per molecule
of oxygen at 127 °C, given that molecular weight of oxygen is 32, R is 8.31 J mol^{-1} K^{-1} and Avogadro's number N_A is 6.02×10^{23} molecules mol^{-1}. [3 Marks]

Solution:

Given: T = 127 °C = 127 + 273 = 400 K
$M = 32\ g = 32 \times 10^{-3}\ kg$
$R = 8.31\ Jmol^{-1}\ K^{-1}$
$N_A = 6.02 \times 10^{23}$ molecules mol^{-1}

Sample Content

To find: i. KE / kmol
ii. KE / kg
iii. KE / molecule

Formulae: i. KE / kmol = $\frac{3}{2}$ RT × 10^3

ii. KE / kg = $\frac{3}{2}\frac{RT}{M_0} \times 10^3$

iii. KE / molecule = $\frac{3}{2}\frac{RT}{N_A}$

Calculation:
From formula (i),

KE / kmol = $\frac{3}{2} \times 8.31 \times 400 \times 10^3$

= $\mathbf{4.986 \times 10^6}$ **J**

From formula (ii),

KE / kg = $\frac{3}{2} \times \frac{8.31 \times 400}{32} \times 10^3$

= $\frac{3 \times 8.31}{2 \times 8} \times 10^5$

= $1.5 \times 1.039 \times 10^5$ = $\mathbf{1.558 \times 10^5}$ **J**

From formula (iii),

KE / molecule = $\frac{3}{2} \times \frac{8.31 \times 400}{6.02 \times 10^{23}}$

= $\frac{6 \times 8.31}{6.02} \times 10^{-21}$

= antilog {log (6) + log (8.31) − log (6.02)} × 10^{-21}

= antilog {(0.7782 + 0.9196 − 0.7796)} × 10^{-21}

= antilog {(0.9181)} × 10^{-21}

= $\mathbf{8.281 \times 10^{-21}}$ **J**

Ans: i. KE / kmol is $\mathbf{4.987 \times 10^6}$ **J.**
ii. KE / kg is $\mathbf{1.558 \times 10^5}$ **J.**
iii. KE / molecule is $\mathbf{8.281 \times 10^{-21}}$ **J.**

*[**Note:** The value of K.E./kg is calculated by converting all the quantities into same system of units.]*

+Q.33. At 300 K, what is the rms speed of Helium atom? [mass of He atom is 4u, 1u = 1.66×10^{-27} kg; $k_B = 1.38 \times 10^{-23}$ J/ K]
(Example 3.2 of Textbook page no. 61)
[3 Marks]

Solution:
Given: T = 300 K, m = 4 × 1.66 × 10^{-27} kg, $k_B = 1.38 \times 10^{-23}$ J /K.
To find: Root mean square velocity (v_{rms})
Formulae: i. K.E = $\frac{1}{2}m\overline{v^2}$

ii. K.E. = $\frac{3}{2}k_BT$

Calculation:
From formulae (i) and (ii),

$\frac{1}{2}m\overline{v^2} = \frac{3}{2}k_BT$

∴ $\overline{v^2} = \frac{3k_BT}{m}$

∴ $v_{rms} = \sqrt{\overline{v^2}}$

$= \sqrt{\frac{3\,k_BT}{m}}$

$= \sqrt{\frac{3 \times 1.38 \times 10^{-23} \times 300}{4 \times 1.66 \times 10^{-27}}}$

$= \sqrt{\frac{12.42 \times 10^6}{6.64}}$

$= \text{antilog}\left\{\frac{1}{2} \times \log(12.42) - \log(6.64)\right\} \times 10^3$

$= \text{antilog}\left\{\frac{1}{2} \times (1.0941 - 0.8222)\right\} \times 10^3$

= antilog {(0.1360)} × 10^3

= 1.368 × 10^3

= **1368 m/s**

Ans: The rms speed of He- atom is **1368 m/s.**

Q.34. At what temperature the root mean square speed of an atom in an argon gas cylinder is equal to the rms speed of a helium gas atom at −20 °C?
[Atomic mass of Ar = 39.9 u, He = 4 u]
[3 Marks] (NCERT)

Solution:
Given: Mass of argon (m)
= 39.9 u
= 39.9 × 1.67 × 10^{-27} kg
= 6.66 × 10^{-26} kg
Mass of helium (m′)
= 4 u
= 4 × 1.67 × 10^{-27} kg
= 6.68 × 10^{-27} kg
Temperature of helium,
T′ = − 20 °C = − 20 + 273 = 253 K
Boltzmann constant (k_B)
= 1.38 × 10^{-23} JK^{-1}

To find: Temperature of argon (T)

Formula: $v_{rms} = \sqrt{\frac{3k_BT}{m}}$

Calculation: Using formula,

∴ $\sqrt{\frac{3k_BT}{m}} = \sqrt{\frac{3k_BT'}{m'}}$ (velocities are equal)

∴ $T = T' \times \frac{m}{m'} = \frac{253 \times 6.66 \times 10^{-26}}{6.68 \times 10^{-27}}$

∴ T = $\mathbf{2.522 \times 10^3}$ **K**

Ans: The required temperature of argon gas cylinder is $\mathbf{2.522 \times 10^3}$ **K.**

Q.35. The kinetic energy of nitrogen per unit mass at 300 K is 2.5 × 10^6 J/Kg. Find the kinetic energy of 4 kg oxygen at 600 K. (Molecular weight of nitrogen = 28, Molecular weight of oxygen = 32) **[2 Marks] [Oct 13]**

Solution:
Given: m_1 = 1 kg, T_1 = 300 K, K_1 = 2.5 × 10^6 J,
m_2 = 4 kg, T_2 = 600 K, M_1 = 28, M_2 = 32

Sample Content

To find: Kinetic energy (K_2)

Formula: $K = \frac{3}{2}nRT$

Calculation: Since, $n = \frac{m}{M_0}$

From formula,

$$K_1 = \frac{3}{2}\left(\frac{1 \times R \times 300}{28}\right)$$

$$K_2 = \frac{3}{2}\left(\frac{4 \times R \times 600}{32}\right)$$

$$\therefore \quad \frac{K_1}{K_2} = \frac{4 \times 600}{32} \times \frac{28}{300}$$

$$K_2 = \frac{224}{32} \times 2.5 \times 10^6$$

$$K_2 = 7 \times 2.5 \times 10^6$$

$$= \mathbf{17.5 \times 10^6\ J}$$

Ans: The kinetic energy of 4 kg oxygen at 600 K is $\mathbf{17.5 \times 10^6}$ **J.**

3.8 Law of Equipartition of Energy

Q.36. State and explain law of equipartition of energy. **[3 Marks]**

Ans: **Statement:** *For a gas in thermal equilibrium at a temperature T, the average energy for molecule associated with each quadratic term is* $\frac{1}{2}k_BT$.

