FSc Part-I · Punjab Board · English Medium

First Year Physics

Complete Notes

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Prepared by freebooks.pk — original student notes covering the Punjab Curriculum and Textbook Board (PTB/PCTB) syllabus. Each chapter includes key concepts, definitions, formulas, diagrams, solved examples, short and long questions, MCQs, revision and exam tips.

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FSc Part-I Physics — Punjab Board

CHAPTER 1

Measurements

Key Concepts · Definitions · Short & Long Questions · MCQs · Diagrams · Exam Tips

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This chapter covers Measurements from the 1st Year (FSc Part-I) Physics syllabus of the Punjab Curriculum and Textbook Board (PTB/PCTB). Physics is an experimental science based on measurement, so this chapter builds the tools every physicist needs: physical quantities and units, the International System of Units (SI), errors and uncertainties, significant figures, and dimensional analysis. These notes are prepared by freebooks.pk.

Once you can measure carefully, record results with the right number of significant figures, estimate the uncertainty, and check an equation by its dimensions, you are ready for the rest of the course. This chapter is short but forms the foundation of all practical and numerical work in Physics.

Learning Objectives

- Distinguish base and derived physical quantities and state the seven SI base units.
- Express quantities in scientific notation and use unit prefixes.
- Explain errors and uncertainties and how to reduce them.
- Apply the rules of significant figures in recording and calculating results.
- Distinguish precision and accuracy and find the least count of an instrument.
- Assess the total uncertainty in a final result.
- Find the dimensions of physical quantities and use dimensional analysis to check and derive equations.

Key Concepts

Physical Quantities: Base and Derived

A physical quantity is any quantity that can be measured, such as length, time or force. Physical quantities are of two kinds. Base (fundamental) quantities are chosen by convention and are independent of one another; there are seven of them. Derived quantities are obtained by combining base quantities through multiplication or division, for example speed (length/time), force (mass x acceleration) and density (mass/volume).

The International System of Units (SI)

To measure a quantity we compare it with a standard called a unit. The internationally agreed system is the SI, which has seven base units: the metre (m) for length, the kilogram (kg) for mass, the second (s) for time, the ampere (A) for electric current, the kelvin (K) for temperature, the mole (mol) for amount of substance and the candela (cd) for luminous intensity. All other units are derived from these, for example the newton (N = kg m s^-2) and the joule (J = N m).

Very large or very small quantities are written in scientific notation (a number between 1 and 10 multiplied by a power of ten) and are given standard prefixes such as kilo (10^3), milli (10^-3), micro (10^-6) and nano (10^-9).

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Errors and Uncertainties

No measurement is perfectly exact; every measurement has some uncertainty. Errors are of two main types. A random error causes readings to scatter above and below the true value; it can be reduced by taking several readings and using their mean. A systematic error shifts every reading in the same direction (for example a zero error in an instrument or a wrongly calibrated scale); it is reduced by correcting or replacing the instrument.

Significant Figures

The significant figures of a measurement are the digits that are reasonably reliable, that is all the certain digits plus the first uncertain digit. The main rules are: all non-zero digits are significant; zeros between non-zero digits are significant; trailing zeros after a decimal point are significant; and in a calculation the result should not have more significant figures than the least precise measurement used. In addition and subtraction the answer is rounded to the least number of decimal places; in multiplication and division it is rounded to the least number of significant figures.

Precision and Accuracy

Precision and accuracy are different ideas. Precision refers to how finely a measurement is made and is linked to the least count of the instrument (the smallest reading it can take); a smaller least count means greater precision, shown by a smaller absolute uncertainty. Accuracy refers to how close a measurement is to the true value and is linked to the fractional or percentage uncertainty. A measurement can be precise without being accurate, and vice versa.

The least count of vernier callipers is 0.1 mm and that of a micrometer screw gauge is 0.01 mm, so the screw gauge is the more precise of the two.

Assessment of Total Uncertainty

The uncertainty in a final result is found from the uncertainties in the measured quantities using simple rules. For addition and subtraction, add the absolute uncertainties. For multiplication and division, add the percentage (fractional) uncertainties. For a power, multiply the percentage uncertainty by the power. For a mean of several readings, the uncertainty is the mean of the deviations. For a timing experiment, the uncertainty is the least count of the timer divided by the number of oscillations.

Dimensions and Dimensional Analysis

The dimensions of a physical quantity show how it is related to the base quantities mass (M), length (L) and time (T). For example, the dimensions of velocity are [LT^-1], of acceleration [LT^-2] and of force [MLT^-2]. Dimensional analysis has two main uses: to check whether an equation is correct (both sides must have the same dimensions, the principle of homogeneity) and to derive the possible form of a relationship between quantities. Its limitation is that it cannot find dimensionless constants (such as the number 2 or the factor 2 pi) and cannot be used when a quantity depends on more than three others.

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Important Definitions

Term	Definition
Physical quantity	Any quantity that can be measured, such as length, time or force.
Base quantity	A fundamental quantity chosen by convention and independent of others; there are seven.
Derived quantity	A quantity obtained by combining base quantities, such as speed, force or density.
SI units	The International System of Units, with seven base units (m, kg, s, A, K, mol, cd).
Significant figures	The reliable digits in a measurement: all certain digits plus the first uncertain one.
Least count	The smallest reading that an instrument can measure.
Precision	How finely a measurement is made; linked to the least count and the absolute uncertainty.
Accuracy	How close a measurement is to the true value; linked to the fractional or percentage uncertainty.
Dimensions	The powers to which the base quantities M, L and T are raised in a physical quantity.

Formulas & Rules

Item	Fact
SI base units	metre (m), kilogram (kg), second (s), ampere (A), kelvin (K), mole (mol), candela (cd)
Least count (vernier)	smallest main-scale division / number of vernier divisions = 1 mm / 10 = 0.1 mm
Least count (micrometer)	pitch / number of circular-scale divisions = 0.5 mm / 50 = 0.01 mm
Addition / subtraction	add the absolute uncertainties
Multiplication / division	add the percentage uncertainties
Power	multiply the percentage uncertainty by the power
Dimensions of force	[MLT^-2]
Dimensions of energy / work	[ML^2T^-2]

Diagrams & Illustrations

SI base quantities and units: a table of the seven SI base quantities with their units and symbols (length/metre/m, mass/kilogram/kg, time/second/s, electric current/ampere/A, temperature/kelvin/K, amount of substance/mole/mol, luminous intensity/candela/cd).

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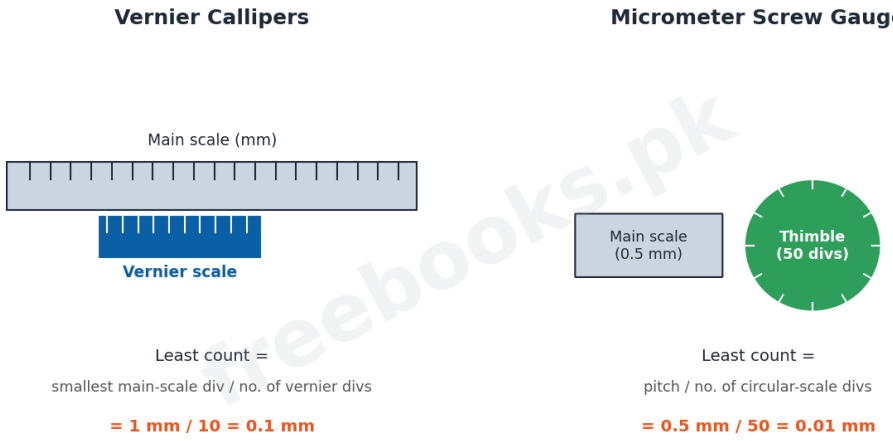
SI Base Quantities and Units

Base Quantity	Unit	Symbol
Length	metre	**m**
Mass	kilogram	**kg**
Time	second	**s**
Electric current	ampere	**A**
Temperature	kelvin	**K**
Amount of substance	mole	**mol**
Luminous intensity	candela	**cd**

All physical quantities are derived from these seven base units.

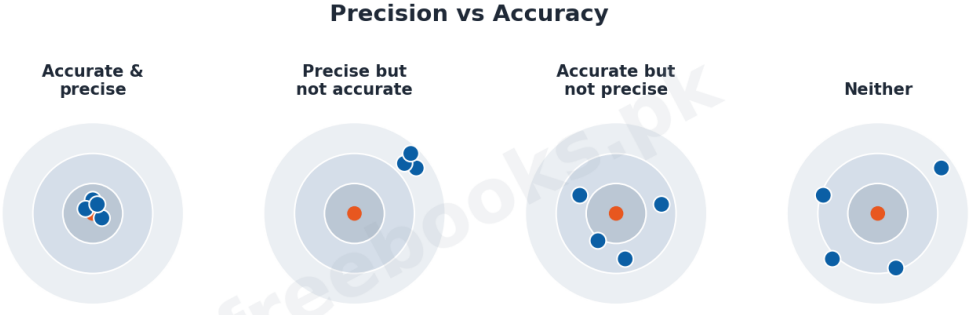
SI base quantities and units

Measuring instruments: schematic diagrams of vernier callipers (least count 0.1 mm) and a micrometer screw gauge (least count 0.01 mm), showing how the least count is calculated.



Measuring instruments

Precision versus accuracy: four target diagrams showing accurate-and-precise, precise-but-not-accurate, accurate-but-not-precise, and neither.



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Solved Examples & Numericals

Significant figures

Round 3.4567 to three significant figures. Counting from the first non-zero digit, the first three significant figures are 3, 4 and 5; the next digit (6) rounds the 5 up, giving 3.46.

Uncertainty in addition

Two lengths are measured as 12.5 +/- 0.1 cm and 8.3 +/- 0.1 cm. Their sum is 20.8 cm, and because we add absolute uncertainties, the uncertainty is 0.1 + 0.1 = 0.2 cm, so the result is 20.8 +/- 0.2 cm.

Dimensional check

Check the equation v = u + at. The dimensions of v and u are [LT^-1]; the dimensions of at are [LT^-2][T] = [LT^-1]. Since every term has the dimensions [LT^-1], the equation is dimensionally correct (homogeneous).

Least count reading

A micrometer screw gauge has a pitch of 0.5 mm and 50 divisions on its circular scale. Its least count is 0.5 mm / 50 = 0.01 mm, so it can measure to the nearest hundredth of a millimetre.

Short Questions & Answers

Q1. Differentiate between base and derived quantities.
Ans. Base quantities are fundamental and independent (there are seven), while derived quantities are obtained by combining base quantities, such as speed or force.

Q2. Why is the mean of several readings taken?
Ans. To reduce random error; averaging readings that scatter above and below the true value gives a value closer to the true one.

Q3. Differentiate between random and systematic errors.
Ans. A random error scatters readings both ways and is reduced by averaging; a systematic error shifts all readings the same way and is reduced by correcting the instrument.

Q4. Differentiate between precision and accuracy.
Ans. Precision is how finely a measurement is made (linked to least count), while accuracy is how close it is to the true value (linked to fractional uncertainty).

Q5. What is the least count of a micrometer screw gauge?
Ans. 0.01 mm (pitch 0.5 mm divided by 50 circular-scale divisions).

Q6. State two uses of dimensional analysis.

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Ans. To check whether an equation is dimensionally correct, and to derive the possible form of a relationship between physical quantities.

Long Questions & Answers

Q1: Explain base and derived quantities and the SI system of units.

A physical quantity is anything that can be measured, and physical quantities are of two kinds. Base or fundamental quantities are chosen by convention and are independent of one another; there are seven of them, and the SI assigns each a base unit: length (metre), mass (kilogram), time (second), electric current (ampere), temperature (kelvin), amount of substance (mole) and luminous intensity (candela). Derived quantities are formed by multiplying or dividing base quantities, for example speed is length divided by time and force is mass times acceleration; their units are derived units such as the newton and the joule. Using one agreed system (the SI) means measurements made anywhere in the world can be compared, which is why it is used in all scientific and technical work.

Q2: Explain errors and uncertainties, and state the rules for assessing the total uncertainty in a result.

No measurement is perfectly exact, so every measurement carries an uncertainty. Errors are of two types: random errors, which scatter readings above and below the true value and are reduced by taking the mean of several readings, and systematic errors, which shift every reading in the same direction (for example a zero error) and are reduced by correcting or replacing the instrument. When measured quantities are combined, the uncertainty in the final result is assessed by simple rules: for addition and subtraction the absolute uncertainties are added; for multiplication and division the percentage uncertainties are added; for a power the percentage uncertainty is multiplied by the power; for a mean the uncertainty is the mean of the deviations; and for a timing experiment the uncertainty is the least count of the timer divided by the number of oscillations. Recording the result with the correct significant figures then reflects this uncertainty honestly.

Q3: What is dimensional analysis? Give its uses and limitations with an example.

The dimensions of a physical quantity express it in terms of the base quantities mass (M), length (L) and time (T); for example force has the dimensions [MLT^-2]. Dimensional analysis uses these to work with equations. Its first use is to check the correctness of an equation: by the principle of homogeneity, every term on both sides must have the same dimensions, so an equation like v = u + at is confirmed because each term has the dimensions [LT^-1]. Its second use is to derive the possible form of a relationship; for instance the time period of a simple pendulum can be shown to depend on the square root of length divided by g, giving T proportional to the square root of (l/g). Its limitations are that it cannot find dimensionless constants (such as the factor 2 pi in the pendulum formula) and cannot handle a quantity that depends on more than three other quantities.

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MCQs with Answers

1. The number of SI base units is:

(a) five (b) six (c) seven (d) eight

Correct Answer: (c) seven. There are seven SI base units.

2. The SI unit of amount of substance is the:

(a) mole (b) candela (c) kelvin (d) ampere

Correct Answer: (a) mole. The mole (mol) measures amount of substance.

3. Which is a derived quantity?

(a) length (b) mass (c) time (d) force

Correct Answer: (d) force. Force is derived from mass and acceleration.

4. A zero error in an instrument is an example of a:

(a) random error (b) systematic error (c) personal error (d) no error

Correct Answer: (b) systematic error. A zero error shifts every reading the same way, so it is systematic.

5. The least count of vernier callipers is:

(a) 1 mm (b) 0.5 mm (c) 0.1 mm (d) 0.01 mm

Correct Answer: (c) 0.1 mm. 1 mm divided by 10 vernier divisions = 0.1 mm.

6. The number of significant figures in 0.00580 is:

(a) two (b) three (c) four (d) five

Correct Answer: (b) three. 5, 8 and the trailing 0 are significant, giving three.

7. The dimensions of force are:

(a) [MLT^-1] (b) [MLT^-2] (c) [ML^2T^-2] (d) [ML^-1T^-2]

Correct Answer: (b) [MLT^-2]. Force = mass x acceleration = [M][LT^-2] = [MLT^-2].

8. In multiplication and division, uncertainties are combined by adding the:

(a) absolute uncertainties (b) percentage uncertainties (c) squares (d) least counts

Correct Answer: (b) percentage uncertainties. Add the percentage (fractional) uncertainties.

9. Random error can be reduced by:

(a) using a better zero (b) taking the mean of several readings (c) a single careful reading (d) changing units

Correct Answer: (b) taking the mean of several readings. Averaging several readings reduces random scatter.

10. Dimensional analysis cannot find:

(a) dimensions of force (b) dimensionless constants (c) unit of energy (d) homogeneity

Correct Answer: (b) dimensionless constants. It cannot determine dimensionless constants such as 2 pi.

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Quick Revision Summary

- Physical quantities are base (seven) or derived; SI base units are m, kg, s, A, K, mol, cd.
- Random errors scatter readings (reduce by averaging); systematic errors shift them (reduce by correcting the instrument).
- Significant figures: keep certain digits plus the first uncertain one; round to the least precise measurement.
- Precision is linked to least count (absolute uncertainty); accuracy to fractional/ percentage uncertainty.
- Least count: vernier 0.1 mm, micrometer 0.01 mm.
- Uncertainty: add absolute (sum/difference), add percentage (product/quotient), multiply percentage by power.
- Dimensions: force [MLT^-2], energy [ML^2T^-2]; use for checking and deriving equations. Notes by freebooks.pk.

Exam Tips

- Learn the seven SI base units and their symbols by heart; a guaranteed MCQ.
- State BOTH the type of error and how to reduce it in error questions.
- For significant-figure questions, apply the addition rule (decimal places) and the multiplication rule (significant figures) correctly.
- Remember least counts: vernier 0.1 mm, micrometer 0.01 mm.
- Practise dimensional checks (v = u + at) and the pendulum derivation.
- Do not confuse precision (least count) with accuracy (closeness to the true value).