Explanation:

i. Translational kinetic energy associated with single molecule is given in terms of x,y and z components as,

$$K.E. = \frac{1}{2}mv_x^2 + \frac{1}{2}mv_y^2 + \frac{1}{2}mv_z^2$$

ii. For a gas at temperature T, the average value of kinetic energy is denoted as $\langle K.E. \rangle$.

$$\therefore \quad \langle K.E. \rangle = \left\langle \frac{1}{2}mv_x^2 \right\rangle + \left\langle \frac{1}{2}mv_y^2 \right\rangle + \left\langle \frac{1}{2}mv_z^2 \right\rangle$$

iii. But, average value of kinetic energy of a gas molecule at temperature T is given as,

$$\langle K.E. \rangle = \frac{3}{2}k_BT$$

$$\therefore \quad \left\langle \frac{1}{2}mv_x^2 \right\rangle + \left\langle \frac{1}{2}mv_y^2 \right\rangle + \left\langle \frac{1}{2}mv_z^2 \right\rangle = \frac{3}{2}k_BT$$

iv. Since there is no preferred direction amongst three components,

$$\left\langle \frac{1}{2}mv_x^2 \right\rangle = \left\langle \frac{1}{2}mv_y^2 \right\rangle = \left\langle \frac{1}{2}mv_z^2 \right\rangle = \frac{1}{2}k_BT$$

v. Thus, the mean energy associated with every component of translational kinetic energy in x, y and z directions is $\frac{1}{2}k_BT$.

Q.37. Define degrees of freedom of a system. **[1 Mark]**

Ans: *Degrees of freedom of a system are defined as the total number of coordinates or independent quantities required to describe the position and configuration of the system completely.*

Q.38. For a molecule which has restricted its motion in a plane, what are the degrees of freedom? Why? **[1 Mark]**

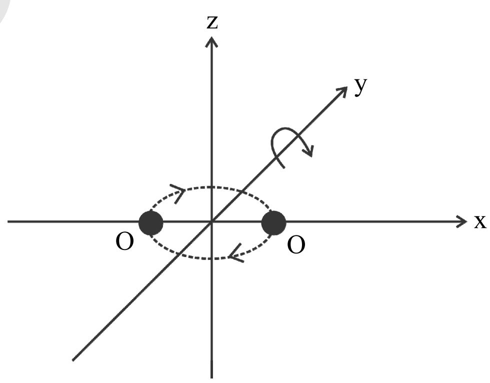
Ans: A molecule, restricted to move in a plane needs two components to describe its location (x and y co-ordinates) and thereby two components of velocity to describe its motion. Thus, it has two degrees of freedom.

Q.39. Explain the classification of degrees of freedom with the help of an example. **[3 Marks]**

Ans:

i. Degrees of freedom (dof) can be classified as
   a. Translational dof
   b. Rotational dof
   c. Vibrational dof

ii. Consider for example, O_2 or N_2 molecules with the two atoms lying along the X-axis.



The two independent axes z and y of rotation

iii. The molecules have 3 translational degrees of freedom.

iv. In addition, a diatomic molecule can rotate about its centre of mass in two directions that are perpendicular to its molecular axis. The diatomic molecules therefore, said to possess 2 additional dof viz., 2 rotational dof.

v. If the molecules are considered to be rigid, then the total dof of diatomic molecules are 3 translational and 2 rotational dof.

vi. However, real molecules contain covalent bonds between the atoms. Thus, atoms of such molecules vibrate about their mean position like one dimensional harmonic oscillator. Such molecules therefore possess additional vibrational dof per atom.

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Page no. **92** to **94** are purposely left blank.

To see complete chapter buy **Target Notes** or **Target E-Notes**

Sample Content

Q.53. With a neat and labelled diagram, explain Ferry's perfectly blackbody.
[4 Marks][Oct 14; Similar in Mar 19]

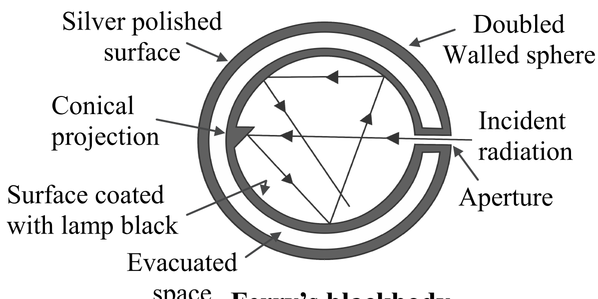
Ans:

i. Ferry's perfectly blackbody consists of a double walled hollow sphere having tiny hole or aperture, through which radiant heat can enter.

ii. The space between the walls is evacuated and outer surface of the sphere is silvered.

iii. The inner surface of sphere is coated with lampblack.

iv. There is a conical projection on the inner surface of sphere opposite the aperture. The projection ensures that a ray travelling along the axis of the aperture is not incident normally on the surface and is therefore not reflected back along the same path.



Ferry's blackbody

v. A heat ray entering the sphere through the aperture suffers multiple reflections and is almost completely absorbed inside.

vi. Thus, the aperture behaves like a perfect blackbody.

vii. The effective area of perfectly blackbody is equal to the area of the aperture.

Q.54. Write a short note on cavity radiator.
[2 Marks]

Ans:

i. Cavity radiator consists of a block of material with internal cavity.

ii. The inner and outer surfaces are connected by a small hole.

iii. The radiation falling on the block that enters through the hole, cannot escape back from it. Hence, the cavity acts as a blackbody.

iv. When the block is heated to high temperature, thermal radiation is emitted. This is called cavity radiation and it resembles the radiation emitted by a blackbody.

v. Its nature depends only on the temperature of the cavity walls and not on the shape and size of the cavity or the material of the cavity walls.

Students can scan the adjacent QR code to get conceptual clarity about ***Blackbody radiations using a cavity radiator*** *with the aid of a linked video.*

Q.55. Do you know? *(Textbook page no. 66)*

i. Can a perfect blackbody be realized in practice? **[1 Mark]**

Ans: A perfect blackbody cannot be realised in practice. However, lampback or platinum black absorbs nearly 97% of incident heat, resemble a perfect blackbody.

ii. Are good absorbers also good emitters?
[2 Marks]

Ans:

a. Consider two objects, which are opaque to thermal radiation, having the same temperature and same surface area.

b. The surface of one object is well-polished and the surface of the other object is painted black.

c. The well-polished object reflects most of the energy falling on it and absorbs little.

d. On the other hand, the black painted object absorbs most of the radiation falling on it and reflects little.

e. But the rate of emission of thermal radiation must be equal to rate of absorption for both the objects, so that temperature is maintained.

f. Black painted object absorbs more, hence it must radiate more to maintain the temperature. Therefore, good absorbers are always good emitters and poor absorbers are poor emitters.

Reading between the lines

Since each object must either absorb or reflect the radiation incident on it, a poor absorber should be a good reflector and vice versa. Hence, a good reflector is also a poor emitter.