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CHAPTER 2

Vectors and Equilibrium

Key Concepts · Definitions · Short & Long Questions · MCQs · Diagrams · Exam Tips

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This chapter covers Vectors and Equilibrium from the 1st Year (FSc Part-I) Physics syllabus of the Punjab Curriculum and Textbook Board (PTB/PCTB). Many physical quantities, such as force and velocity, have both magnitude and direction and are called vectors. This chapter teaches how to resolve, add and multiply vectors, and how to apply the idea of torque and the conditions of equilibrium. These notes are prepared by freebooks.pk.

Mastering vectors is essential because they are used throughout mechanics. You will learn to break a vector into rectangular components, add vectors by components, take scalar and vector products, and decide when a body is in equilibrium.

Learning Objectives

- Distinguish scalars and vectors and represent vectors graphically.
- Resolve a vector into its rectangular components and reconstruct it.
- Add vectors by the method of rectangular components.
- Define unit vectors and the position vector.
- Find the scalar (dot) and vector (cross) products of two vectors.
- Define torque and state the two conditions of equilibrium.
- Distinguish stable, unstable and neutral equilibrium.

Key Concepts

Scalars and Vectors

A scalar quantity has only magnitude, such as mass, time or temperature, and is completely specified by a number with a unit. A vector quantity has both magnitude and direction, such as displacement, velocity, acceleration and force, and must be specified by both. A vector is represented by a directed line segment whose length shows the magnitude and whose arrow shows the direction.

Rectangular Components of a Vector

A vector can be resolved (split) into two mutually perpendicular components along the x and y axes. If a vector A makes an angle theta with the x-axis, its components are Ax = A cos(theta) along the x-axis and Ay = A sin(theta) along the y-axis. Conversely, the magnitude is A = sqrt(Ax^2 + Ay^2) and the direction is theta = tan^-1(Ay/Ax).

Addition of Vectors by Rectangular Components

To add several vectors, resolve each into its x and y components, add all the x-components to get Rx and all the y-components to get Ry. The resultant has magnitude R = sqrt(Rx^2 + Ry^2) and direction theta = tan^-1(Ry/Rx). This method is exact and works for any number of vectors.

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Unit Vectors and the Position Vector

A unit vector has a magnitude of one and only shows direction; the unit vectors along the x, y and z axes are written i, j and k. Any vector can be written in terms of unit vectors, for example A = Ax i + Ay j. The position vector r locates a point relative to the origin and is written r = x i + y j.

Product of Two Vectors

There are two ways to multiply vectors. The scalar or dot product is A . B = AB cos(theta) and gives a scalar; it is maximum when the vectors are parallel and zero when they are perpendicular. The vector or cross product is A x B = AB sin(theta) n, where n is a unit vector perpendicular to both; it gives a vector, is zero for parallel vectors and maximum for perpendicular vectors, and its direction is given by the right-hand rule.

Torque

Torque (the moment of a force) measures the turning effect of a force about a point or axis. It is the product of the force and the perpendicular distance (moment arm) from the axis to the line of action of the force: torque = F x d = rF sin(theta). Torque is a vector; a force whose line of action passes through the axis produces no torque.

Conditions of Equilibrium and Its Types

A body is in equilibrium when it is at rest or moving with uniform velocity. There are two conditions. The first condition is that the vector sum of all forces is zero (sum of forces = 0), which prevents linear acceleration. The second condition is that the sum of all torques about any point is zero (sum of torques = 0), which prevents angular acceleration. A body in complete equilibrium satisfies both. Equilibrium is of three kinds: stable (the body returns to its original position when slightly displaced), unstable (it moves further away) and neutral (it stays in its new position).

Important Definitions

Term	Definition
Scalar	A quantity that has magnitude only, such as mass or time.
Vector	A quantity that has both magnitude and direction, such as force or velocity.
Unit vector	A vector of magnitude one that shows only direction.
Resultant	The single vector that has the same effect as two or more vectors combined.
Scalar (dot) product	A . B = AB cos(theta); the product of two vectors giving a scalar.
Vector (cross) product	A x B = AB sin(theta) n; the product of two vectors giving a vector perpendicular to both.
Torque	The turning effect of a force, equal to force times moment arm.

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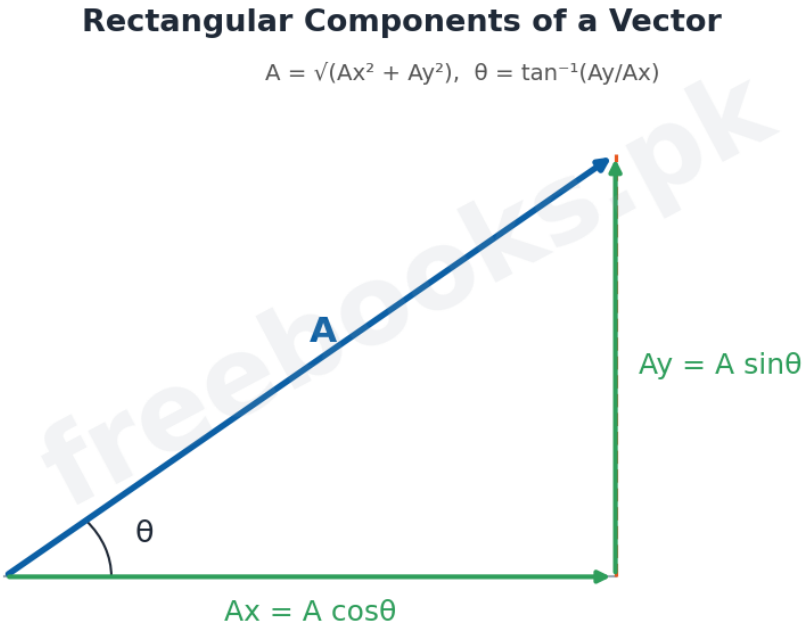
Term	Definition
Equilibrium	The state of a body at rest or moving with uniform velocity, with zero net force and zero net torque.

Formulas & Rules

Item	Fact
Components	Ax = A cos(theta), Ay = A sin(theta)
Magnitude and direction	A = sqrt(Ax^2 + Ay^2), theta = tan^-1(Ay/Ax)
Resultant by components	Rx = sum of x-components, Ry = sum of y-components; R = sqrt(Rx^2 + Ry^2)
Dot product	A . B = AB cos(theta) (scalar)
Cross product	A x B = AB sin(theta) n (vector)
Torque	torque = F x d = rF sin(theta)
Equilibrium	first condition: sum of forces = 0; second condition: sum of torques = 0

Diagrams & Illustrations

Rectangular components: a vector A resolved into its x-component (A cos theta) and y-component (A sin theta), with the angle theta shown at the origin.



Rectangular components

Scalar and vector products: two panels comparing the dot product (A . B = AB cos theta, a scalar) and the cross product (A x B = AB sin theta n, a vector perpendicular to both).

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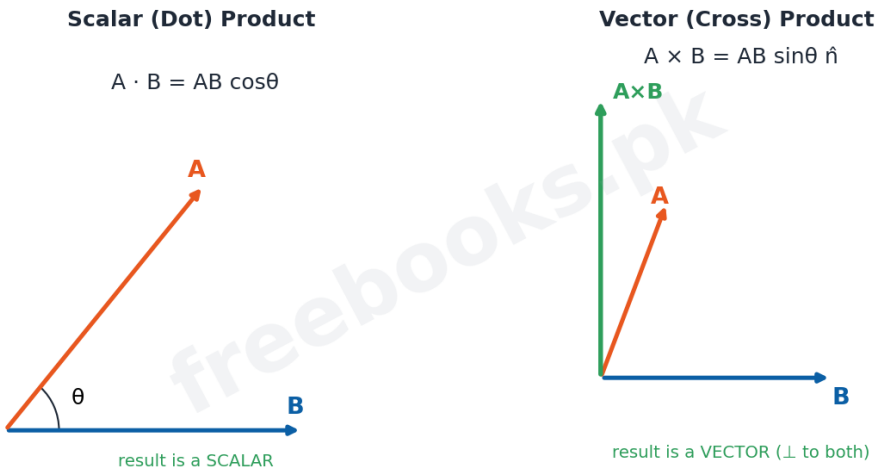
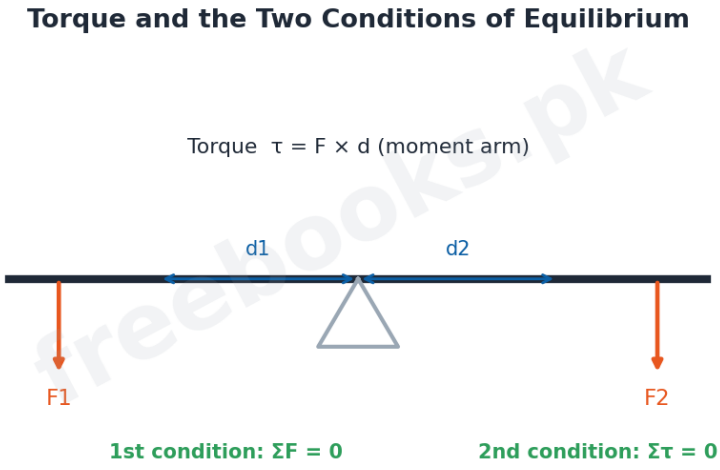


Scalar and vector products

Torque and equilibrium: a balanced see-saw showing two forces and their moment arms, illustrating torque and the two conditions of equilibrium (sum of forces zero and sum of torques zero).



Torque and equilibrium

Solved Examples & Numericals

Resolving a vector

A force of 10 N acts at 30 degrees to the x-axis. Its components are Fx = 10 cos30 = 8.66 N and Fy = 10 sin30 = 5 N.

Dot product

If A = 3 units along x and B = 4 units along x (parallel), then A . B = AB cos0 = 3 x 4 x 1 = 12 (a scalar).

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Cross product magnitude

Two perpendicular vectors of magnitudes 3 and 4 give a cross product of magnitude AB sin90 = 3 x 4 x 1 = 12, directed perpendicular to both.

Torque

A force of 20 N acts at the end of a spanner 0.25 m long, perpendicular to it. The torque is F x d = 20 x 0.25 = 5 N m.

Short Questions & Answers

Q1. Differentiate between scalars and vectors.
Ans. A scalar has magnitude only (such as mass); a vector has both magnitude and direction (such as force).

Q2. What is a unit vector?
Ans. A vector of magnitude one that only indicates direction, such as i, j and k.

Q3. When is the dot product of two vectors zero?
Ans. When the vectors are perpendicular, because cos90 = 0.

Q4. When is the cross product of two vectors zero?
Ans. When the vectors are parallel, because sin0 = 0.

Q5. Define torque.
Ans. The turning effect of a force about an axis, equal to the force times the perpendicular moment arm.

Q6. State the two conditions of equilibrium.
Ans. The sum of all forces is zero, and the sum of all torques about any point is zero.

Long Questions & Answers

Q1: Explain how two or more vectors are added by the method of rectangular components.

To add several vectors accurately, each vector is first resolved into its rectangular components along the x and y axes; for a vector A at angle theta these are Ax = A cos(theta) and Ay = A sin(theta). Next, all the x-components are added together to give the x-component of the resultant, Rx, and all the y-components are added to give Ry. The magnitude of the resultant is then found from R = sqrt(Rx^2 + Ry^2), and its direction from theta = tan^-1(Ry/Rx), with the quadrant decided by the signs of Rx and Ry. This method is exact, works for any number of vectors, and is more reliable than graphical methods.

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Q2: Distinguish between the scalar and vector products of two vectors and give their properties.

Two vectors can be multiplied in two different ways. The scalar (dot) product is defined as A . B = AB cos(theta) and always gives a scalar; it is commutative (A . B = B . A), is maximum when the vectors are parallel, and is zero when they are perpendicular. Work done by a force is an example of a dot product. The vector (cross) product is defined as A x B = AB sin(theta) n, where n is a unit vector perpendicular to the plane of A and B given by the right-hand rule; it always gives a vector, is not commutative (A x B = -B x A), is zero when the vectors are parallel, and is maximum when they are perpendicular. Torque is an example of a cross product.

Q3: State and explain the two conditions of equilibrium, and describe the types of equilibrium.

A body is in equilibrium if it is at rest or moving with uniform velocity, and this requires two conditions. The first (translational) condition is that the vector sum of all the forces acting on the body is zero, so there is no linear acceleration. The second (rotational) condition is that the sum of all the torques about any point is zero, so there is no angular acceleration. A body in complete equilibrium must satisfy both conditions together. Equilibrium is of three types: in stable equilibrium a body returns to its original position after a small displacement (its centre of gravity rises when displaced); in unstable equilibrium it moves further from its position (its centre of gravity falls); and in neutral equilibrium it remains in its new position (its centre of gravity stays at the same height).

MCQs with Answers

1. Which of the following is a vector quantity?
(a) mass (b) time (c) force (d) temperature
Correct Answer: (c) force. Force has both magnitude and direction.

2. The x-component of a vector A at angle theta is:
(a) A sin(theta) (b) A cos(theta) (c) A tan(theta) (d) A
Correct Answer: (b) A cos(theta). Ax = A cos(theta).

3. A unit vector has a magnitude of:
(a) zero (b) one (c) two (d) infinity
Correct Answer: (b) one. A unit vector has magnitude one.

4. The dot product of two perpendicular vectors is:
(a) maximum (b) zero (c) negative (d) one
Correct Answer: (b) zero. cos90 = 0, so the dot product is zero.

5. The cross product of two parallel vectors is:
(a) maximum (b) zero (c) AB (d) one
Correct Answer: (b) zero. sin0 = 0, so the cross product is zero.

6. The dot product A . B is equal to:

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(a) AB sin(theta) (b) AB cos(theta) (c) AB tan(theta) (d) AB
Correct Answer: (b) AB cos(theta). A . B = AB cos(theta).

7. Torque is equal to:
(a) F/d (b) F + d (c) F x d (moment arm) (d) F - d
Correct Answer: (c) F x d (moment arm). Torque = force times moment arm.

8. The result of a cross product is a:
(a) scalar (b) vector (c) number (d) unit
Correct Answer: (b) vector. The cross product gives a vector.

9. The first condition of equilibrium states that:
(a) sum of torques is zero (b) sum of forces is zero (c) velocity is zero (d) mass is constant
Correct Answer: (b) sum of forces is zero. The vector sum of forces is zero.

10. A body that returns to its position after a small displacement is in ___ equilibrium:
(a) unstable (b) neutral (c) stable (d) dynamic
Correct Answer: (c) stable. This is stable equilibrium.

Quick Revision Summary

- Scalars have magnitude only; vectors have magnitude and direction.
- Components: Ax = A cos(theta), Ay = A sin(theta); magnitude A = sqrt(Ax^2 + Ay^2).
- Add vectors by components: Rx = sum of x, Ry = sum of y; R = sqrt(Rx^2 + Ry^2).
- Dot product A . B = AB cos(theta) (scalar); cross product A x B = AB sin(theta) n (vector).
- Torque = force x moment arm; it is the turning effect of a force.
- Equilibrium: sum of forces = 0 (first) and sum of torques = 0 (second).
- Equilibrium types: stable, unstable, neutral. Notes by freebooks.pk.

Exam Tips

- Practise resolving vectors and adding by components; a common numerical.
- Remember: dot product is a scalar, cross product is a vector.
- Dot product zero means perpendicular; cross product zero means parallel.
- State BOTH conditions of equilibrium in equilibrium questions.
- Torque depends on the perpendicular moment arm, not just the force.
- Link the equilibrium types to how the centre of gravity moves.

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FSc Part-I Physics — Punjab Board

CHAPTER 3

Motion and Force

Key Concepts · Definitions · Short & Long Questions · MCQs · Diagrams · Exam Tips

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This chapter covers Motion and Force from the 1st Year (FSc Part-I) Physics syllabus of the Punjab Curriculum and Textbook Board (PTB/PCTB). It studies how objects move, the equations of motion, Newton's laws, momentum and its conservation, and projectile motion. These notes are prepared by freebooks.pk.

Motion and force are at the heart of mechanics. You will learn the equations that link displacement, velocity and acceleration, Newton's three laws, the very important law of conservation of momentum, and how projectiles move.

Learning Objectives

- Define displacement, velocity and acceleration and use the equations of motion.
- State and explain Newton's three laws of motion.
- Define momentum and impulse and relate force to the rate of change of momentum.
- State and apply the law of conservation of momentum.
- Distinguish elastic and inelastic collisions.
- Describe projectile motion and find its range, height and time of flight.