3.12 Emission of Heat Radiation

Q.56. State Prevost's theory of exchange of heat.
[1 Mark]

Ans: *All bodies at all temperatures above 0 K (absolute zero temperature) radiate thermal energy and at the same time, they absorb radiation received from the surroundings.*

Q.57. Explain the variation of temperature according to Prevost's theory of heat exchange.
[3 Marks]

Ans:

i. The average translational kinetic energy determines the temperature of the body.

ii. According to theory of heat exchange, all the bodies above 0 K absorb radiations from the surroundings.

iii. For a body, the absorbed radiation (being energy) increases the kinetic energy of the constituent atoms oscillating about their mean positions.

Sample Content

iv. The absorbed radiation therefore causes a rise in the temperature of the body.

v. The body itself also radiates, therefore its energy decreases, causing lowering of temperature.

vi. If a body radiates more than it absorbs, its temperature decreases and if the body absorbs more than it radiates, then the temperature of the body increases.

vii. When the rate of absorption of radiation is same as the rate of emission of radiation, the temperature of the body remains constant and the body is said to be in thermal equilibrium with its surroundings. This means, all bodies radiate as well as absorb radiation also at room temperature, but their rate of emission and rate of absorption are same, hence their temperature remains constant.

It can be inferred from this, that hot bodies would radiate more than cooler bodies.

Q.58. On which factors does amount of heat radiated by a body depend? [2 Marks]

Ans: Amount of heat radiated by a body depends on:

i. The absolute temperature of the body (T)

ii. The nature of the body – the material, nature of surface – polished or not, etc.

iii. Surface area of the body (A)

iv. Time duration for which body emits radiation (t).

Q.59. Define emissive power of the body. [Mar 16] State its S.I. units and dimensions. [2 Marks]

Ans: *The quantity of heat radiated per unit area per unit time is defined as emissive power of the body at given temperature.*

OR

The power emitted per unit area at given temperature is defined as emissive power or radiant power of the body.

$\therefore \quad R = \dfrac{Q}{AT}$

i. S.I. unit of emissive power is $Jm^{-2}\ s^{-1}$ or W/m^2.

ii. Dimensions of emissive power are $[L^0M^1T^{-3}]$.

Q.60. Write a short note on coefficient of emission. [2 Marks]

Ans:

i. *The coefficient of emission or emissivity (e) of a given surface is the ratio of the emissive power R of the surface to the emissive power R_B of a perfect black surface, at the same temperature.*

$\therefore \quad e = \dfrac{R}{R_B}$

ii. For a perfect blackbody e = 1, whereas for a perfect reflector e = 0.

iii. For an ordinary body, $0 < e < 1$ depending on the nature of the surface.

Reading between the lines

The nature of emitting surface (material or its polishing) is not a physical quantity. To incorporate material aspect, objects of different materials with identical geometries at same temperature are compared.

As, at a given temperature, a perfect blackbody has maximum emissive power, it is convenient to compare emissive power of a given surface with that of the perfectly blackbody.

Q.61. Use your brain power. *(Textbook page no. 64)*

i. Why are the bottoms of cooking utensils blackened and tops polished? [2 Marks]

Ans:

a. The amount of heat absorbed as well as radiated from a body depends on the nature of material of the body and colour of the body.

b. Light coloured and polished surfaces reflect most of the radiations whereas dark coloured rough surfaces absorb most of the incident radiations.

c. Thus, the bottom part of cooking utensils is blackened to absorb the heat from the flame more quickly.

d. Also, the upper part of the utensil and the outer surface are kept polished and shining to reduce heat loss due to radiation.

ii. If surfaces of all bodies are continuously emitting radiant energy, why do they not cool down to 0 K? [2 Marks]

Ans: Surfaces of all the bodies emit as well as absorb the radiation continuously. Thus although the heat is given out decreasing the temperature of the body, some amount of heat is also absorbed by the body from its surrounding increasing the temperature of the body. Hence, the bodies do not cool down to 0 K.

Solved Examples

***Q.62. The emissive power of a sphere of area 0.02 m^2 is 0.5 kcal s^{-1} m^{-2}. What is the amount of heat radiated by the spherical surface in 20 second? [2 Marks]**

Solution:

Given: $R = 0.5$ kcal s^{-1} m^{-2}, T = 20 sec, A = 0.02 m^2

To find: Heat radiated by spherical surface (Q)

Formula: $R = \dfrac{Q}{At}$

Calculation: From formula,

Q = RAt

Q = 0.5 × 0.02 × 20 = **0.2 kcal**

Ans: The amount of heat radiated by the spherical surface is **0.2 kcal.**

Sample Content

Q.63. The energy of 6000 J is radiated in 5 minutes by a body of surface area 100 cm^2. Find emissive power of the body. [2 Marks]

Solution:

Given: $Q = 6000$ J,
$t = 5$ minutes $= 5 \times 60$ s $= 300$ s,
$A = 100$ cm$^2 = 100 \times 10^{-4}$ m$^2 = 10^{-2}$ m^2

To find: Emissive power (R)

Formula: $R = \dfrac{Q}{At}$

Calculation: From formula,

$$R = \frac{6000}{10^{-2} \times 300} = \frac{20}{10^{-2}} = 20 \times 10^2$$

$\therefore$ $R =$ **2000 J/m^{2}s**

Ans: The emissive power of the body is **2000 J/m^{2}s**.

3.13 Kirchhoff's Law of Heat Radiation and its Theoretical Proof

***Q.64. State and prove Kirchhoff's law of heat radiation. [3 Marks] [July 19]**

Ans: Statement: *At a given temperature, the ratio of emissive power to coefficient of absorption of a body is equal to the emissive power of a perfect blackbody at the same temperature for all wavelengths.*

OR

For a body emitting and absorbing thermal radiation in thermal equilibrium, the emissivity is equal to its absorptivity.

Symbolically, $a = e$ or $a(\lambda) = e(\lambda)$

Theoretical proof:

i. Consider an ordinary body A and a perfect blackbody B of identical geometric shapes placed in an enclosure. In thermal equilibrium, both bodies will be at same temperature as that of the enclosure.

ii. Let R = emissive power of body A,
R_B = emissive power of blackbody B
a = coefficient of absorption of body A.
Q = quantity of radiant heat incident on each body in unit time and
Q_a = quantity of radiant heat absorbed by the body A,
then $Q_a = a\,Q$.

iii. As the temperatures of the body A and blackbody B remain the same, both must emit the same amount as they absorb in unit time.

$\therefore$ Quantity of radiant heat absorbed by body A = Quantity of heat emitted by body A

$\therefore$ $aQ = R$ ….(1)

iv. For the perfect blackbody B,
$Q = R_B$ ….(2)

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

$a = \dfrac{R}{R_B}$

vi. But by definition of emissivity, $e = \dfrac{R}{R_B}$

$\therefore$ $a = e$

Hence, Kirchhoff's law is theoretically proved.