Key Concepts

Motion and the Equations of Motion

Displacement is the change in position of a body in a particular direction; velocity is the rate of change of displacement and acceleration is the rate of change of velocity. For uniformly accelerated motion in a straight line, three equations of motion are used: v = u + at, s = ut + (1/2)at^2 and v^2 = u^2 + 2as, where u is the initial velocity, v the final velocity, a the acceleration, t the time and s the displacement.

Newton's Laws of Motion

Newton's first law (the law of inertia) states that a body remains at rest or in uniform motion unless acted upon by a net external force. The second law states that the rate of change of momentum of a body is proportional to the applied force and takes place in the direction of the force, giving F = ma. The third law states that to every action there is an equal and opposite reaction.

Momentum and Impulse

The linear momentum of a body is the product of its mass and velocity, p = mv, and is a vector. Newton's second law can be written as force equals the rate of change of momentum, F = (change in p)/(time). The impulse of a force is the product of the force and the time for which it acts, and equals the change in momentum: impulse = F t = change in p.

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Law of Conservation of Momentum

The law of conservation of momentum states that if no external force acts on a system, its total momentum remains constant. For two bodies colliding, m1u1 + m2u2 = m1v1 + m2v2. This law follows directly from Newton's third law and is one of the most important principles in physics, used to analyse collisions and explosions.

Elastic and Inelastic Collisions

In an elastic collision both momentum and kinetic energy are conserved, and the bodies separate after impact. In an inelastic collision momentum is conserved but some kinetic energy is lost (converted to heat, sound or deformation); in a perfectly inelastic collision the bodies stick together after impact.

Projectile Motion

A projectile is a body thrown into the air that moves under gravity alone. Its motion has two independent parts: a constant horizontal velocity and a vertical motion with acceleration g. For a projectile launched with speed v at angle theta, the time of flight is (2 v sin theta)/g, the maximum height is (v^2 sin^2 theta)/(2g) and the horizontal range is (v^2 sin 2theta)/g. The range is maximum when theta is 45 degrees.

Important Definitions

Term	Definition
Displacement	The change in position of a body in a specified direction.
Velocity	The rate of change of displacement; a vector.
Acceleration	The rate of change of velocity; a vector.
Momentum	The product of mass and velocity, p = mv; a vector.
Impulse	The product of force and the time for which it acts; equals the change in momentum.
Newton's first law	A body stays at rest or in uniform motion unless acted on by a net force.
Conservation of momentum	If no external force acts, the total momentum of a system stays constant.
Projectile	A body moving through the air under the action of gravity only.

Formulas & Rules

Item	Fact
Equations of motion	v = u + at; s = ut + (1/2)at^2; v^2 = u^2 + 2as
Newton's second law	F = ma = (change in momentum)/(time)
Momentum	p = mv

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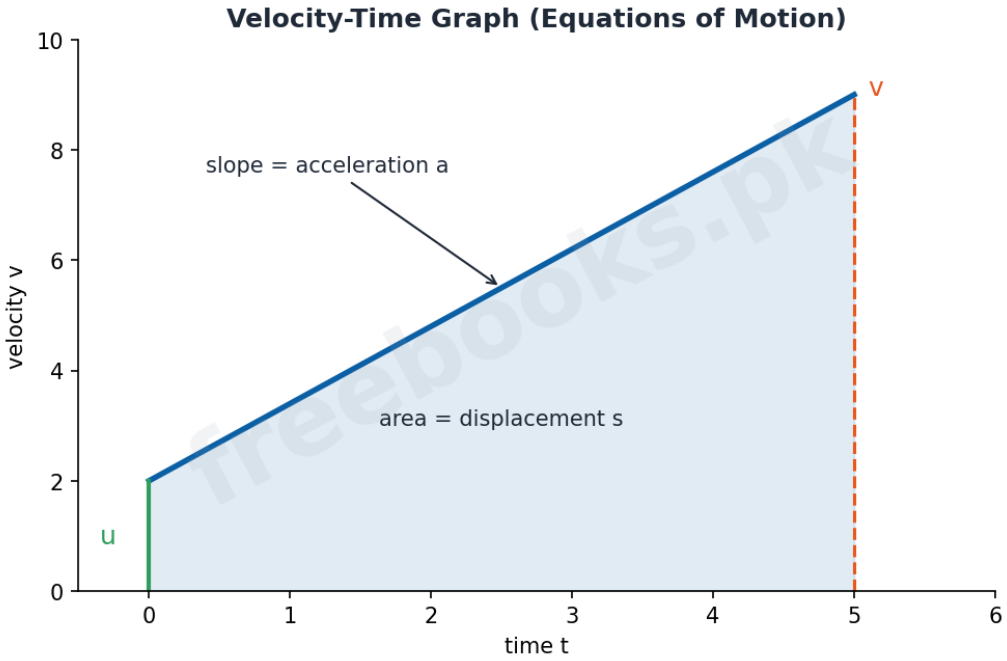
Item	Fact
Impulse	impulse = F t = change in momentum
Conservation of momentum	m1u1 + m2u2 = m1v1 + m2v2
Time of flight	(2 v sin theta)/g
Maximum height	(v^2 sin^2 theta)/(2g)
Range	(v^2 sin 2theta)/g; maximum at theta = 45 degrees

Diagrams & Illustrations

Velocity-time graph: a velocity-time graph in which the slope of the line gives the acceleration and the area under the line gives the displacement, illustrating the equations of motion.



Velocity-time graph

Projectile motion: the parabolic path of a projectile launched at an angle, with the horizontal component (v cos theta), vertical component (v sin theta), maximum height and horizontal range marked.

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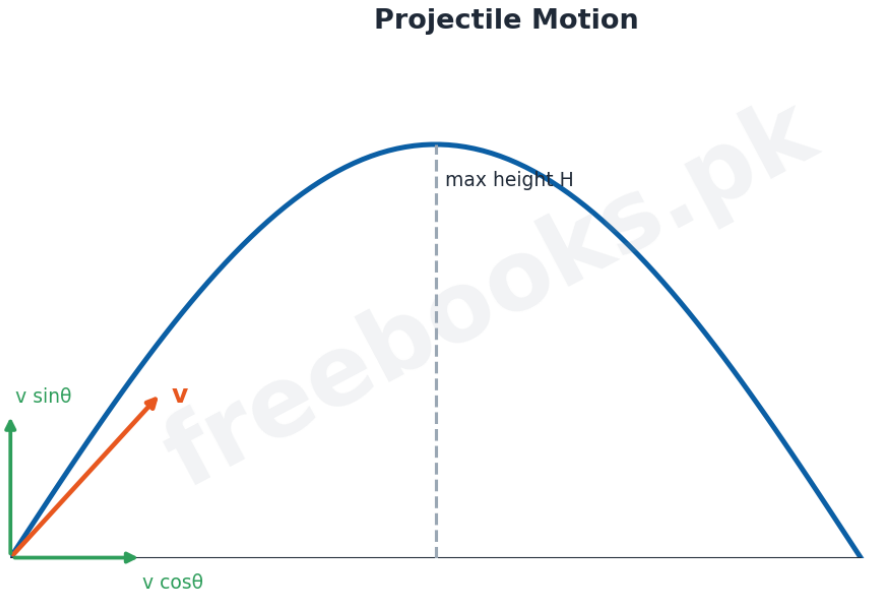
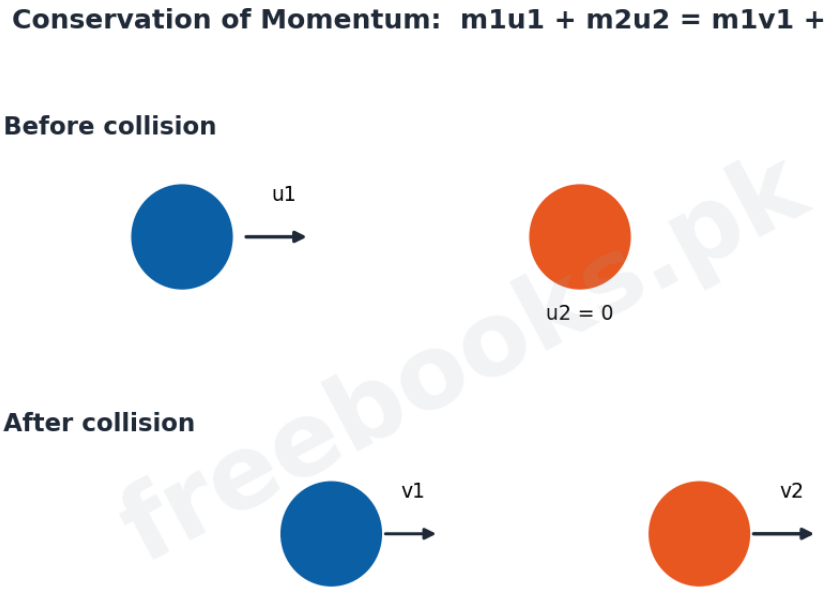


Projectile motion

Conservation of momentum: a collision between two bodies before and after impact, showing that the total momentum m1u1 + m2u2 before equals m1v1 + m2v2 after.



Conservation of momentum

Solved Examples & Numericals

Equation of motion

A car starts from rest and accelerates at 2 m/s^2 for 5 s. Its final velocity is v = u + at = 0 + 2 x 5 = 10 m/s, and the distance is s = ut + (1/2)at^2 = 0 + (1/2)(2)(25) = 25 m.

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Momentum

A ball of mass 0.5 kg moves at 4 m/s. Its momentum is p = mv = 0.5 x 4 = 2 kg m/s.

Conservation of momentum

A 2 kg trolley moving at 3 m/s hits a stationary 1 kg trolley and they stick together. By conservation of momentum, 2 x 3 = (2 + 1) v, so v = 2 m/s.

Projectile range

A ball is thrown at 20 m/s at 45 degrees (g = 10 m/s^2). Its range is (v^2 sin 2theta)/g = (400 x 1)/10 = 40 m.

Short Questions & Answers

Q1. State Newton's first law of motion.
Ans. A body remains at rest or in uniform motion in a straight line unless acted upon by a net external force.

Q2. Define momentum.
Ans. The product of the mass and velocity of a body, p = mv; it is a vector quantity.

Q3. What is impulse?
Ans. The product of a force and the time for which it acts; it equals the change in momentum.

Q4. State the law of conservation of momentum.
Ans. If no external force acts on a system, its total momentum remains constant.

Q5. Differentiate elastic and inelastic collisions.
Ans. In an elastic collision both momentum and kinetic energy are conserved; in an inelastic collision momentum is conserved but some kinetic energy is lost.

Q6. At what angle is the range of a projectile maximum?
Ans. At 45 degrees, because sin 2theta is maximum (equal to 1) at that angle.

Long Questions & Answers

Q1: State and explain Newton's three laws of motion.

Newton's laws describe how forces affect motion. The first law, or law of inertia, states that a body remains at rest or continues to move with uniform velocity in a straight line unless a net external force acts on it; this defines force as the agent that changes a body's state of motion. The second law states that the rate of change of momentum of a body is directly proportional to the applied force and occurs in the direction of the force; for constant mass this gives the familiar equation F = ma, so a given force produces a smaller acceleration in a more massive body. The third law states that to every action there is an equal and opposite reaction; the two forces act on different bodies, which is why they do not cancel and why, for example, a gun recoils when a bullet is fired.

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Q2: State and prove the law of conservation of momentum for two colliding bodies.

The law of conservation of momentum states that in the absence of an external force, the total momentum of a system remains constant. Consider two bodies of masses m1 and m2 moving with velocities u1 and u2 that collide and afterwards move with velocities v1 and v2. During the collision each exerts a force on the other; by Newton's third law these forces are equal and opposite and act for the same time, so the impulses are equal and opposite and the changes in momentum are equal and opposite. Therefore the momentum gained by one body equals the momentum lost by the other, and the total momentum before the collision equals the total momentum after it: m1u1 + m2u2 = m1v1 + m2v2. This law is used to analyse collisions, explosions and rocket propulsion.

Q3: Describe projectile motion and derive expressions for its time of flight, maximum height and range.

A projectile is a body that moves through the air under gravity alone, and its motion is treated as two independent motions: a uniform horizontal velocity v cos theta and a vertical motion with initial velocity v sin theta and downward acceleration g. The time of flight is found from the vertical motion: the projectile rises, stops momentarily and falls back, giving a total time of (2 v sin theta)/g. The maximum height is reached when the vertical velocity becomes zero, giving H = (v^2 sin^2 theta)/(2g). The horizontal range is the horizontal velocity multiplied by the time of flight, R = v cos theta x (2 v sin theta)/g = (v^2 sin 2theta)/g. Since sin 2theta is greatest at theta = 45 degrees, the range is maximum at that angle.

MCQs with Answers

1. Which equation of motion does NOT contain time?
(a) v = u + at (b) s = ut + (1/2)at^2 (c) v^2 = u^2 + 2as (d) s = vt
Correct Answer: (c) v^2 = u^2 + 2as. v^2 = u^2 + 2as has no t.

2. Newton's second law gives the equation:
(a) F = mv (b) F = ma (c) F = m/a (d) F = m + a
Correct Answer: (b) F = ma. F = ma.

3. The momentum of a body is:
(a) mv (b) ma (c) m/v (d) mgh
Correct Answer: (a) mv. Momentum p = mv.

4. Impulse is equal to the change in:
(a) velocity (b) momentum (c) energy (d) force
Correct Answer: (b) momentum. Impulse equals the change in momentum.

5. In an elastic collision, the quantity conserved besides momentum is:
(a) mass (b) kinetic energy (c) charge (d) volume
Correct Answer: (b) kinetic energy. Kinetic energy is conserved in an elastic collision.

6. The law of conservation of momentum follows from Newton's ___ law:

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(a) first (b) second (c) third (d) law of gravitation
Correct Answer: (c) third. It follows from the third law.

7. The range of a projectile is maximum at an angle of:
(a) 30 degrees (b) 45 degrees (c) 60 degrees (d) 90 degrees
Correct Answer: (b) 45 degrees. Range is maximum at 45 degrees.

8. The horizontal component of a projectile's velocity:
(a) increases (b) decreases (c) remains constant (d) becomes zero
Correct Answer: (c) remains constant. It stays constant (no horizontal force).

9. The SI unit of momentum is:
(a) N (b) J (c) kg m/s (d) m/s
Correct Answer: (c) kg m/s. Momentum is measured in kg m/s.

10. A body moving with uniform velocity has:
(a) increasing momentum (b) zero acceleration (c) increasing force (d) zero velocity
Correct Answer: (b) zero acceleration. Uniform velocity means zero acceleration.

Quick Revision Summary

- Equations of motion: v = u + at; s = ut + (1/2)at^2; v^2 = u^2 + 2as.
- Newton: 1st (inertia), 2nd (F = ma = rate of change of momentum), 3rd (action-reaction).
- Momentum p = mv; impulse = F t = change in momentum.
- Conservation of momentum: m1u1 + m2u2 = m1v1 + m2v2 (no external force).
- Elastic: momentum + kinetic energy conserved; inelastic: only momentum.
- Projectile: range = (v^2 sin 2theta)/g, maximum at 45 degrees. Notes by freebooks.pk.

Exam Tips

- Pick the equation of motion that has the three known quantities plus the unknown.
- State each Newton law precisely and give an example.
- Conservation of momentum questions: total momentum before = total after.
- For projectiles, treat horizontal and vertical motions separately.
- Remember range is maximum at 45 degrees.
- Momentum and impulse are vectors; keep directions consistent.

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CHAPTER 4

Work and Energy

Key Concepts · Definitions · Short & Long Questions · MCQs · Diagrams · Exam Tips

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This chapter covers Work and Energy from the 1st Year (FSc Part-I) Physics syllabus of the Punjab Curriculum and Textbook Board (PTB/PCTB). It defines work and power, introduces kinetic and potential energy, and states the work-energy principle and the law of conservation of energy. These notes are prepared by freebooks.pk.

Energy is the capacity to do work, and it can change from one form to another but is never destroyed. You will learn how to calculate work and power, the two main forms of mechanical energy, and how energy is conserved.

Learning Objectives

- Define work and calculate it for a constant and a variable force.
- Define power and relate it to force and velocity.
- Define kinetic energy and potential energy and calculate them.
- State and apply the work-energy principle.
- State the law of conservation of energy and describe energy interconversion.
- Describe some non-conventional sources of energy.

Key Concepts

Work Done by a Constant Force

Work is done when a force moves its point of application in the direction of the force. For a constant force F acting on a body that moves a displacement d at an angle theta to the force, the work done is W = F d cos(theta); this is the scalar (dot) product of force and displacement. Work is a scalar and its SI unit is the joule (J). No work is done if the displacement is zero or if the force is perpendicular to the displacement (theta = 90 degrees).

Work Done by a Variable Force

When a force varies with position, the work done is found from the area under the force-displacement (F-x) graph. The total displacement is divided into very small steps in each of which the force is nearly constant, and the small amounts of work are added; graphically this equals the area between the curve and the x-axis.

Power

Power is the rate of doing work, P = W/t, and its SI unit is the watt (W), equal to one joule per second. If a constant force F moves a body at velocity v, the power delivered is P = F v (the dot product of force and velocity). Power tells us how quickly energy is transferred.

Kinetic and Potential Energy

Energy is the capacity to do work. Kinetic energy is the energy a body has because of its motion and is given by KE = (1/2)mv^2. Potential energy is the energy a body has because

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of its position or state; gravitational potential energy near the Earth's surface is PE = mgh, where h is the height above a reference level.

Work-Energy Principle

The work-energy principle states that the net work done on a body equals the change in its kinetic energy: W(net) = change in KE = (1/2)mv^2 - (1/2)mu^2. This links the ideas of force, work and motion, and is often the quickest way to solve problems involving speed and distance.

Conservation of Energy

The law of conservation of energy states that energy can neither be created nor destroyed but only changed from one form to another; the total energy of an isolated system remains constant. For a freely falling body, potential energy is steadily converted into kinetic energy while their sum stays the same. Besides conventional sources, non-conventional (renewable) sources of energy include solar energy, wind energy, tidal energy, geothermal energy and biomass.

Important Definitions

Term	Definition
Work	The product of a force and the displacement in the direction of the force; W = F d cos(theta).
Power	The rate of doing work, P = W/t; SI unit the watt.
Energy	The capacity of a body to do work.
Kinetic energy	The energy of a body due to its motion, KE = (1/2)mv^2.
Potential energy	The energy of a body due to its position or state, PE = mgh for gravity.
Work-energy principle	The net work done on a body equals the change in its kinetic energy.
Conservation of energy	Energy cannot be created or destroyed, only changed in form.
Joule	The SI unit of work and energy; one joule is one newton-metre.

Formulas & Rules

Item	Fact
Work (constant force)	W = F d cos(theta)
Work (variable force)	area under the force-displacement graph
Power	P = W/t = F v
Kinetic energy	KE = (1/2)mv^2
Potential energy	PE = mgh

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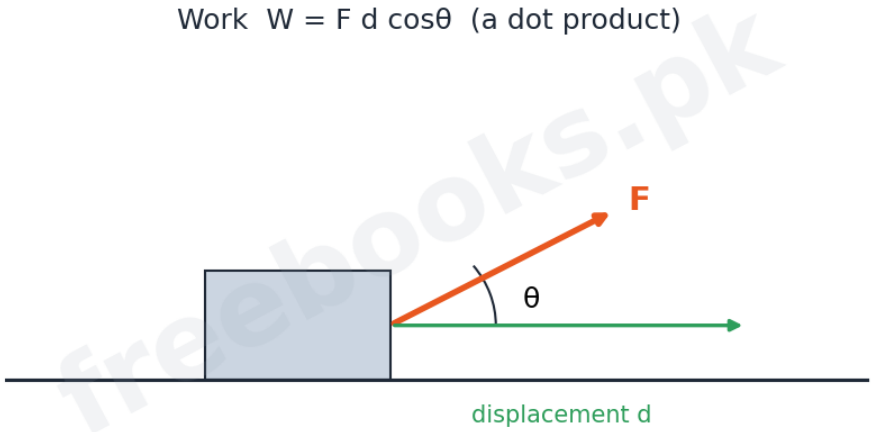
Item	Fact
Work-energy principle	W(net) = (1/2)mv^2 - (1/2)mu^2
Units	work and energy in joule (J); power in watt (W)

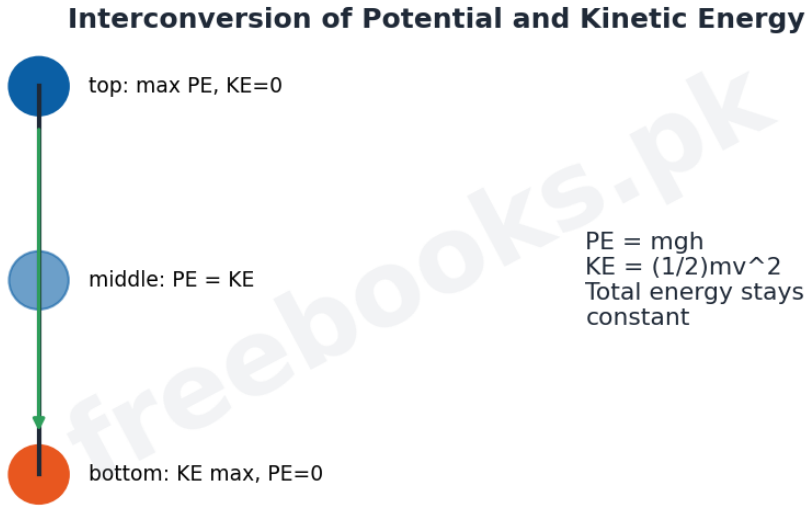
Diagrams & Illustrations

Work by a force at an angle: a block pulled by a force F at angle theta to the horizontal displacement d, with the work given by W = F d cos theta.



Work by a force at an angle

Interconversion of energy: a body falling from a height showing potential energy at the top converting into kinetic energy at the bottom while the total energy stays constant.



Interconversion of energy

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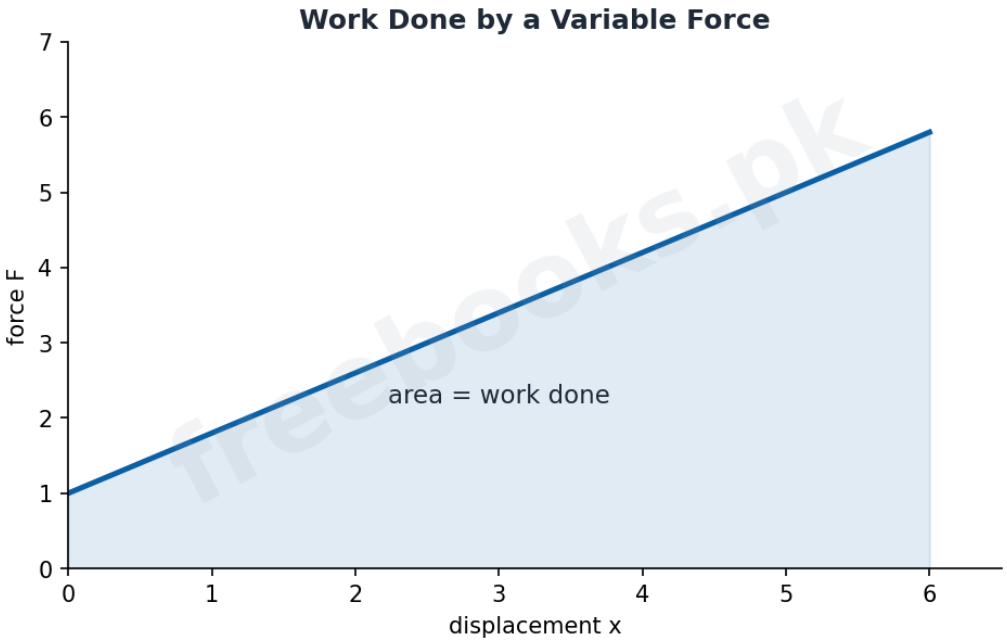
Work by a variable force: a force-displacement graph in which the area under the curve equals the work done by a varying force.



Work by a variable force

Solved Examples & Numericals

Work done

A force of 15 N pulls a box 4 m along the direction of the force. The work done is W = F d cos0 = 15 x 4 x 1 = 60 J.

Work at an angle

A force of 20 N acts at 60 degrees to a displacement of 3 m. The work done is W = F d cos60 = 20 x 3 x 0.5 = 30 J.

Kinetic energy

A 2 kg body moves at 5 m/s. Its kinetic energy is KE = (1/2)mv^2 = (1/2)(2)(25) = 25 J.

Power

A motor does 6000 J of work in 30 s. Its power is P = W/t = 6000/30 = 200 W.

Short Questions & Answers

Q1. When is the work done by a force zero?
Ans. When the displacement is zero, or when the force is perpendicular to the displacement (theta = 90 degrees).

Q2. Define power and give its SI unit.

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Ans. Power is the rate of doing work, P = W/t; its SI unit is the watt.

Q3. Write the expression for kinetic energy.
Ans. KE = (1/2)mv^2, where m is mass and v is speed.

Q4. State the work-energy principle.
Ans. The net work done on a body equals the change in its kinetic energy.

Q5. State the law of conservation of energy.
Ans. Energy cannot be created or destroyed, only changed from one form to another; the total energy stays constant.

Q6. Name two non-conventional sources of energy.
Ans. Solar energy and wind energy (also tidal, geothermal and biomass).

Long Questions & Answers

Q1: Define work and explain the work done by a constant force and by a variable force.

Work is done when a force moves its point of application in the direction of the force. For a constant force F acting on a body that undergoes a displacement d at an angle theta to the force, the work done is the dot product W = F d cos(theta); it is a scalar measured in joules. The work is maximum when the force and displacement are parallel (theta = 0) and zero when they are perpendicular (theta = 90 degrees) or when there is no displacement. When the force varies with position, it is not possible to use a single value of F; instead the displacement is divided into very small intervals in each of which the force is almost constant, the small amounts of work are added, and the total work equals the area under the force-displacement graph. This method allows the work done by any varying force, such as that of a stretched spring, to be found.

Q2: Define kinetic and potential energy and state the work-energy principle.

Energy is the capacity of a body to do work, and mechanical energy has two forms. Kinetic energy is the energy a body possesses because of its motion; a body of mass m moving with speed v has kinetic energy KE = (1/2)mv^2. Potential energy is the energy a body possesses because of its position or configuration; a body of mass m raised to a height h above a reference level has gravitational potential energy PE = mgh. The work-energy principle connects work and motion: the net work done on a body equals the change in its kinetic energy, W(net) = (1/2)mv^2 - (1/2)mu^2. This principle shows that doing positive work on a body increases its kinetic energy (speeds it up), while negative work decreases it.

Q3: State the law of conservation of energy and illustrate it with a freely falling body.

The law of conservation of energy states that energy can neither be created nor destroyed; it can only be transformed from one form into another, so the total energy of an isolated

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system remains constant. A freely falling body illustrates this well. At the top of its fall the body is momentarily at rest and has maximum gravitational potential energy (mgh) and zero kinetic energy. As it falls, its height decreases so its potential energy decreases, while its speed increases so its kinetic energy increases by exactly the same amount; at every point the sum of potential and kinetic energy is the same. Just before it hits the ground its potential energy is (almost) zero and its kinetic energy is maximum. Thus energy is continuously converted from potential to kinetic form while the total stays constant.

MCQs with Answers

1. The work done by a force is maximum when the angle between force and displacement is:
(a) 0 degrees (b) 45 degrees (c) 90 degrees (d) 180 degrees
Correct Answer: (a) 0 degrees. cos0 = 1, so work is maximum.

2. The SI unit of work is the:
(a) watt (b) joule (c) newton (d) pascal
Correct Answer: (b) joule. Work is measured in joules.

3. Power is the rate of doing:
(a) force (b) work (c) distance (d) mass
Correct Answer: (b) work. Power = work/time.

4. The SI unit of power is the:
(a) joule (b) newton (c) watt (d) volt
Correct Answer: (c) watt. Power is measured in watts.

5. The kinetic energy of a body is given by:
(a) mgh (b) (1/2)mv^2 (c) mv (d) Fd
Correct Answer: (b) (1/2)mv^2. KE = (1/2)mv^2.

6. The potential energy of a body at height h is:
(a) (1/2)mv^2 (b) mgh (c) mv (d) Fd cos theta
Correct Answer: (b) mgh. PE = mgh.

7. The work-energy principle relates net work to the change in:
(a) momentum (b) kinetic energy (c) power (d) force
Correct Answer: (b) kinetic energy. Net work equals the change in kinetic energy.

8. When force is perpendicular to displacement, the work done is:
(a) maximum (b) zero (c) negative (d) infinite
Correct Answer: (b) zero. cos90 = 0, so work is zero.

9. Which is a non-conventional source of energy?
(a) coal (b) petroleum (c) solar (d) natural gas
Correct Answer: (c) solar. Solar energy is renewable and non-conventional.

10. If a constant force F moves a body at velocity v, the power is:
(a) F/v (b) F + v (c) F v (d) F - v
Correct Answer: (c) F v. Power P = F v.

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Quick Revision Summary

- Work W = F d cos(theta) (dot product); unit joule; zero if force is perpendicular to displacement.
- Variable force: work = area under the force-displacement graph.
- Power P = W/t = F v; unit watt.
- Kinetic energy = (1/2)mv^2; potential energy = mgh.
- Work-energy principle: net work = change in kinetic energy.
- Conservation of energy: total energy stays constant; non-conventional sources include solar and wind. Notes by freebooks.pk.

Exam Tips

- Always include cos(theta) when force and displacement are not parallel.
- Use the work-energy principle for speed-distance problems; it is quick.
- Remember units: joule for work/energy, watt for power.
- For a falling body, PE lost = KE gained.
- P = F v is handy when velocity is given.
- List renewable sources (solar, wind, tidal, geothermal, biomass) for energy questions.

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CHAPTER 5

Circular Motion

Key Concepts · Definitions · Short & Long Questions · MCQs · Diagrams · Exam Tips

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This chapter covers Circular Motion from the 1st Year (FSc Part-I) Physics syllabus of the Punjab Curriculum and Textbook Board (PTB/PCTB). It studies angular quantities, the link between linear and angular motion, centripetal force, moment of inertia, angular momentum and its conservation, and the motion of satellites. These notes are prepared by freebooks.pk.

When a body moves in a circle, a force is always needed to keep it turning. You will learn the angular quantities that describe rotation, how they relate to linear ones, and the important idea of centripetal force.

Learning Objectives

- Define angular displacement, angular velocity and angular acceleration.
- Relate linear and angular quantities (v = r omega).
- Define centripetal acceleration and centripetal force.
- Define moment of inertia and rotational kinetic energy.
- Define angular momentum and state its conservation.
- Describe artificial satellites and orbital velocity.

Key Concepts

Angular Displacement, Velocity and Acceleration

When a body rotates, the angle it turns through is the angular displacement (theta), measured in radians. The rate of change of angular displacement is the angular velocity (omega), and the rate of change of angular velocity is the angular acceleration (alpha). These angular quantities describe rotation in the same way that displacement, velocity and acceleration describe straight-line motion.

Relation between Linear and Angular Quantities

For a body moving in a circle of radius r, the linear (tangential) quantities are related to the angular ones by simple equations: the linear speed is v = r omega, the tangential acceleration is a = r alpha, and the arc length is s = r theta. The linear velocity is always directed along the tangent to the circle.

Centripetal Acceleration and Force

A body moving in a circle is continuously changing direction, so it has an acceleration directed towards the centre of the circle called the centripetal acceleration, a = v^2/r = r omega^2. The force that provides this acceleration and keeps the body moving in the circle is the centripetal force, F = mv^2/r = m r omega^2, always directed towards the centre. Examples of centripetal force are the tension in a whirling string, gravity for a satellite, and friction for a car turning a corner.

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Moment of Inertia and Rotational Kinetic Energy

The moment of inertia of a body is its resistance to a change in its rotation, and depends on the mass and how that mass is distributed about the axis; for a point mass, I = m r^2. A rotating body has rotational kinetic energy KE = (1/2) I omega^2, which is the rotational analogue of (1/2)mv^2.

Angular Momentum and Its Conservation

The angular momentum of a rotating body is L = I omega, the rotational analogue of linear momentum. The law of conservation of angular momentum states that if no external torque acts on a system, its total angular momentum remains constant. This is why an ice skater spins faster when she pulls her arms in: reducing her moment of inertia increases her angular velocity so that L stays the same.