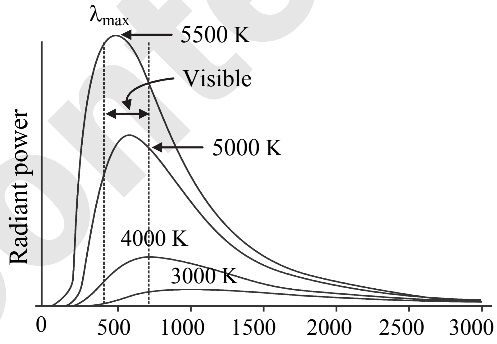
3.14 Spectral Distribution of Blackbody Radiation

***Q.65. Explain spectral distribution of blackbody radiation. OR Explain blackbody radiation spectrum in terms of wavelength. [3 Marks] [Oct 13]**

Ans:

i. The rate of emission per unit area or power per unit area of a surface is defined as a function of the wavelength λ of the emitted radiation.

ii. Scientists studied the energy distribution of blackbody radiation as a function of wavelength.



iii. By keeping the source of radiation (such as a cavity radiator) at different temperatures they measured the radiant power corresponding to different wavelengths. The measurements were represented graphically in the form of curves showing variation of radiant power per unit area as a function of wavelength λ at different constant temperatures as shown in figure.

Scan the adjacent QR Code to know more about our ***"Board Questions"*** book for Std. XII (Sci.) and Learn about the types of questions that are asked in the XII Board Examination.

Q.66. What observations can be made from the curves of the blackbody spectrum? [3 Marks]

Ans: Observations from experimental curves of blackbody spectrum:

i. At a given temperature, the energy is not uniformly distributed in the spectrum of blackbody.

ii. At a given temperature, the radiant power emitted initially increases with increase of wavelength, reaches its maximum and then decreases. The wavelength corresponding to the radiation of maximum intensity (λ_{max}) is characteristic of the temperature of the radiating body.

iii. Area under the curve represents total energy emitted per unit time per unit area by the blackbody at all wavelengths.

iv. The peak of the curves shifts towards the left i.e., the value of λ_{max} decreases with increase in temperature.

v. At higher temperatures, the radiant power or total energy emitted per unit time per unit area (i.e., the area under the curve) corresponding to all the wavelengths increases.

vi. At a temperature of 300 K (around room temperature), the most intense of these waves has a wavelength of about 5×10^{-6} m.

Reading between the lines

i. Remember, λ_{max} is not the maximum wavelength emitted by the object.

ii. Practically all the radiant energy at room temperature is carried by waves longer than those corresponding to red light. These are infrared radiations.

***Q.67. State Wien's displacement law.**
[2 Marks] [Mar 15]

Ans:

i. **Statement:** *The wavelength, for which emissive power of a blackbody is maximum is inversely proportional to the absolute temperature of the blackbody.*

ii. This is Wien's displacement law, i.e.,

$\lambda_{max} \propto \frac{1}{T}$ Or $\lambda_{max} \propto \frac{b}{T}$

$\therefore$ $\lambda_{max} T = b$

where b is called the Wien's constant and its value is 2.897×10^{-3} m K.

Solved Examples

+Q.68. Calculate the value of λ_{max} for solar radiation assuming that surface temperature of Sun is 5800 K. (b = 2.897×10^{-3} m K). In which part of the electromagnetic spectrum, does this value lie?
(Example 3.5 of Textbook page no. 70)
[3 Marks]

Solution:

Given: T = 5800 K, b = 2.897×10^{-3} mK

To find: i. Wavelength of radiation (λ_{max})
ii. The region in electromagnetic spectrum to which the radiation belongs

Formula: $\lambda_{max} = \frac{b}{T}$

Calculation: From formula,

$$\lambda_{max} = \frac{2.897 \times 10^{-3}}{5800}$$

$= \text{antilog}\ \{\log(2.897) - \log(5.8)\} \times 10^{-6}$

$= \text{antilog}\ \{(0.4620 - 0.7634)\} \times 10^{-6}$

$= \text{antilog}\ \{(\bar{1}.6986)\} \times 10^{-6}$

$= 4.996 \times 10^{-1} \times 10^{-6}$

$= 4.996 \times 10^{-7}$ m = **4996Å**

Ans: Value of λ_{max} is **4996 Å**. This value lies in the **visible region** of the electromagnetic spectrum.

***Q.69. Find the temperature of a blackbody if its spectrum has a peak at**

i. λ_{max} = 700 nm (visible),

ii. λ_{max} = 3 cm (microwave region) and

iii. λ_{max} = 3 m (short radio waves)

(Take Wien's constant b = 2.897×10^{-3} m K).
[3 Marks]

Solution:

Given: $(\lambda_{max})_1$ = 700 nm = 700×10^{-9} m
= 7×10^{-7}m
$(\lambda_{max})_2$ = 3 cm = 3×10^{-2} m, $(\lambda_{max})_3$ = 3 m
b = 2.897×10^{-3} mK

To find: Temperature of blackbody for peaks

Formula: $\lambda_{max} = \frac{b}{T}$

Calculation:

From formula,

$$T = \frac{b}{\lambda_{max}}$$

i. $T_1 = \frac{2.897 \times 10^{-3}}{7 \times 10^{-7}} = 0.4138 \times 10^4 = \mathbf{4138\ K}$

ii. $T_2 = \frac{2.897 \times 10^{-3}}{3 \times 10^{-2}} = 0.966 \times 10^{-1} = \mathbf{0.0966\ K}$

iii. $T_3 = \frac{2.897 \times 10^{-3}}{3} = \mathbf{0.966 \times 10^{-3}\ K}$

Ans: The respective temperatures of blackbody are **4138 K**, **0.0966 K** and **0.966×10^{-3} K**.

***Q.70. Earth's mean temperature can be assumed to be 280 K. How will the curve of blackbody radiation look like for this temperature? Find out λ_{max}. In which part of the electromagnetic spectrum, does this value lie?** **[3 Marks]**

Solution:

Given: T = 280 K

To find: Wavelength of radiation (λ_{max})

Formula: $\lambda_{max} = \frac{b}{T}$

Calculation:

From formula,

$$\lambda_{max} = \frac{2.897 \times 10^{-3}}{280} \quad \ldots(\because\ b = 2.897 \times 10^{-3}\ \text{mk})$$

$= 0.01035 \times 10^{-3}$

$= \mathbf{1.035 \times 10^{-5}\ m}$

This radiation belongs to **microwave region** of electromagnetic spectrum.

The curve of blackbody radiation for the earth will look like the curve shown in the figure:

Sample Content

Page no. **99** to **101** are purposely left blank.