Artificial Satellites and Orbital Velocity

An artificial satellite is a body that orbits the Earth; the gravitational pull of the Earth provides the centripetal force needed to keep it in orbit. For a satellite close to the Earth the orbital speed is v = sqrt(gR), about 7.9 km/s. A geostationary satellite orbits once every 24 hours above the equator, so it appears fixed over one point and is used for communications. An astronaut in an orbiting satellite feels weightless because both the astronaut and the satellite fall together with the same acceleration.

Important Definitions

Term	Definition
Angular displacement	The angle turned through by a rotating body, measured in radians.
Angular velocity	The rate of change of angular displacement, omega.
Angular acceleration	The rate of change of angular velocity, alpha.
Centripetal acceleration	The acceleration directed towards the centre, a = v^2/r.
Centripetal force	The force directed towards the centre that keeps a body in a circle, F = mv^2/r.
Moment of inertia	The resistance of a body to a change in its rotation; I = m r^2 for a point mass.
Angular momentum	The rotational analogue of linear momentum, L = I omega.
Orbital velocity	The speed a satellite needs to stay in orbit, v = sqrt(gR) near the Earth.

Formulas & Rules

Item	Fact
Linear-angular relations	v = r omega; a = r alpha; s = r theta

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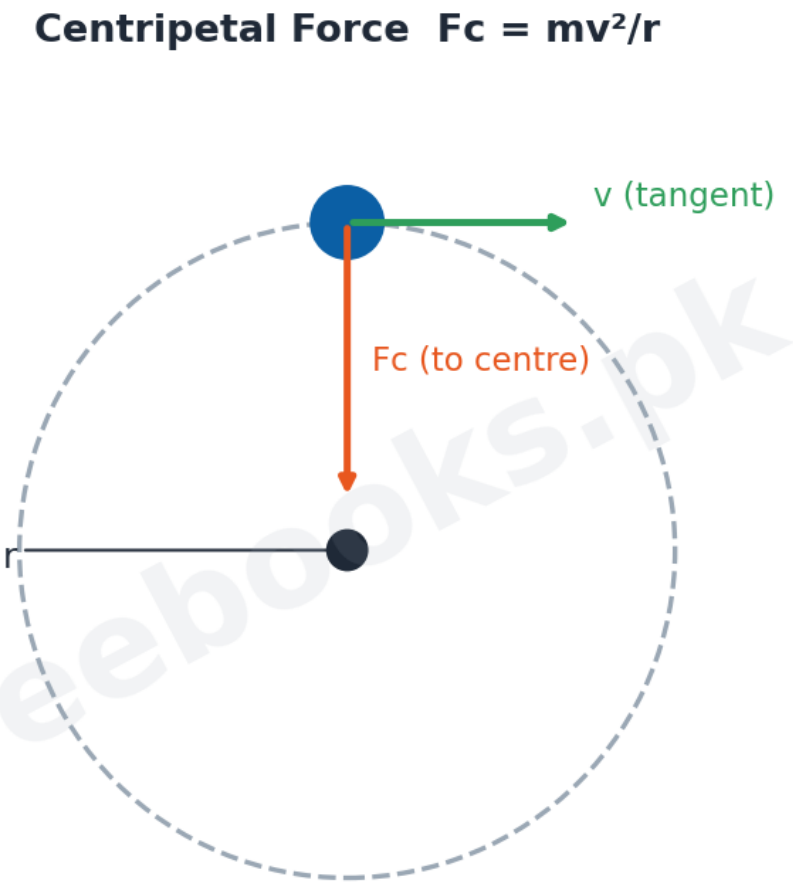
Item	Fact
Centripetal acceleration	a = v^2/r = r omega^2
Centripetal force	F = mv^2/r = m r omega^2
Moment of inertia (point mass)	I = m r^2
Rotational kinetic energy	KE = (1/2) I omega^2
Angular momentum	L = I omega
Orbital velocity (near Earth)	v = sqrt(gR) (about 7.9 km/s)

Diagrams & Illustrations

Centripetal force: a body moving in a circle with its velocity along the tangent and the centripetal force directed towards the centre, F = mv^2/r.



Centripetal force

Angular and linear quantities: a rotating radius sweeping an angle theta, showing the relation between the linear speed and the angular velocity, v = r omega.

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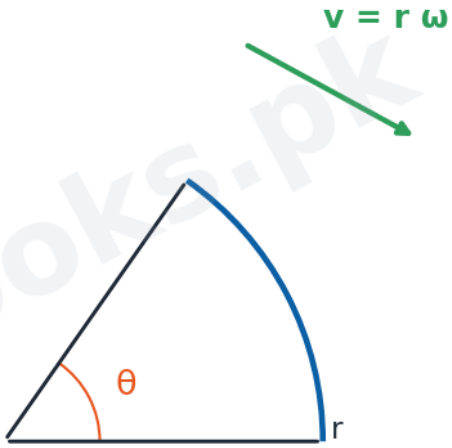
Angular and Linear Quantities



Angular and linear quantities

Artificial satellite: a satellite orbiting the Earth, with its velocity along the orbit and gravity providing the centripetal force.

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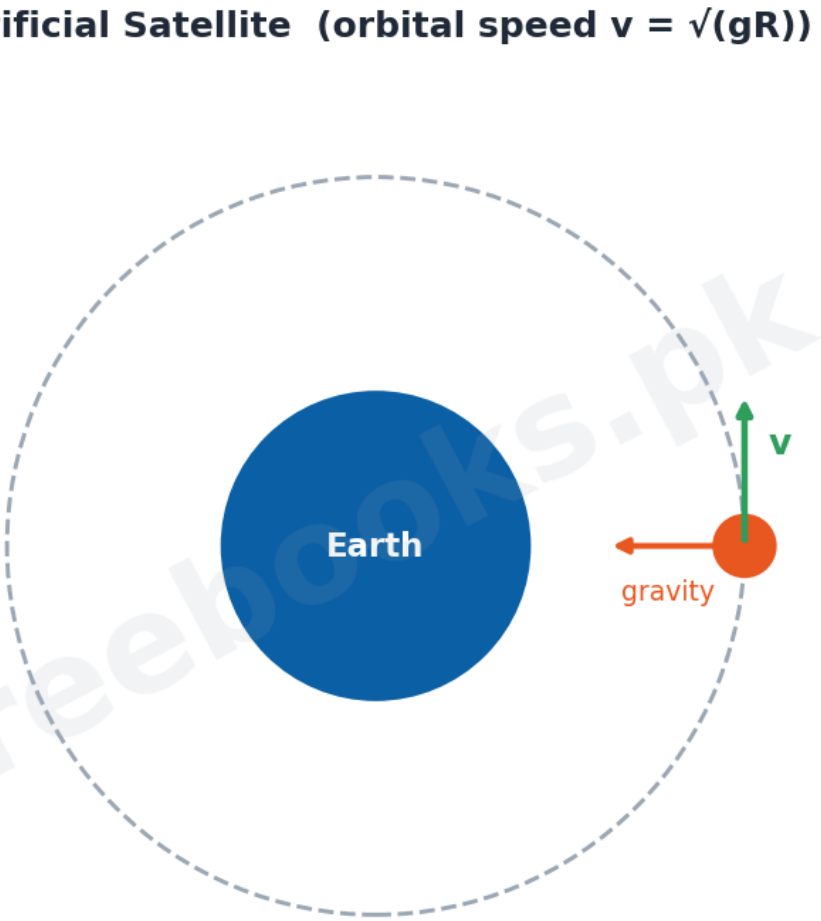

Artificial satellite

Solved Examples & Numericals

Linear speed

A wheel of radius 0.5 m turns at an angular velocity of 4 rad/s. The linear speed of a point on its rim is v = r omega = 0.5 x 4 = 2 m/s.

Centripetal force

A 2 kg ball is whirled in a circle of radius 1 m at 3 m/s. The centripetal force is F = mv^2/r = 2 x 9 / 1 = 18 N.

Centripetal acceleration

A car moves at 10 m/s around a circle of radius 25 m. Its centripetal acceleration is a = v^2/r = 100/25 = 4 m/s^2.

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Angular momentum

A body of moment of inertia 2 kg m^2 rotates at 5 rad/s. Its angular momentum is L = I omega = 2 x 5 = 10 kg m^2/s.

Short Questions & Answers

Q1. Define angular velocity.
Ans. The rate of change of angular displacement of a rotating body, omega, measured in radians per second.

Q2. Write the relation between linear and angular speed.
Ans. v = r omega, where r is the radius and omega the angular velocity.

Q3. What is centripetal force?
Ans. The force directed towards the centre of a circle that keeps a body moving in that circle, F = mv^2/r.

Q4. Define moment of inertia.
Ans. The resistance of a body to a change in its rotational motion; for a point mass I = m r^2.

Q5. State the law of conservation of angular momentum.
Ans. If no external torque acts on a system, its total angular momentum stays constant.

Q6. Why does an astronaut in orbit feel weightless?
Ans. Because the astronaut and the satellite fall together with the same acceleration, so there is no reaction force.

Long Questions & Answers

Q1: Define centripetal acceleration and centripetal force and give examples.

A body moving in a circle constantly changes the direction of its velocity, and any change in velocity is an acceleration. Because the direction change is always towards the centre of the circle, this acceleration is directed towards the centre and is called the centripetal acceleration, given by a = v^2/r = r omega^2, where v is the linear speed, r the radius and omega the angular velocity. By Newton's second law an acceleration requires a force, so a force directed towards the centre must act on the body; this is the centripetal force, F = mv^2/r = m r omega^2. The centripetal force is not a new kind of force but is provided by some real force in each situation: the tension in the string when a stone is whirled around, the gravitational pull of the Earth for a satellite, and the friction between the tyres and the road for a car going round a bend.

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Q2: Define angular momentum and explain the law of its conservation with an example.

The angular momentum of a rotating body is the rotational analogue of linear momentum and is defined as L = I omega, where I is the moment of inertia and omega the angular velocity. The law of conservation of angular momentum states that if the net external torque acting on a system is zero, the total angular momentum of the system remains constant. This means that if the moment of inertia of a body changes, its angular velocity must change in the opposite way so that the product I omega stays the same. A familiar example is a spinning ice skater: when she pulls her arms and one leg inwards, she reduces her moment of inertia, and because angular momentum is conserved her angular velocity increases and she spins faster; stretching her arms out again slows her down. The same principle explains how a diver controls the speed of a somersault.

Q3: Describe an artificial satellite and derive its orbital velocity near the Earth.

An artificial satellite is a man-made body that revolves around the Earth in a fixed orbit. The gravitational pull of the Earth on the satellite provides exactly the centripetal force needed to keep it moving in its circular orbit. For a satellite orbiting close to the Earth's surface, the gravitational force mg provides the centripetal force mv^2/R, where R is the radius of the Earth; equating these gives mg = mv^2/R, so the orbital velocity is v = sqrt(gR), which works out to about 7.9 km/s. A special case is the geostationary satellite, which orbits above the equator once every 24 hours so that it appears to stay fixed over one point of the Earth; such satellites are used for communications and weather monitoring.

MCQs with Answers

1. The SI unit of angular displacement is the:
(a) metre (b) radian (c) degree (d) second
Correct Answer: (b) radian. Angular displacement is measured in radians.

2. The relation between linear and angular speed is:
(a) v = r/omega (b) v = r omega (c) v = omega/r (d) v = r + omega
Correct Answer: (b) v = r omega. v = r omega.

3. Centripetal acceleration is directed:
(a) along the tangent (b) towards the centre (c) away from the centre (d) upward
Correct Answer: (b) towards the centre. It points towards the centre.

4. Centripetal force is given by:
(a) mv/r (b) mv^2/r (c) m/r (d) mvr
Correct Answer: (b) mv^2/r. F = mv^2/r.

5. The moment of inertia of a point mass is:
(a) mr (b) mr^2 (c) m/r (d) m^2 r
Correct Answer: (b) mr^2. I = m r^2.

6. Angular momentum is equal to:

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(a) I/omega (b) I omega (c) omega/I (d) I + omega
Correct Answer: (b) I omega. L = I omega.

7. An ice skater spins faster when she pulls her arms in because of conservation of:
(a) energy (b) linear momentum (c) angular momentum (d) mass
Correct Answer: (c) angular momentum. Angular momentum is conserved.

8. The centripetal force on a satellite is provided by:
(a) friction (b) tension (c) gravity (d) magnetism
Correct Answer: (c) gravity. Earth's gravity provides it.

9. The approximate orbital speed of a satellite near the Earth is:
(a) 3 km/s (b) 7.9 km/s (c) 11 km/s (d) 30 km/s
Correct Answer: (b) 7.9 km/s. About 7.9 km/s.

10. The rotational kinetic energy of a body is:
(a) (1/2)mv^2 (b) (1/2) I omega^2 (c) I omega (d) mgh
Correct Answer: (b) (1/2) I omega^2. KE = (1/2) I omega^2.

Quick Revision Summary

- Angular quantities: displacement theta, velocity omega, acceleration alpha (in radians).
- Linear-angular: v = r omega; a = r alpha; s = r theta.
- Centripetal acceleration a = v^2/r; centripetal force F = mv^2/r (towards centre).
- Moment of inertia I = m r^2; rotational KE = (1/2) I omega^2.
- Angular momentum L = I omega; conserved if no external torque.
- Satellite: gravity provides centripetal force; v = sqrt(gR) near Earth. Notes by freebooks.pk.

Exam Tips

- Work in radians for all angular quantities.
- Remember centripetal force always points towards the centre.
- Use conservation of angular momentum for spinning-body problems.
- Learn v = sqrt(gR) for a near-Earth satellite.
- Distinguish moment of inertia (I) from momentum.
- Weightlessness in orbit: both astronaut and satellite fall together.

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FSc Part-I Physics — Punjab Board

CHAPTER 6

Fluid Dynamics

Key Concepts · Definitions · Short & Long Questions · MCQs · Diagrams · Exam Tips

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This chapter covers Fluid Dynamics from the 1st Year (FSc Part-I) Physics syllabus of the Punjab Curriculum and Textbook Board (PTB/PCTB). It studies viscosity and viscous drag, the terminal velocity of a falling body, types of fluid flow, the equation of continuity and Bernoulli's equation with its applications. These notes are prepared by freebooks.pk.

Fluids (liquids and gases) can flow, and their motion follows simple and beautiful rules. You will learn why some bodies reach a steady falling speed, how the speed of a fluid changes when a pipe narrows, and how Bernoulli's principle explains lift and many everyday effects.

Learning Objectives

- Define viscosity and viscous drag and state Stokes' law.
- Explain terminal velocity and how it arises.
- Distinguish streamline (laminar) and turbulent flow.
- State and apply the equation of continuity.
- State Bernoulli's equation and describe its applications.

Key Concepts

Viscosity and Viscous Drag

Viscosity is the internal friction of a fluid that opposes the relative motion of its layers; thick fluids such as honey have high viscosity while thin fluids such as water have low viscosity. When a body moves through a fluid it experiences a retarding force called viscous drag. For a small sphere of radius r moving slowly with speed v through a fluid of viscosity eta, Stokes' law gives the drag force as F = 6 pi eta r v.

Terminal Velocity

When a small sphere falls through a fluid, its weight acts downward while the upthrust and the viscous drag act upward. As the sphere speeds up, the drag increases until the upward and downward forces balance; after this the sphere falls with a constant maximum speed called the terminal velocity. A raindrop and a parachutist both reach a terminal velocity.

Types of Fluid Flow

Fluid flow is of two kinds. In streamline (laminar) flow the fluid moves in smooth layers and every particle passing a point follows the same path; this happens at low speeds. In turbulent flow the motion is irregular with eddies and whirls; this happens at high speeds. Streamline flow becomes turbulent when the speed exceeds a certain critical value.

Equation of Continuity

For an incompressible fluid flowing steadily through a pipe, the mass entering any section per second equals the mass leaving it. This gives the equation of continuity, A1 v1 = A2 v2, where A is the cross-sectional area and v the speed. It shows that a fluid speeds up when the

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pipe narrows and slows down when it widens; this is why water from a hose speeds up when the nozzle is squeezed.

Bernoulli's Equation and Its Applications

Bernoulli's equation is a statement of the conservation of energy for a flowing fluid: P + (1/2) rho v^2 + rho g h = constant, where P is pressure, rho the density, v the speed and h the height. It shows that where a fluid moves faster its pressure is lower, and where it moves slower its pressure is higher. Applications include the lift on an aeroplane wing, the working of a carburettor and an atomiser, the swing of a spinning ball, and Torricelli's theorem for the speed of liquid leaving a hole in a tank.