To see complete chapter buy **Target Notes** or **Target E-Notes**

Sample Content

Quick Review

Ideal Gas

Equation of state
- $PV = nRT$
- $PV = Nk_BT$

where, $k_B = 1.38 \times 10^{-23}$ J/K

Mean free path
- The average distance traversed by a molecule between two succesive collisions
- $\lambda = \dfrac{1}{\sqrt{2}\pi d^2\left(\dfrac{N}{V}\right)}$

Kinetic energy
- Average K.E:

$\text{K.E.} = \frac{1}{2}m\overline{v^2}$

$\text{K.E.} = \frac{3}{2}PV$

$\frac{\text{K.E.}}{\text{molecule}} = \frac{3}{2}k_BT$

$\frac{\text{K.E.}}{\text{mol}} = \frac{3}{2}RT$

RMS speed
- Average speed at given temperature
- $v_{rms} = \sqrt{\dfrac{3RT}{M_0}} = \sqrt{\dfrac{3}{2}k_BT}$

Pressure of gas
- Pressure exerted by gas is,

$P = \frac{1}{3}\frac{MN}{V}\overline{v^2}$

Law of equipartition of energy
- For a gas in thermal equilibrium at temperature T, the average energy for molecule associated with each quadratic term is $\frac{1}{2}k_BT$.
- **Translational K.E.:** $\frac{1}{2}mv_x^2 + \frac{1}{2}mv_y^2 + \frac{1}{2}mv_z^2$
- **Rotational K.E.:** $\frac{1}{2}I\omega_x^2 + \frac{1}{2}I\omega_y^2 + \frac{1}{2}I\omega_z^2$
- **Vibrational K.E.:** $\frac{1}{2}mu^2 + \frac{1}{2}kr^2$

Degrees of Freedom
- The total number of coordinates or independent quantities required to describe the position and configuration of the system completely
- **Monatomic Gas:**

Translation dof : 3
- **Diatomic Gas:**

Translation dof : 3

Rotational dof : 2 or 3

Vibrational dof : 0 or 2

Specific heat capacity

Mayer's Relation	Monatomic Gas	Diatomic Gas (Rigid)	Diatomic Gas (non-rigid)	Polyatomic Gas
$C_P - C_V = R$	$C_P = \frac{5}{2}R$	$C_P = \frac{7}{2}R$	$C_P = \frac{9}{2}R$	$C_P = (4 + f) R$
$S_P - S_V = \frac{R}{M_0J}$	$C_V = \frac{3}{2}R$	$C_V = \frac{5}{2}R$	$C_V = \frac{7}{2}R$	$C_V = (3 + f)R$
$\frac{C_P}{C_V} = \gamma$	$\gamma = \frac{5}{3}$	$\gamma = \frac{7}{5}$	$\gamma = \frac{9}{7}$	$\gamma = \frac{(4+f)}{(3+f)}$

Sample Content

Radiation

Absorption
- Coefficient of Absorption (a)
  $a = \frac{Q_a}{Q}$

Reflection
- Coefficient of reflection (r)
  $r = \frac{Q_r}{Q}$

Transmission
- Coefficient of transmission (t_r)
  $t_r = \frac{Q_t}{Q}$

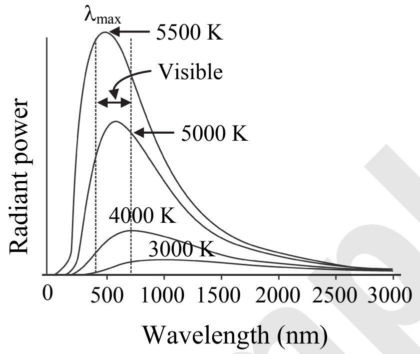
$a + r + t_r = 1$

Emission
- Coefficient of emission or emissivity (e)
  $e = \frac{R}{R_B}$
- **Emissive power**
  $R = \frac{Q}{At}$

Perfect blackbody
- A body which absorbs the entire radiant energy incident on it.
- For perfect blackbody, a = 1
- In practice, Ferry's body is considered perfect blackbody as lampblack used in it absorbs 97% of incident energy.
- It appears black in light and glows in dark because good absorber is always a good emitter.

Prevost's theory of heat exchange
- All bodies at all temperatures above 0 K radiate thermal energy and at the same time, they absorb radiation received from surroundings.

Spectrum of blackbody



- **Wien's displacement law:**
  $\lambda_{max} = \frac{b}{T}$

Stefan-Boltzmann law
- Radiating power per unit time is directly proportional to fourth power of the temperature.
  $Q = \sigma At T^4$ (for perfect blackbody)
  $Q = e\sigma At T^4$ (for ordinary body)
- σ = Stefan's Constant
  $= 5.67 \times 10^{-8}$ J/s m^2 K^4

Kirchhoff's Law of radiation
- At a given temperature, the ratio of emissive power to coefficient of absorption of a body is equal to the emissive power of a perfect blackbody at the same temperature for all wavelengths
  $a = e = \frac{R}{R_B}$

Sample Content

Impotant formula

1. Ideal gas equation:

i. $PV = nRT$

ii. $PV = Nk_BT$

2. Mean free path:

i. $\lambda = \frac{1}{\sqrt{2}\pi d^2\left(\frac{N}{V}\right)}$

ii. $\lambda = \frac{k_BT}{\sqrt{2}\pi d^2 P}$

3. Pressure exerted by gas:

$P = \frac{1}{3}\frac{N}{V}m\overline{v^2}$

4. Root mean square speed:

i. $v_{rms} = \sqrt{\frac{3RT}{M_0}}$

ii. $v_{rms} = \sqrt{\frac{3P}{\rho}}$

iii. $v_{rms} = \sqrt{\frac{3}{2}k_BT}$

5. Kinetic energy of gas molecule:

i. K.E of gas molecules $= \frac{3}{2}$ PV

ii. K.E per unit mole $= \frac{3}{2}$ RT

iii. K.E per unit mass $= \frac{3}{2}\frac{RT}{M_0}$

iv. K.E per molecule $= \frac{3}{2}k_BT$

6. Relation between C_p and C_v:

i. $C_P - C_V = R$

….(When all quantities are expressed in same unit.)