Important Definitions

Term	Definition
Viscosity	The internal friction of a fluid that opposes the relative motion of its layers.
Viscous drag	The retarding force on a body moving through a fluid.
Stokes' law	The drag on a small sphere moving slowly in a fluid, F = 6 pi eta r v.
Terminal velocity	The constant maximum speed of a body falling through a fluid when the forces balance.
Streamline flow	Smooth, layered fluid flow in which particles follow the same path.
Turbulent flow	Irregular fluid flow with eddies and whirls at high speed.
Equation of continuity	A1 v1 = A2 v2 for an incompressible fluid.
Bernoulli's equation	P + (1/2) rho v^2 + rho g h = constant for a flowing fluid.

Formulas & Rules

Item	Fact
Stokes' law	F = 6 pi eta r v
Terminal velocity	reached when weight = upthrust + drag
Equation of continuity	A1 v1 = A2 v2
Bernoulli's equation	P + (1/2) rho v^2 + rho g h = constant
Torricelli's theorem	v = sqrt(2 g h) for liquid leaving a hole at depth h

Diagrams & Illustrations

Terminal velocity: a sphere falling through a fluid with its weight acting downward and the upthrust and viscous drag acting upward, balancing at the terminal velocity.

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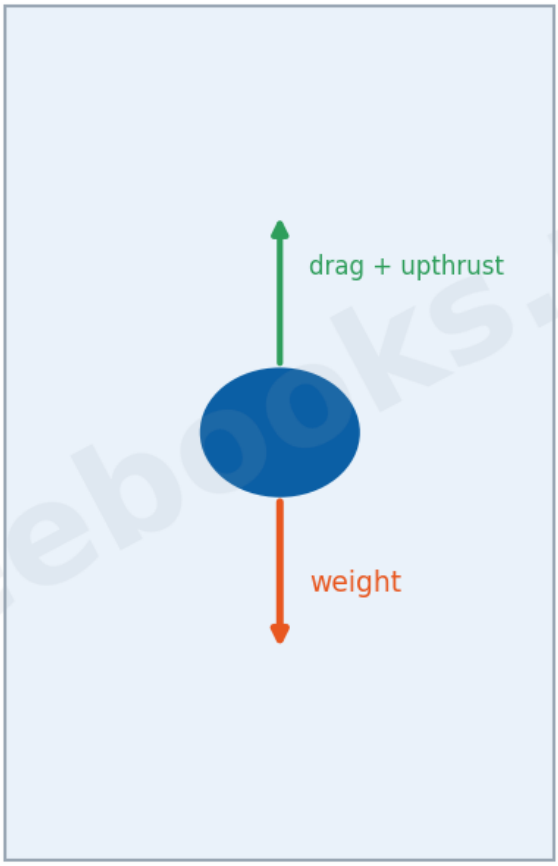
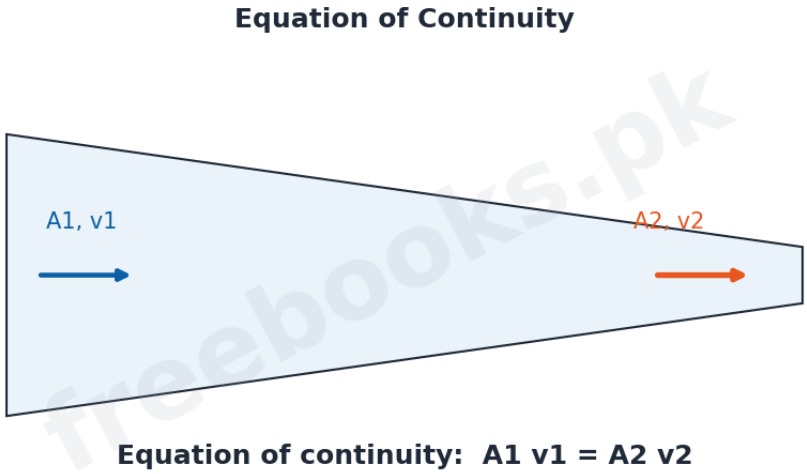


Terminal velocity

Equation of continuity: a pipe that narrows, showing that the fluid speeds up where the area is smaller, with A1 v1 = A2 v2.



Equation of continuity

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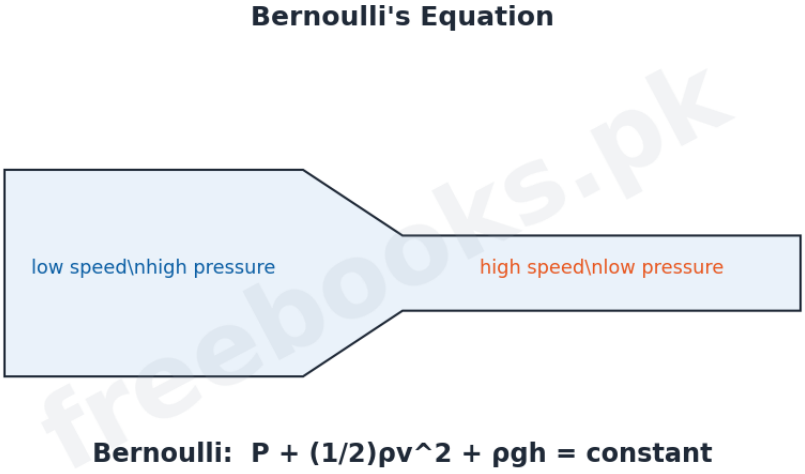
Bernoulli's equation: flow through a pipe that narrows, showing high pressure where the speed is low and low pressure where the speed is high.



Bernoulli's equation

Solved Examples & Numericals

Equation of continuity

Water flows through a pipe whose area falls from 6 cm^2 to 2 cm^2. If the speed in the wide part is 1 m/s, then A1 v1 = A2 v2 gives 6 x 1 = 2 x v2, so v2 = 3 m/s.

Stokes' law

The drag on a sphere increases with speed, so as a falling sphere speeds up the drag grows until it balances the weight, giving a constant terminal velocity.

Torricelli's theorem

Water leaves a hole 0.2 m below the surface of a tank. Its speed is v = sqrt(2 g h) = sqrt(2 x 10 x 0.2) = 2 m/s.

Bernoulli effect

Air moves faster over the curved top of an aeroplane wing than under it, so by Bernoulli's principle the pressure on top is lower, giving an upward lift.

Short Questions & Answers

Q1. Define viscosity.
Ans. The internal friction of a fluid that opposes the relative motion of its layers.

Q2. State Stokes' law.
Ans. The viscous drag on a small sphere moving slowly through a fluid is F = 6 pi eta r v.

Q3. What is terminal velocity?

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Ans. The constant maximum speed of a body falling through a fluid, reached when the upward and downward forces balance.

Q4. Differentiate streamline and turbulent flow.

Ans. In streamline flow the fluid moves in smooth layers; in turbulent flow the motion is irregular with eddies.

Q5. State the equation of continuity.

Ans. For an incompressible fluid, A1 v1 = A2 v2; the fluid speeds up where the pipe narrows.

Q6. Why does an aeroplane wing experience lift?

Ans. Air moves faster over the top than the bottom, so the pressure on top is lower (Bernoulli's principle), giving an upward lift.

Long Questions & Answers

Q1: Explain viscous drag, Stokes' law and terminal velocity.

When a body moves through a fluid, the layers of fluid resist the motion and exert a retarding force on the body called viscous drag; the drag increases with the speed of the body. For a small sphere of radius r moving slowly with speed v through a fluid of viscosity eta, the drag is given by Stokes' law, F = 6 pi eta r v. Consider a small sphere falling through a fluid: its weight acts downward while the upthrust of the fluid and the viscous drag act upward. At first the weight is greater, so the sphere accelerates; but as it speeds up the drag grows, until the total upward force (upthrust plus drag) becomes equal to the weight. After this the net force is zero, the sphere stops accelerating, and it falls with a constant maximum speed called the terminal velocity. Raindrops and parachutists reach a terminal velocity in this way.

Q2: State and explain the equation of continuity.

The equation of continuity expresses the conservation of mass for a fluid flowing steadily through a pipe. If the fluid is incompressible, the mass of fluid entering any cross-section per second must equal the mass leaving it, otherwise fluid would build up. Since the mass per second at a section equals density times area times speed, and the density is constant, the product of area and speed must be the same everywhere: A1 v1 = A2 v2, where A1 and A2 are the cross-sectional areas at two points and v1 and v2 the corresponding speeds. This equation shows that where the pipe is narrow the fluid moves fast, and where the pipe is wide the fluid moves slowly, which is why the water from a hose speeds up when the nozzle opening is made smaller.

Q3: State Bernoulli's equation and describe two of its applications.

Bernoulli's equation is a statement of the conservation of energy for a fluid in streamline flow, and states that P + (1/2) rho v^2 + rho g h = constant along a streamline, where P is the pressure, rho the density, v the speed and h the height of the fluid. The key idea is that where a fluid flows faster its pressure is lower, and where it flows slower its pressure is higher. One application is the lift on an aeroplane wing: the wing is shaped so that air flows

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faster over the curved top than under the flatter bottom, so the pressure on top is lower and the wing is pushed up. Another application is the carburettor or atomiser, in which fast-moving air creates a region of low pressure that draws liquid up and sprays it out. Torricelli's theorem, which gives the speed of liquid leaving a hole in a tank as v = sqrt(2 g h), is also derived from Bernoulli's equation.

MCQs with Answers

1. The internal friction of a fluid is called:
(a) pressure (b) viscosity (c) density (d) upthrust
Correct Answer: (b) viscosity. Viscosity is the internal friction.

2. Stokes' law for the drag on a small sphere is:
(a) 6 pi eta r v (b) eta r v (c) pi r^2 v (d) eta v/r
Correct Answer: (a) 6 pi eta r v. F = 6 pi eta r v.

3. Terminal velocity is reached when the net force on the falling body is:
(a) maximum (b) zero (c) upward (d) increasing
Correct Answer: (b) zero. Forces balance, so net force is zero.

4. Smooth, layered fluid flow is called:
(a) turbulent (b) streamline (c) random (d) rotational
Correct Answer: (b) streamline. Streamline (laminar) flow.

5. The equation of continuity is:
(a) A1 v1 = A2 v2 (b) P1 = P2 (c) v1 = v2 (d) A1 = A2
Correct Answer: (a) A1 v1 = A2 v2. A1 v1 = A2 v2.

6. When a pipe narrows, the speed of the fluid:
(a) decreases (b) increases (c) stays same (d) becomes zero
Correct Answer: (b) increases. It increases (continuity).

7. Bernoulli's equation is based on the conservation of:
(a) mass (b) momentum (c) energy (d) charge
Correct Answer: (c) energy. It is a form of energy conservation.

8. Where a fluid moves faster, its pressure is:
(a) higher (b) lower (c) the same (d) zero
Correct Answer: (b) lower. Faster flow means lower pressure.

9. The lift on an aeroplane wing is explained by:
(a) Stokes' law (b) Bernoulli's principle (c) Newton's first law (d) continuity only
Correct Answer: (b) Bernoulli's principle. Bernoulli's principle.

10. Torricelli's theorem gives the efflux speed as:
(a) sqrt(g h) (b) sqrt(2 g h) (c) 2 g h (d) g h
Correct Answer: (b) sqrt(2 g h). v = sqrt(2 g h).

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Quick Revision Summary

- Viscosity = internal friction; viscous drag opposes motion; Stokes' law F = 6 pi eta r v.
- Terminal velocity: constant speed when weight = upthrust + drag.
- Flow: streamline (smooth) versus turbulent (irregular).
- Equation of continuity: A1 v1 = A2 v2 (fluid speeds up where narrow).
- Bernoulli: P + (1/2) rho v^2 + rho g h = constant; faster flow = lower pressure.
- Applications: wing lift, carburettor, Torricelli v = sqrt(2 g h). Notes by freebooks.pk.

Exam Tips

- Remember Stokes' law F = 6 pi eta r v.
- Terminal velocity means zero net force (constant speed).
- Use A1 v1 = A2 v2 for pipe-flow numericals.
- Bernoulli: faster fluid has lower pressure; use it to explain lift.
- Learn Torricelli v = sqrt(2 g h).
- State applications of Bernoulli's principle for full marks.

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CHAPTER 7

Oscillations

Key Concepts · Definitions · Short & Long Questions · MCQs · Diagrams · Exam Tips

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This chapter covers Oscillations from the 1st Year (FSc Part-I) Physics syllabus of the Punjab Curriculum and Textbook Board (PTB/PCTB). It studies simple harmonic motion (SHM), the simple pendulum and mass-spring system, energy in SHM, and free and forced oscillations with resonance. These notes are prepared by freebooks.pk.

Many things in nature vibrate back and forth: a pendulum, a spring, a guitar string. The simplest and most important such motion is simple harmonic motion, which this chapter explains.

Learning Objectives

- Define simple harmonic motion and state its characteristics.
- Relate SHM to circular motion.
- Find the time period of a simple pendulum and a mass-spring system.
- Describe the interchange of kinetic and potential energy in SHM.
- Distinguish free and forced oscillations and explain resonance.
- Explain damping.

Key Concepts

Simple Harmonic Motion

Simple harmonic motion (SHM) is a to-and-fro motion in which the acceleration of the body is always directed towards a fixed point (the mean position) and is directly proportional to the displacement from that point: a = -omega^2 x, where omega is the angular frequency. The minus sign shows that the acceleration is opposite to the displacement. The maximum displacement from the mean position is the amplitude, the time for one complete oscillation is the time period T, and the number of oscillations per second is the frequency f = 1/T.

SHM and Circular Motion

SHM can be regarded as the projection of uniform circular motion onto a diameter. If a point moves in a circle at constant angular speed omega, the foot of the perpendicular from that point onto a diameter moves back and forth in SHM. This link gives the useful result omega = 2 pi f and helps derive the equations for displacement, velocity and acceleration.

The Simple Pendulum

A simple pendulum is a small heavy bob suspended by a light, inextensible string. For small angles its motion is SHM, and its time period is T = 2 pi sqrt(l/g), where l is the length of the pendulum and g the acceleration due to gravity. Notably, the period does not depend on the mass of the bob or on the amplitude (for small swings).

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The Mass-Spring System

A mass attached to a spring and set oscillating also performs SHM. Its time period is T = 2 pi sqrt(m/k), where m is the mass and k the spring constant (the force needed to stretch the spring by unit length). A stiffer spring (larger k) or a smaller mass gives a shorter period.

Energy in SHM

During SHM energy is continually interchanged between kinetic and potential forms. At the mean position the speed is maximum, so the kinetic energy is maximum and the potential energy is zero; at the extreme positions the body is momentarily at rest, so the kinetic energy is zero and the potential energy is maximum. In the absence of friction the total energy remains constant throughout the motion.

Free and Forced Oscillations, Resonance and Damping

A body oscillating on its own at its natural frequency performs free oscillations. When an external periodic force drives a body, it performs forced oscillations at the frequency of the driving force. Resonance occurs when the driving frequency equals the natural frequency of the body, causing a very large amplitude; examples include pushing a swing at the right moments and the shattering of a glass by sound. Damping is the gradual loss of energy (usually to friction or air resistance) that makes the amplitude of an oscillation die away with time.

Important Definitions

Term	Definition
Simple harmonic motion	Motion in which acceleration is proportional to displacement and directed towards the mean position, a = -omega^2 x.
Amplitude	The maximum displacement of a body from its mean position.
Time period	The time taken for one complete oscillation, T.
Frequency	The number of oscillations per second, f = 1/T.
Angular frequency	omega = 2 pi f, related to the rate of oscillation.
Resonance	The large-amplitude response when the driving frequency equals the natural frequency.
Damping	The gradual loss of energy that reduces the amplitude of an oscillation.
Spring constant	The force required to stretch a spring by unit length, k.