$C_P - C_V = \frac{R}{J}$

….(When C_P, C_V are in heat units and R is in work unit.)

ii. $\frac{C_P}{C_V} = \gamma$ iii. $S_p - S_v = \frac{R}{M_0 J}$

7. Radiant energy incident on a surface:

$Q = Q_a + Q_r + Q_t$

8. Coefficient of radiation:

i. **Coefficient of absorption,** $a = \frac{Q_a}{Q}$

ii. **Coefficient of reflection,** $r = \frac{Q_r}{Q}$

iii. **Coefficient of transmission,** $t_r = \frac{Q_t}{Q}$

9. Relation between a, r, and t: $a + r + t_r = 1$

10. Coefficient of emission (Emissivity): $e = \frac{R}{R_b} = a$

11. Emissive power: $R = \frac{Q}{At}$

12. Quantity of radiant heat emitted by a blackbody:

i. $Q = \sigma AT^4t$

(When temperature of surrounding is not given)

ii. $Q = \sigma A (T^4 - T_0^4)t$

(When temperature of the surrounding is given)

13. Radiant energy emitted by ordinary body:

i. $Q = eA\sigma T^4 t$ ii. $Q = eA\sigma (T^4 - T_0^4) t$

14. Wien's law: $\lambda_{max} = \frac{b}{T}$

15. Rate of heat radiation: $\frac{dQ}{dt} = eA\sigma(T^4 - T_0^4)$

16. Total radiant energy emitted from a body:

$Q = eAt\sigma(T^4 - T_0^4)$

Exercise

3.1 Introduction

1. Prove the relation, $PV = Nk_BT$. **[3 Marks]**

Ans: *Refer Q.1*

2. 14 g of nitrogen occupy 0.028 m^3 at 27 °C. If the universal gas constant is 8.4 J/mol K. Find the pressure exerted by it. [Molecular weight of nitrogen = 28] **[2 Marks]**

Ans: 45×10^3 N/m^2

R 3.2 Behaviour of a Gas

3. Why cannot the behaviour of a gas molecule be studied using Newtonian mechanics? **[2 Marks]**

Ans: *Refer Q.7*

R 3.3 Ideal Gas and Real Gas

4. Define ideal gas. **[1 Mark]**

Ans: *Refer Q.8*

5. When can a real gas be treated as ideal gas? **[1 Mark]**

Ans: *Refer Q.9*

R 3.4 Mean Free Path

6. What is a mean free path? **[1 Mark]**

Ans: *Refer Q.10 (v)*

7. How does a mean free path of a gas molecule vary with number density and size of the molecule? **[1 Mark]**

Ans: *Refer Q.10 (vi)*

8. Obtain the mean free path of nitrogen molecule at 0 °C and 1.0 atm pressure. The molecular diameter of oxygen is 335 pm (assume that the gas is ideal). (Take $k_B = 1.38 \times 10^{-23}$ J/K) **[3 Marks]**

Ans: 74.65 nm

3.5 Pressure of Ideal Gas

9. Derive an expression for pressure exerted by a gas molecule. **[4 Marks]**

Ans: *Refer Q.14*

10. A gas in a cylinder is at pressure 500 N/m^2. If the masses of all the molecules are made one fifth of their original value and their speeds are doubled, then find the resultant pressure. **[2 Marks]**

Ans: 400 N/m^2

3.6 Root Mean Square (rms) Speed

11. Show that r.m.s. velocity of a gas molecule is directly proportional to the square root of the absolute temperature of the gas. **[2 Marks] [Mar 14]**

Ans: *Refer Q.17*

12. State the relation between mean square velocity of a gas molecule and its absolute temperature. **[1 Marks]**

Ans: *Refer Q.18*

13. Compare the speed of sound in a gas and r.m.s. speed of that gas molecule. **[2 Marks]**

Ans: *Refer Q.20*

Sample Content

14. Calculate the temperature (in °C) at which the r.m.s velocity of O_2 gas molecule will be 0.5 km s^{-1}. [Given R = 8.311 J mol^{-1} K^{-1}] **[2 Marks]**

Ans: 47.86 °C

15. Determine the pressure of oxygen at 0 °C, if the density of oxygen at N.T.P is 1.44 kg/m^3 and r.m.s. speed of the molecules at N.T.P is 456.4 m/s. **[2 Marks]**

Ans: 10^5 N/m^2

16. Calculate the ratio of mean square speeds of molecules of a gas at 30 K and 150 K. **[2 Marks]**

Ans: 1 : 5

17. The r.m.s speed of oxygen molecules at N.T.P is 461.2 m/s. Find the temperature at which the r.m.s speed becomes 90% of the speed at N.T.P. **[2 Marks]**

Ans: 221.1 K

3.7 Interpretation of Temperature in Kinetic Theory

18. Explain how kinetic energy of gas molecules varies with the temperature using kinetic theory of gases. **[3 Marks]**

Ans: *Refer Q.29*

19. Deduce Boyle's law using the expression for pressure exerted by the gas. **[2 Marks][Feb 20]**

Ans: *Refer Q.30*

20. Find kinetic energy of 2.5 litre of a gas at S.T.P. Given standard pressure is 1×10^5 N/m^2. **[2 Marks]**

Ans: 375 J

21. The kinetic energy of 1 kg of oxygen at 300 K is 1.356×10^6 J. Find the kinetic energy of 4 kg of oxygen at 400 K. **[2 Marks]**

Ans: 7.232×10^6 J

22. Find the average kinetic energy of a molecule of nitrogen at 27 °C. [Boltzmann constant, $k_B = 1.381 \times 10^{-23}$ J/molecule K] **[2 Marks]**

Ans: 6.215×10^{-21} J

23. Calculate the molecular K.E per k mol and per kg of hydrogen at 127 °C.
[R = 8310 J/k mol K, molecular weight of hydrogen = 2] **[3 Marks]**

Ans: 4.986×10^6 J, 2.493×10^6 J

R 3.8 Law of Equipartition of Energy

24. What is the law of equipartition of energy? **[3 Marks]**

Ans: *Refer Q.36*

25. What are degrees of freedom of a system? How many degrees of freedom a body moving in a plane has? **[2 Marks]**

Ans: *Refer Q.37 and Q.38*

26. How many degrees of freedom a monatomic gas has? **[1 Mark]**

Ans: *Refer Q.40*

27. Describe the energy associated with each degree of freedom for a diatomic gas. **[3 Marks]**

Ans: *Refer Q.41*

3.9 Specific Heat Capacity

28. Calculate molar specific heat at constant volume and constant pressure of a diatomic gas. **[2 Marks]**

Ans: *Refer Q.44 (ii)*

29. Deduce the molar specific heat at constant volume and constant pressure of a monatomic gas. **[2 Marks]**

Ans: *Refer Q.44 (i)*

30. The ratio of specific heats of a gas is 1.4. Its specific heat at constant volume is 4.96 k cal/k mol K. Calculate the universal gas constant. [J = 4200J/ k cal] **[2 Marks]**

Ans: 8332.8 J/k mol K

31. Specific heat of nitrogen at constant pressure and at constant volume is 0.24 kcal/kg-K and 0.17 kcal/kg-K respectively. Calculate the mechanical equivalent of heat.
[Molecular weight of nitrogen = 28, R = 8.31×10^3 J/k mol k cal] **[2 Marks]**

Ans: 4.24×10^3 J /K

3.10 Absorption, Reflection and Transmission of Heat Radiation

32. Derive the relation between a, r and t_r. **[2 Marks]**

Ans: *Refer Q.48*

33. Define:
i. Coefficient of absorption
ii. Coefficient of transmission **[2 Marks]**

Ans: *Refer Q.49 (i) and (iii)*

34. What are athermanous and diathermanous substances? **[2 Marks]**

Ans: *Refer Q.50*

35. What is coefficient of reflection? When can a body be said to be a perfect reflector? **[2 Marks]**

Ans: *Refer Q.49 (ii) and Q. 51 (ii)*

3.11 Perfect Blackbody

36. What is a perfect blackbody? **[1 Mark] [Mar 19]**

Ans: *Refer Q.52*

37. Describe Ferry's blackbody with the help of a neat labelled diagram. **[4 Marks]**

Ans: *Refer Q.53*

38. Draw a neat labelled diagram for Ferry's perfectly blackbody. **[2 Marks][July 18; Mar 13]**

Ans: *Refer Q.53 (Diagram only)*

Sample Content

39. Explain what is cavity radiator. **[2 Marks]**
Ans: *Refer Q.54*

3.12 Emission of Heat Radiation

40. How does heat exchange takes place according to Prevost's theory? **[3 Marks]**
Ans: *Refer Q.57*

41. On which factors does amount of heat radiated by a body depend? **[2 Marks]**
Ans: *Refer Q. 58*

42. What is emissive power? **[1 Mark]**
Ans: *Refer Q.59*

43. Define coefficient of emission. **[Mar 16][2 Marks]**
Ans: *Refer Q.60*

44. The energy of 3000 J is radiated in 2 minutes by a body of surface area 100 cm^2. Find emissive power of the body. **[2 Marks]**
Ans: 2500 J/m^2s

3.13 Kirchhoff's Law of Heat Radiation and its Theoretical Proof

45. State Kirchhoff's law of heat radiations. **[1 Mark]**
Ans: *Refer Q.64(Statement only)*

46. Prove Kirchhoff's law of radiation theoretically. **[2 Marks] [July 17]**
Ans: *Refer Q.64 (Theoretical proof only)*

3.14 Spectral Distribution of Blackbody Radiation

47. Explain energy distribution spectrum of a black body radiation in terms of wavelength. **[3 Marks] [Feb 20]**
Ans: *Refer Q.65*

48. State and explain Wien's displacement law. **[2 Marks]**
Ans: *Refer Q.67*

49. For a perfectly blackbody at temperature of 4000 K, find the value of λ_{max}.
(Take b = 2.897×10^{-3} m K) **[2 Marks]**
Ans: 7242.5 Å

50. Calculate the value of λ_{max} for radiations coming from a star with surface temperature of 6500 K.
(b = 2.897×10^{-3} m K) **[2 Marks]**
Ans: 4457 Å

51. Find the temperature of a blackbody if its spectrum has a peak at λ_{max} = 500 nm (visible) **[2 Marks]**
Ans: 5794 K

3.15 Stefan-Boltzmann Law of Radiation

52. What does Stefan-Boltzmann law state? **[1 Mark]**
Ans: *Refer Q.71*

53. Obtain the expression for the rate of loss of heat by a blackbody in cooler surroundings. **[2 Marks]**
Ans: *Refer Q.73*

54. A body of surface area 20 cm^2 and temperature 527 °C emits 400 J of energy per minute. Find its emissivity.
[Given: $\sigma = 5.67 \times 10^{-8}$ watt/m^2K^4] **[2 Marks]**
Ans: 0.1435

55. Compare the rates of emission of heat by a blackbody maintained at 327 °C and at 127 °C, if the blackbodies are surrounded by an enclosure (black) at 27 °C. What would be the ratio of their rates of loss of heat? **[3 Marks]**
Ans: 243 : 35 or 6.94 : 1

Multiple Choice Questions

[1 Mark Each]

*1. In an ideal gas, the molecules possess
(A) only kinetic energy
(B) both kinetic energy and potential energy
(C) only potential energy
(D) neither kinetic energy nor potential energy

2. In the case of ideal gases,
(A) the molar specific heat at constant pressure is the same for all gases.
(B) the molar specific heat at constant volume is the same for all gases.
(C) the ratio of the molar specific heats at constant volume and at constant pressure is the same for all gases.
(D) the difference between the molar specific heats at constant pressure and at constant volume is the same for all gases.

*3. The mean free path λ of molecules is given by
(A) $\sqrt{\frac{2}{\pi n d^2}}$ (B) $\frac{1}{\pi n d^2}$
(C) $\frac{1}{\sqrt{2}\pi n d^2}$ (D) $\frac{1}{\sqrt{2}\pi n d}$
where n is the number of molecules per unit volume and d is the diameter of the molecules.

*4. If pressure of an ideal gas is decreased by 10% isothermally, then its volume will
(A) decrease by 9%
(B) increase by 9%
(C) decrease by 10%
(D) increase by 11.11%

5. The average distance covered by a molecule between two successive collision is ________.
(A) free path
(B) constant path
(C) mean free path
(D) free path per unit time.

Sample Content

6. 'P' is the pressure and 'd' is the density of gas at constant temperature, then
(A) $P \propto d$
(B) $P \propto 1/d$
(C) $P \propto \sqrt{d}$
(D) $P \propto 1/\sqrt{d}$

7. The expression for pressure of gas and the gas equation shows that the absolute temperature of a gas is proportional to the average
(A) sum of vibrational, translational and rotational kinetic energies of molecules.
(B) translational kinetic energy of molecules.
(C) rotational kinetic energy of molecules.
(D) vibrational kinetic energy of molecules.

8. The r.m.s. speed of a gas molecule is directly proportional to _______.
(A) its absolute temperature
(B) the square root of its absolute temperature
(C) the square of its absolute temperature
(D) fourth power of its absolute temperature

9. The absolute temperature of a gas increased three times. The root mean square velocity of the gas will be _______.
(A) 3 times
(B) 9 times
(C) $\frac{1}{3}$ times
(D) $\sqrt{3}$ times

10. The kinetic energy per molecule of a gas at temperature T is _______. **[Mar 18]**
(A) $\left(\frac{3}{2}\right)RT$
(B) $\left(\frac{3}{2}\right)k_BT$
(C) $\left(\frac{2}{3}\right)RT$
(D) $\left(\frac{3}{2}\right)\left(\frac{RT}{M}\right)$

11. A vessel contains mixture of hydrogen and oxygen gases in the ratio of their masses equal to 1 : 5. The ratio of mean kinetic energy of the two gases is
(A) 5 : 16
(B) 16 : 5
(C) 1 : 16
(D) 16 : 1

12. The average kinetic energy of the molecules of a gas is
(A) inversely proportional to the absolute temperature of the gas.
(B) directly proportional to the absolute temperature of the gas.
(C) independent of the absolute temperature of the gas.
(D) independent from mass of the gas molecules.