Formulas & Rules

Item	Fact
SHM condition	a = -omega^2 x
Angular frequency	omega = 2 pi f = 2 pi / T

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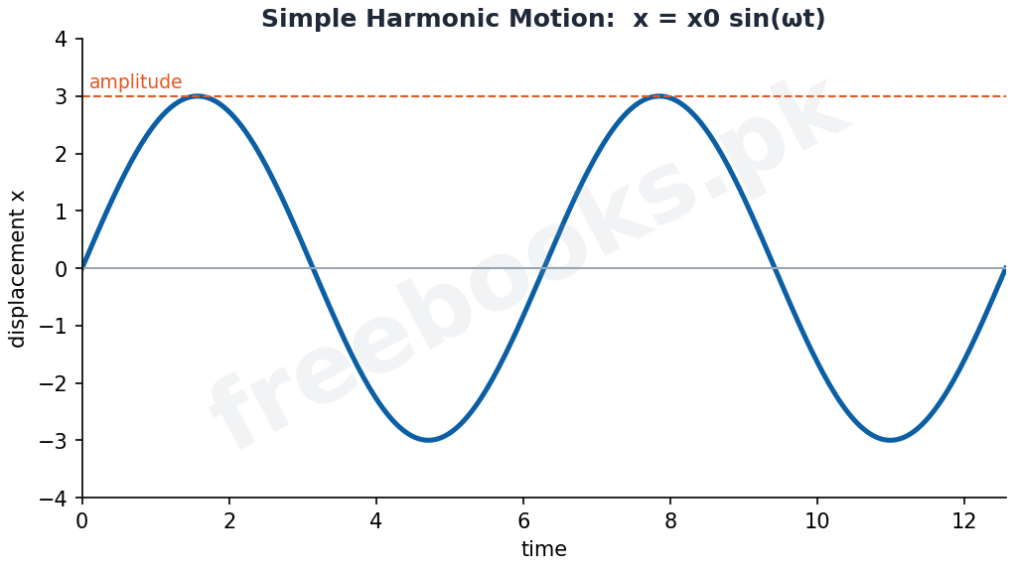
Item	Fact
Simple pendulum	T = 2 pi sqrt(l/g)
Mass-spring system	T = 2 pi sqrt(m/k)
Frequency	f = 1/T
Velocity in SHM	v = omega sqrt(x0^2 - x^2) (maximum at the mean position)

Diagrams & Illustrations

Simple harmonic motion: a displacement-time graph of SHM in the form of a sine curve, with the amplitude marked as the maximum displacement.



Simple harmonic motion

Simple pendulum: a simple pendulum swinging about its mean position, with its length l marked and the time period T = 2 pi sqrt(l/g).

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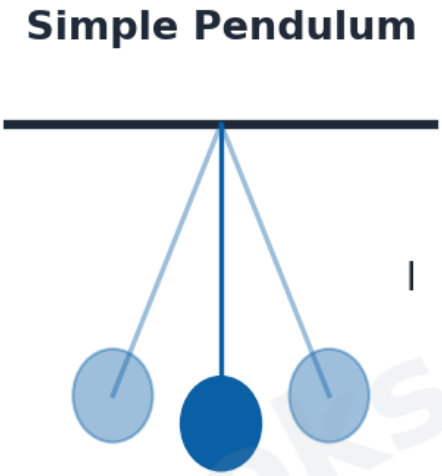

Simple pendulum

Mass-spring system: a mass hanging from a spring and oscillating up and down, with the time period T = 2 pi sqrt(m/k).

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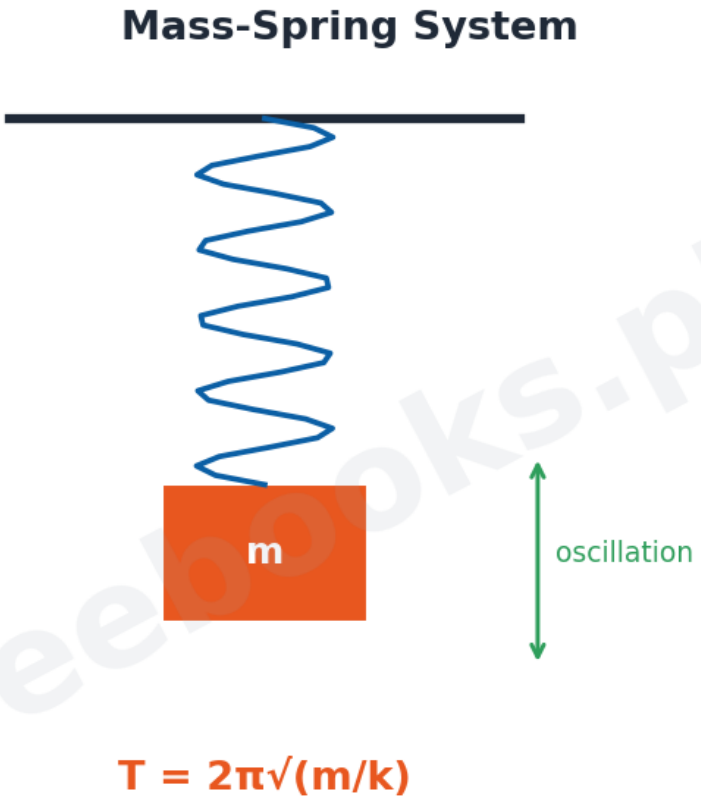

Mass-spring system

Solved Examples & Numericals

Simple pendulum

A pendulum has length 1 m (g = 10 m/s^2). Its period is T = 2 pi sqrt(l/g) = 2 pi sqrt(0.1) = 2 pi x 0.316 = 1.99 s, about 2 s.

Frequency

A body completes 20 oscillations in 10 s. Its frequency is f = 20/10 = 2 Hz and its period is T = 1/f = 0.5 s.

Mass-spring

A 0.5 kg mass on a spring of constant 50 N/m has period T = 2 pi sqrt(m/k) = 2 pi sqrt(0.01) = 2 pi x 0.1 = 0.63 s.

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Energy in SHM

At the mean position of an oscillation the kinetic energy is maximum and the potential energy is zero; at the extreme position the reverse is true, while the total energy stays the same.

Short Questions & Answers

Q1. Define simple harmonic motion.
Ans. A to-and-fro motion in which the acceleration is proportional to the displacement and directed towards the mean position, a = -omega^2 x.

Q2. On what does the period of a simple pendulum depend?
Ans. On its length and the acceleration due to gravity, T = 2 pi sqrt(l/g); it does not depend on the mass or (for small swings) the amplitude.

Q3. Write the time period of a mass-spring system.
Ans. T = 2 pi sqrt(m/k), where m is the mass and k the spring constant.

Q4. Where is the kinetic energy maximum in SHM?
Ans. At the mean position, where the speed is maximum.

Q5. What is resonance?
Ans. The large-amplitude oscillation that occurs when the driving frequency equals the natural frequency of the body.

Q6. What is damping?
Ans. The gradual loss of energy that causes the amplitude of an oscillation to decrease with time.

Long Questions & Answers

Q1: Define simple harmonic motion and describe its characteristics using the example of a mass on a spring.

Simple harmonic motion is a to-and-fro (oscillatory) motion in which the acceleration of the body is always directed towards a fixed mean position and is directly proportional to the displacement from that position, expressed as a = -omega^2 x, where the minus sign shows that the acceleration opposes the displacement. A mass attached to a spring illustrates this well: when the mass is pulled from its rest position and released, the spring exerts a restoring force proportional to the displacement (by Hooke's law), so the acceleration is proportional to the displacement and directed back towards the rest position, which is exactly the condition for SHM. The mass therefore oscillates about the mean position with a fixed amplitude (its maximum displacement), a fixed time period T (the time for one complete oscillation), and a frequency f = 1/T. Its period is T = 2 pi sqrt(m/k), showing that a heavier mass or a weaker spring gives a slower oscillation.

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Q2: Derive/describe the time period of a simple pendulum and state the factors on which it depends.

A simple pendulum consists of a small heavy bob suspended by a light, inextensible string from a fixed point. When the bob is displaced through a small angle and released, gravity provides a restoring force that is directed back towards the mean position and, for small angles, is proportional to the displacement; this makes the motion simple harmonic. Analysis of this restoring force shows that the time period of the pendulum is T = 2 pi sqrt(l/g), where l is the length of the pendulum and g the acceleration due to gravity. An important feature of this result is that the period depends only on the length and on g; it does not depend on the mass of the bob or, provided the swings are small, on the amplitude. This is why a pendulum keeps steady time and can be used in clocks and to measure g.

Q3: Explain the interchange of energy in SHM and describe free and forced oscillations and resonance.

In simple harmonic motion energy is continually exchanged between kinetic and potential forms while, in the absence of friction, the total energy stays constant. At the mean position the speed is greatest, so the kinetic energy is maximum and the potential energy is zero; as the body moves towards an extreme position it slows down, its kinetic energy falls and its potential energy rises, until at the extreme position it is momentarily at rest with maximum potential energy and zero kinetic energy. A body left to oscillate on its own vibrates at its natural frequency and performs free oscillations. If an external periodic force is applied, the body performs forced oscillations at the frequency of that force. When the driving frequency equals the natural frequency, the amplitude becomes very large: this is resonance, seen when a swing is pushed at just the right moments or when a loud note shatters a glass. In real systems friction and air resistance cause damping, which gradually reduces the amplitude.

MCQs with Answers

1. In SHM the acceleration is:

(a) constant (b) proportional to displacement (c) zero (d) proportional to time

Correct Answer: (b) proportional to displacement. a = -omega^2 x, proportional to displacement.

2. The maximum displacement of a body in SHM is the:

(a) frequency (b) amplitude (c) period (d) phase

Correct Answer: (b) amplitude. It is called the amplitude.

3. The time period of a simple pendulum is:

(a) 2 pi sqrt(m/k) (b) 2 pi sqrt(l/g) (c) 2 pi sqrt(g/l) (d) 2 pi l g

Correct Answer: (b) 2 pi sqrt(l/g). T = 2 pi sqrt(l/g).

4. The period of a simple pendulum does NOT depend on:

(a) length (b) gravity (c) mass of bob (d) none

Correct Answer: (c) mass of bob. It is independent of the mass of the bob.

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5. The time period of a mass-spring system is:

(a) 2 pi sqrt(m/k) (b) 2 pi sqrt(k/m) (c) 2 pi m k (d) 2 pi sqrt(l/g)

Correct Answer: (a) 2 pi sqrt(m/k). T = 2 pi sqrt(m/k).

6. In SHM the kinetic energy is maximum at the:

(a) extreme position (b) mean position (c) top (d) string

Correct Answer: (b) mean position. At the mean position where speed is maximum.

7. The number of oscillations per second is the:

(a) period (b) amplitude (c) frequency (d) phase

Correct Answer: (c) frequency. Frequency f = 1/T.

8. Resonance occurs when the driving frequency equals the ___ frequency:

(a) double (b) natural (c) half (d) zero

Correct Answer: (b) natural. The natural frequency.

9. The gradual decrease of amplitude due to friction is called:

(a) resonance (b) damping (c) forcing (d) phase

Correct Answer: (b) damping. This is damping.

10. The angular frequency omega is equal to:

(a) 2 pi f (b) f/2 pi (c) pi f (d) f

Correct Answer: (a) 2 pi f. omega = 2 pi f.

Quick Revision Summary

- SHM: a = -omega^2 x (acceleration towards mean position, proportional to displacement).
- Amplitude = maximum displacement; period T; frequency f = 1/T; omega = 2 pi f.
- Simple pendulum: T = 2 pi sqrt(l/g) (independent of mass and small-angle amplitude).
- Mass-spring: T = 2 pi sqrt(m/k).
- Energy: KE maximum at mean position, PE maximum at extremes; total constant.
- Resonance: driving frequency = natural frequency; damping reduces amplitude. Notes by freebooks.pk.

Exam Tips

- State the SHM condition a = -omega^2 x clearly.
- Remember pendulum period is independent of mass.
- Learn both period formulas: pendulum and mass-spring.
- In energy questions, KE and PE swap; total stays constant.
- Resonance = matching frequencies; give an example.
- Keep units consistent when using g in the pendulum formula.

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FSc Part-I Physics — Punjab Board

CHAPTER 8

Waves

Key Concepts · Definitions · Short & Long Questions · MCQs · Diagrams · Exam Tips

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This chapter covers Waves from the 1st Year (FSc Part-I) Physics syllabus of the Punjab Curriculum and Textbook Board (PTB/PCTB). It studies progressive waves, transverse and longitudinal waves, the wave equation v = f lambda, the speed of sound, the principle of superposition, interference, beats, stationary waves and the Doppler effect. These notes are prepared by freebooks.pk.

Waves carry energy from one place to another without carrying matter with them. Sound, light and ripples on water are all examples, and this chapter explains how they behave.

Learning Objectives

- Distinguish transverse and longitudinal (progressive) waves.
- Apply the wave equation v = f lambda.
- State the factors affecting the speed of sound.
- State the principle of superposition and explain interference and beats.
- Describe stationary waves, nodes and antinodes.
- Explain the Doppler effect.

Key Concepts

Progressive Waves

A progressive (or travelling) wave is a disturbance that moves through a medium, carrying energy from one place to another without any net movement of the medium itself. In a transverse wave the particles of the medium vibrate at right angles to the direction in which the wave travels (for example waves on a string or water ripples), while in a longitudinal wave the particles vibrate along the direction of travel, producing compressions and rarefactions (for example sound waves in air).

The Wave Equation

The speed of a wave is related to its frequency and wavelength by v = f lambda, where v is the speed, f the frequency (number of waves per second) and lambda the wavelength (distance between two consecutive crests or compressions). Since the period T = 1/f, the wave also moves one wavelength in one period.

Speed of Sound

Sound is a longitudinal wave and needs a material medium to travel; it cannot pass through a vacuum. Its speed depends on the properties of the medium: it is greatest in solids, less in liquids and least in gases. In air the speed of sound increases with temperature (roughly 0.6 m/s for each degree Celsius) and is essentially independent of pressure. At 0 degrees Celsius the speed of sound in air is about 332 m/s.

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Principle of Superposition

When two or more waves pass through the same region at the same time, the resultant displacement at any point is the vector sum of the displacements due to the individual waves. This principle of superposition explains interference, beats and stationary waves.

Interference and Beats

Interference occurs when two waves of the same frequency overlap: where they arrive in phase they reinforce (constructive interference) and where they arrive out of phase they cancel (destructive interference). Beats are the periodic rise and fall in loudness heard when two sound waves of slightly different frequencies are sounded together; the number of beats per second equals the difference of the two frequencies.

Stationary Waves

A stationary (or standing) wave is formed when two identical waves travelling in opposite directions superpose, for example a wave and its reflection. The wave appears to stand still: certain points called nodes stay permanently at rest, while points midway between them called antinodes vibrate with the largest amplitude. Stationary waves are set up in stretched strings and in air columns and are the basis of musical instruments.

The Doppler Effect

The Doppler effect is the apparent change in the frequency (pitch) of a wave when there is relative motion between the source and the observer. When the source moves towards the observer the pitch heard is higher, and when it moves away the pitch is lower; a familiar example is the changing pitch of a siren on a passing ambulance.

Important Definitions

Term	Definition
Progressive wave	A wave that travels through a medium carrying energy without net movement of matter.
Transverse wave	A wave in which particles vibrate perpendicular to the direction of travel.
Longitudinal wave	A wave in which particles vibrate along the direction of travel.
Wavelength	The distance between two consecutive crests or compressions, lambda.
Interference	The superposition of two waves giving reinforcement or cancellation.
Beats	The periodic variation in loudness from two waves of slightly different frequency.
Node	A point on a stationary wave that stays permanently at rest.
Doppler effect	The apparent change in frequency due to relative motion of source and observer.

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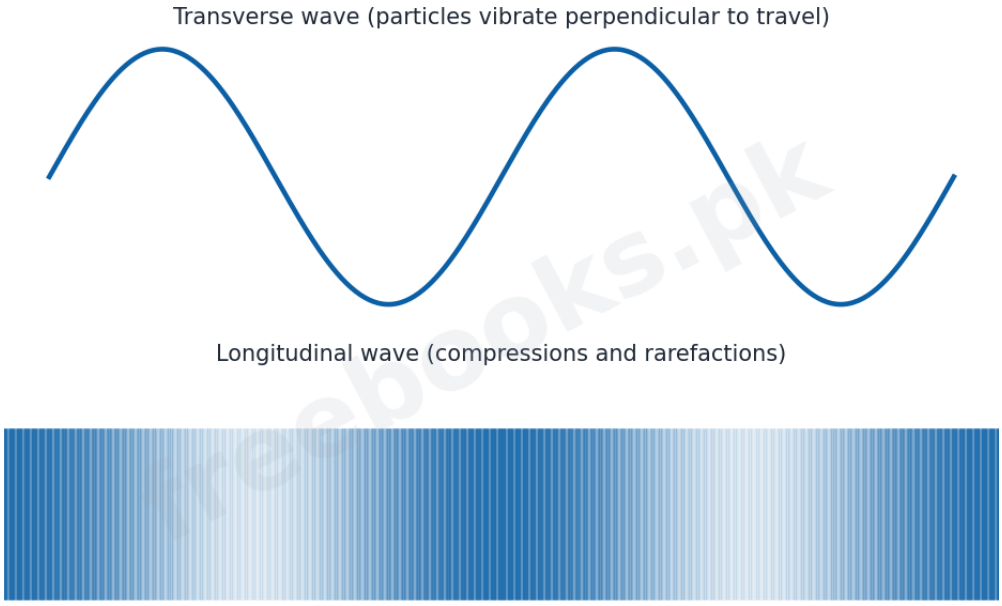
Formulas & Rules

Item	Fact
Wave equation	v = f lambda
Frequency and period	f = 1/T
Number of beats	beats per second = f1 - f2
Speed of sound in air	about 332 m/s at 0 C, rising ~0.6 m/s per degree C
Speed of sound v_t	v_t = v_0 + 0.6 t (t in degrees C)

Diagrams & Illustrations

Transverse and longitudinal waves: a transverse wave shown as a sine curve above a longitudinal wave shown as compressions and rarefactions, comparing the two types.