13. If the total kinetic energy per unit volume of gas enclosed in a container is E, the pressure exerted by the gas is _______. **[July 17]**
(A) E
(B) $\frac{3}{2}E$
(C) $\sqrt{3}E$
(D) $\frac{2}{3}E$

14. The root mean square velocity of gas molecules is 10 km s^{-1}. The gas is heated till its pressure becomes 4 times. The velocity of the gas molecules will now be
(A) 10 km s^{-1}
(B) 20 km s^{-1}
(C) 40 km s^{-1}
(D) 80 km s^{-1}

R 15. The law of equipartition of energy is valid for
(A) high temperatures
(B) extremely low temperatures
(C) only absolute zero temperature
(D) temperatures within the range −273 K to −100 K.

16. For hydrogen gas C_P = 4000 cal/kg K and C_V = 3000 cal/kg K and R = 8300 J/k mol K. The value of J will be [mol. wt. of H_2 = 2]
(A) 4.18
(B) 4.17
(C) 4.16
(D) 4.15

R 17. According to the law of equipartition of energy, the average kinetic energy of one molecule of diatomic gas will be
(A) $3k_BT/2$
(B) $5k_BT/2$
(C) 3RT/2
(D) 5RT/2

R 18. If the degrees of freedom for polyatomic gas are f, then the average kinetic energy per molecule of the gas will be [N_A: Avogadro's number]
(A) fk_BT/N
(B) $fk_BT/2N$
(C) $fk_BT/2$
(D) fk_BT

19. For polyatomic molecules having 'f' vibrational modes, the ratio of two specific heats, $\frac{C_P}{C_V}$ is _______. **[Mar 16]**
(A) $\frac{1+f}{2+f}$
(B) $\frac{2+f}{3+f}$
(C) $\frac{4+f}{3+f}$
(D) $\frac{5+f}{4+f}$

20. Coefficient of emission or emissivity (e) is defined as
(A) ratio of emissive power of a surface to that of a perfectly black surface at the same temperature.
(B) product of the emissive powers of the surface and perfectly blackbody at the same temperature.
(C) ratio of emissive power of the surface to that of perfectly blackbody.
(D) product of emissive powers of the surface and perfectly blackbody.

21. If the incident energy is 200 cal, absorptive power is 0.31 and reflection coefficient is 0.41, then the amount of energy transmitted will be
(A) 48 cal
(B) 56 cal
(C) 58 cal
(D) 54 cal

Sample Content

22. A body which absorbs all the radiations incident over it is called a
(A) blackbody.
(B) perfectly blackbody.
(C) good absorber.
(D) good emitter.

23. The best ideal blackbody is
(A) lamp of charcoal heated to a high temperature.
(B) metal coated with a black dye.
(C) glass surface coated with coal tar.
(D) hollow enclosure blackened inside and having a small hole.

*24. If a = 0.72 and r = 0.24, then the value of t_r is
(A) 0.02 (B) 0.04 (C) 0.4 (D) 0.2

25. The amount of thermal radiation emitted per unit time depends on
(A) nature of emitting surface
(B) temperature of emitting surface
(C) area of emitting surface
(D) all of these

26. Find the wavelength at which a blackbody radiates maximum energy, if its temperature is 427 °C. [Wien's constant b = 2.898×10^{-3} mK] **[Mar 17]**
(A) 0.0414×10^{-6} m (B) 4.14×10^{-6} m
(C) 41.4×10^{-6} m (D) 414×10^{-6} m

27. "Good absorbers are good emitters" This statement is of
(A) Newton's law (B) Kirchhoff's law
(C) Stefan's law (D) Wien's law

28. Two stars emit maximum radiation at wavelength 3600 Å and 4800 Å respectively. The ratio of their temperature is
(A) 1 : 2 (B) 3 : 4
(C) 4 : 3 (D) 2 : 1

29. The mathematical relation of Stefan's law is
(A) $Q = \sigma T^2$ (B) $Q = \sigma T^3$
(C) $Q = \sigma T^4$ (D) $Q = \sigma T^5$

*30. The ratio of emissive power of perfectly blackbody at 1327 °C and 527 °C is
(A) 4 : 1 (B) 16 : 1
(C) 2 : 1 (D) 8 : 1

31. If wavelengths of maximum intensity of radiations emitted by the Sun and the moon are 0.5×10^{-6} m and 10^{-4} m respectively, the ratio of their temperature is
(A) 1/100 (B) 1/200
(C) 100 (D) 200

32. The temperature of a blackbody is increased by 50%. The amount of radiations emitted by the body increases by
(A) 50% (B) 100%
(C) 225% (D) 500%

33. The surface area of a blackbody maintained at 127°C radiating energy at the rate of 1459.2 J/s is ________. [$\sigma = 5.7 \times 10^{-8}$ S.I. unit]
(A) 4 m^2 (B) 3 m^2
(C) 2 m^2 (D) 1 m^2

34. The SI unit of Stefan's constant is
(A) N m/s K^4 (B) W/m K^4
(C) J/s m^2 K^4 (D) erg/s m^3 K^4

Answers to Multiple Choice Questions

1.	(A)	2.	(D)	3.	(C)	4.	(D)
5.	(C)	6.	(A)	7.	(B)	8.	(B)
9.	(D)	10.	(B)	11.	(B)	12.	(B)
13.	(D)	14.	(B)	15.	(A)	16.	(D)
17.	(B)	18.	(C)	19.	(C)	20.	(A)
21.	(B)	22.	(B)	23.	(D)	24.	(B)
25.	(D)	26.	(B)	27.	(B)	28.	(C)
29.	(C)	30.	(B)	31.	(D)	32.	(D)
33.	(D)	34.	(C)				

Hints to Multiple Choice Questions

4. From ideal gas equation,
PV = nRT
For isothermal process, T = constant
∴ PV = constant …(i)
∴ When pressure is decreased by 10%,
$$P' = P - \frac{10}{100} P$$
∴ $P' = 0.9P$ …(ii)
Now, $P'V' = PV$ …[from (i)]
∴ $\frac{V'}{V} = \frac{P}{P'} = \frac{1}{0.9}$ …[from (ii)]
∴ $\frac{V' - V}{V} = \frac{0.1}{0.9}$.
∴ $\frac{V' - V}{V} \times 100 = 0.1111 \times 100 = 11.11\%$
As, in isothermal process
$P \propto \frac{1}{V}$
V will increase by 11.11%

15. Law of equilibrium of energy cannot be applied where quantum effects become important.

24. $a + r + t_r = 1$
∴ $0.72 + 0.24 + t_r = 1$
∴ $t_r = 1 - 0.96 = 0.04$

26. According to Wien's displacement law,
$$\lambda_m = \frac{b}{T} = \frac{2.898 \times 10^{-3}}{700} = 4.14 \times 10^{-6} \text{ m}$$

30. Power (P) ∝ T^4
∴ $$\frac{P_1}{P_2} = \left(\frac{T_1}{T_2}\right)^4 = \frac{(1327 + 273)^4}{(527 + 273)^4} = \left(\frac{1600}{800}\right)^4 = 16 : 1$$

Sample Content

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