Transverse and longitudinal waves

Stationary wave: a stationary wave showing fixed nodes (N) where the string is at rest and antinodes (A) where the amplitude is largest.

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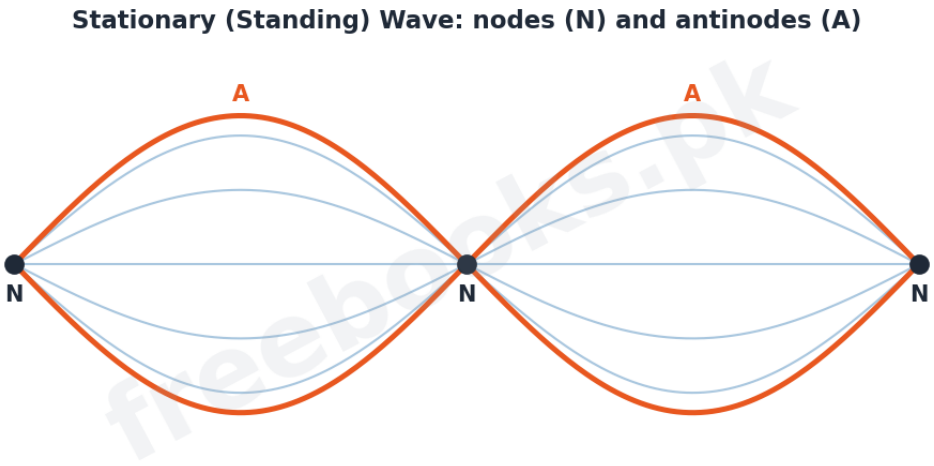
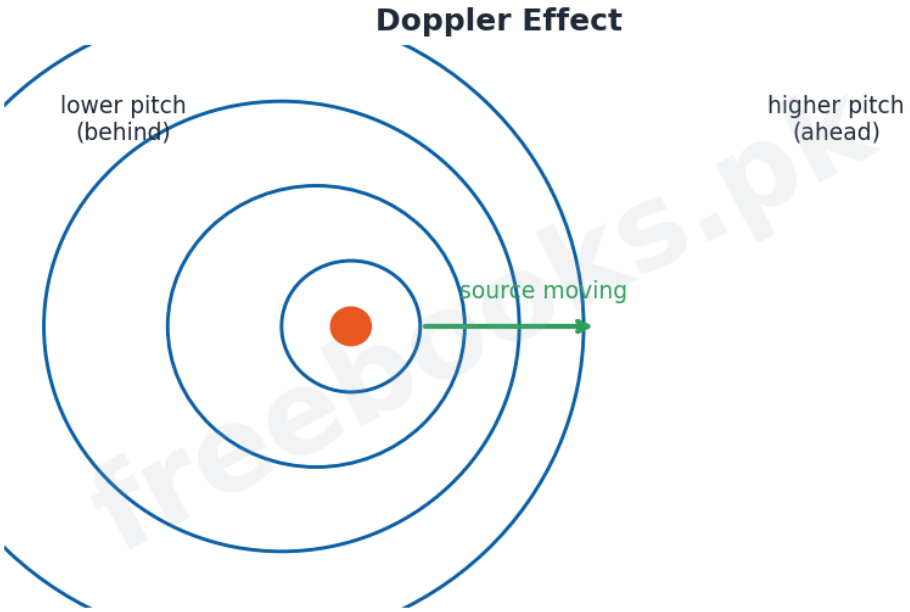


Stationary wave

Doppler effect: a moving sound source with bunched-up wavefronts ahead (higher pitch) and spread-out wavefronts behind (lower pitch).



Doppler effect

Solved Examples & Numericals

Wave equation

A wave has frequency 50 Hz and wavelength 4 m. Its speed is v = f lambda = 50 x 4 = 200 m/s.

Finding wavelength

Sound of frequency 340 Hz travels at 340 m/s. Its wavelength is lambda = v/f = 340/340 = 1 m.

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Beats

Two tuning forks of 256 Hz and 260 Hz are sounded together. The number of beats per second is 260 - 256 = 4.

Speed of sound with temperature

If the speed of sound is 332 m/s at 0 C, at 20 C it is about 332 + 0.6 x 20 = 344 m/s.

Short Questions & Answers

Q1. Differentiate transverse and longitudinal waves.
Ans. In a transverse wave particles vibrate perpendicular to the direction of travel; in a longitudinal wave they vibrate along the direction of travel.

Q2. Write the wave equation.
Ans. v = f lambda, where v is speed, f frequency and lambda wavelength.

Q3. Can sound travel through vacuum?
Ans. No. Sound is a mechanical (longitudinal) wave and needs a material medium; it cannot travel through a vacuum.

Q4. What are beats?
Ans. The periodic rise and fall in loudness heard when two sounds of slightly different frequency are sounded together; beats per second = difference of frequencies.

Q5. What is a node?
Ans. A point on a stationary wave that always stays at rest (zero amplitude).

Q6. State the Doppler effect.
Ans. The apparent change in the pitch of a wave due to relative motion between the source and the observer.

Long Questions & Answers

Q1: Distinguish between transverse and longitudinal waves and give examples of each.

A progressive wave transfers energy through a medium without any net movement of the medium. Such waves are of two main kinds. In a transverse wave the particles of the medium vibrate at right angles (perpendicular) to the direction in which the wave travels; the wave then consists of crests and troughs. Waves on a stretched string, ripples on the surface of water and electromagnetic waves such as light are transverse. In a longitudinal wave the particles vibrate back and forth along the same direction in which the wave travels; the wave then consists of regions where the particles are pushed together, called compressions, and regions where they are spread apart, called rarefactions. Sound waves in air are the most important example of longitudinal waves. In both types the speed is given by v = f lambda, but only transverse waves can be polarised, which is one experimental way to tell them apart.

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Q2: State the principle of superposition and use it to explain interference and beats.

The principle of superposition states that when two or more waves pass through the same region of a medium at the same time, the resultant displacement at any point is the algebraic (vector) sum of the displacements that each wave would produce on its own. This simple rule explains several important effects. Interference results when two waves of the same frequency overlap: at points where the waves arrive in phase (crest on crest) they reinforce each other to give a large disturbance, called constructive interference, and at points where they arrive exactly out of phase (crest on trough) they cancel, called destructive interference. Beats arise when two sound waves of slightly different frequencies are sounded together; the waves alternately reinforce and cancel, so the loudness rises and falls periodically. The number of beats heard per second is equal to the difference between the two frequencies, a fact used to tune musical instruments.

Q3: Describe stationary waves and explain nodes and antinodes.

A stationary or standing wave is produced when two progressive waves of the same frequency and amplitude travel through a medium in opposite directions and superpose; this commonly happens when a wave is reflected back on itself, for example in a stretched string fixed at both ends or in an air column. By the principle of superposition the two waves combine so that the resultant pattern appears to stay in one place rather than travelling. Certain points, called nodes, are always at rest because the two waves there always cancel; the distance between consecutive nodes is half a wavelength. Midway between the nodes are the antinodes, where the two waves always reinforce and the particles vibrate with the greatest amplitude. Unlike a progressive wave, a stationary wave does not transport energy along the medium; instead the energy stays localised, oscillating between kinetic and potential forms. Stationary waves in strings and air columns are responsible for the notes produced by musical instruments.

MCQs with Answers

1. A wave that needs no material medium is:
(a) sound (b) longitudinal (c) transverse light (d) all
Correct Answer: (c) transverse light. Light is transverse and needs no medium.

2. The wave equation is:
(a) v = f/lambda (b) v = f lambda (c) v = lambda/f (d) f = v lambda
Correct Answer: (b) v = f lambda. v = f lambda.

3. Sound waves are:
(a) transverse (b) longitudinal (c) stationary (d) electromagnetic
Correct Answer: (b) longitudinal. Sound is longitudinal.

4. Sound cannot travel through:
(a) air (b) water (c) steel (d) vacuum
Correct Answer: (d) vacuum. It needs a medium; not a vacuum.

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5. Beats per second equal the ___ of the two frequencies:
(a) sum (b) product (c) difference (d) ratio
Correct Answer: (c) difference. The difference.

6. A point of zero amplitude on a stationary wave is a:
(a) antinode (b) node (c) crest (d) trough
Correct Answer: (b) node. A node.

7. The distance between two consecutive crests is the:
(a) amplitude (b) frequency (c) wavelength (d) period
Correct Answer: (c) wavelength. The wavelength.

8. The apparent change of pitch due to relative motion is the:
(a) beat (b) interference (c) Doppler effect (d) echo
Correct Answer: (c) Doppler effect. The Doppler effect.

9. The speed of sound in air at 0 C is about:
(a) 332 m/s (b) 3x10^8 m/s (c) 1500 m/s (d) air has none
Correct Answer: (a) 332 m/s. About 332 m/s.

10. Constructive interference occurs when waves meet:
(a) out of phase (b) in phase (c) at nodes (d) never
Correct Answer: (b) in phase. In phase.

Quick Revision Summary

- Progressive waves carry energy, not matter; transverse (perpendicular) vs longitudinal (along).
- Wave equation v = f lambda; f = 1/T.
- Sound is longitudinal, needs a medium; ~332 m/s at 0 C, +0.6 m/s per degree C.
- Superposition: interference (in phase reinforce, out of phase cancel); beats = |f1 - f2|.
- Stationary waves: nodes at rest, antinodes maximum; no net energy transport.
- Doppler effect: pitch higher approaching, lower receding. Notes by freebooks.pk.

Exam Tips

- Learn the difference between transverse and longitudinal with examples.
- Memorise v = f lambda and be ready to rearrange it.
- State that sound cannot travel through vacuum.
- Beats per second = difference of frequencies.
- Define node and antinode precisely.
- Give the ambulance siren as a Doppler example.

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CHAPTER 9

Physical Optics

Key Concepts · Definitions · Short & Long Questions · MCQs · Diagrams · Exam Tips

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This chapter covers Physical Optics from the 1st Year (FSc Part-I) Physics syllabus of the Punjab Curriculum and Textbook Board (PTB/PCTB). It treats the wave nature of light, Huygens principle, interference (Young's double-slit experiment), diffraction, the diffraction grating and polarisation. These notes are prepared by freebooks.pk.

Physical optics explains those properties of light that only make sense if light behaves as a wave, such as interference and diffraction, which cannot be explained by treating light merely as rays.

Learning Objectives

- State Huygens principle and the concept of a wavefront.
- Explain interference of light and Young's double-slit experiment.
- Describe diffraction and the diffraction grating.
- Use d sin(theta) = n lambda for a grating.
- Explain polarisation and what it tells us about light.

Key Concepts

Wavefronts and Huygens Principle

A wavefront is a surface joining all points of a wave that are in the same phase (for example all the crests). Huygens principle states that every point on a wavefront may be regarded as a source of secondary wavelets, and the new wavefront a moment later is the surface that touches all these wavelets. This idea explains how waves travel and how they reflect and refract.

Interference of Light

Interference is the superposition of two light waves. To see steady interference the two sources must be coherent, meaning they have the same frequency and a constant phase difference; in practice this is achieved by taking the two waves from a single source. Where the waves meet in phase they reinforce to give a bright region (constructive interference) and where they meet out of phase they cancel to give a dark region (destructive interference).

Young's Double-Slit Experiment

In Young's experiment light from a single source passes through two narrow, closely spaced slits. The two slits act as coherent sources, and the light spreading from them overlaps to produce a pattern of alternate bright and dark bands, called interference fringes, on a screen. This experiment was historic evidence that light is a wave. The spacing of the fringes depends on the wavelength of the light, the separation of the slits and the distance to the screen.

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Diffraction of Light

Diffraction is the bending or spreading of light as it passes the edge of an obstacle or through a narrow opening. It becomes noticeable when the size of the opening is comparable with the wavelength of the light. Diffraction, like interference, is a property that only waves show, and it confirms the wave nature of light.

The Diffraction Grating

A diffraction grating is a plate ruled with a very large number of equally spaced parallel slits (lines). When light passes through it, the many slits produce sharp, bright beams in particular directions given by d sin(theta) = n lambda, where d is the spacing between the slits (the grating element), theta the angle of the beam, n the order and lambda the wavelength. Because different wavelengths are sent in different directions, a grating spreads white light into its spectrum and is used to measure wavelengths accurately.

Polarisation

In an ordinary beam of light the vibrations of the electric field occur in all directions perpendicular to the direction of travel; such light is unpolarised. When the vibrations are confined to a single plane the light is said to be plane-polarised. Light can be polarised by passing it through a polarising material (such as Polaroid) or by reflection. The fact that light can be polarised proves that it is a transverse wave, because only transverse waves can be polarised.

Important Definitions

Term	Definition
Wavefront	A surface joining all points of a wave that are in the same phase.
Huygens principle	Every point on a wavefront acts as a source of secondary wavelets.
Coherent sources	Sources of the same frequency with a constant phase difference.
Interference	The superposition of two light waves giving bright and dark regions.
Diffraction	The bending or spreading of light around edges or through narrow openings.
Diffraction grating	A plate with many equally spaced parallel slits used to disperse light.
Polarisation	Restriction of the vibrations of light to a single plane.
Plane-polarised light	Light whose vibrations are confined to one plane.

Formulas & Rules

Item	Fact
Grating equation	d sin(theta) = n lambda
Grating element	d = 1 / (number of lines per metre)

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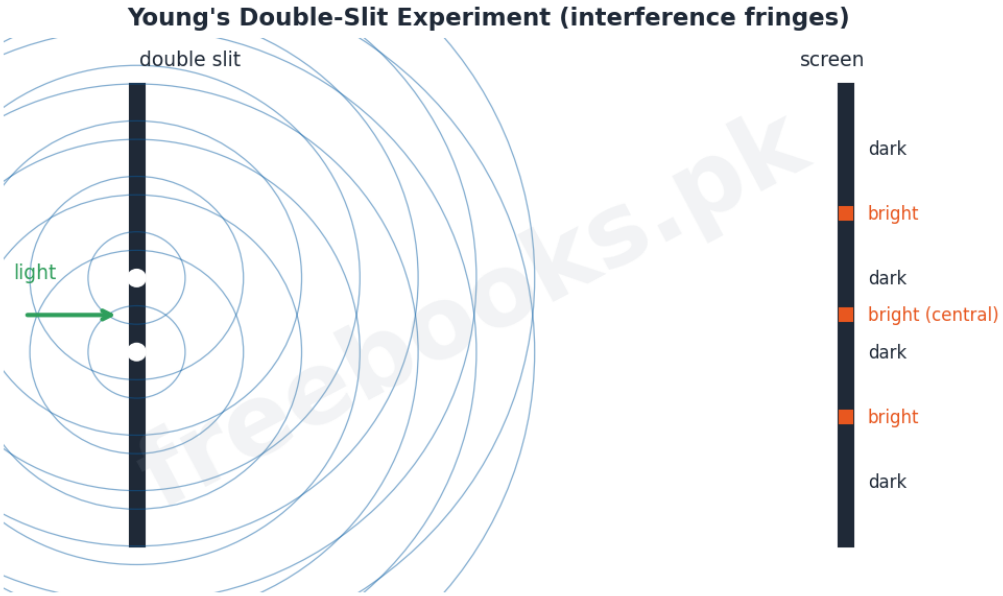
Item	Fact
Constructive interference	path difference = n lambda
Destructive interference	path difference = (n + 1/2) lambda

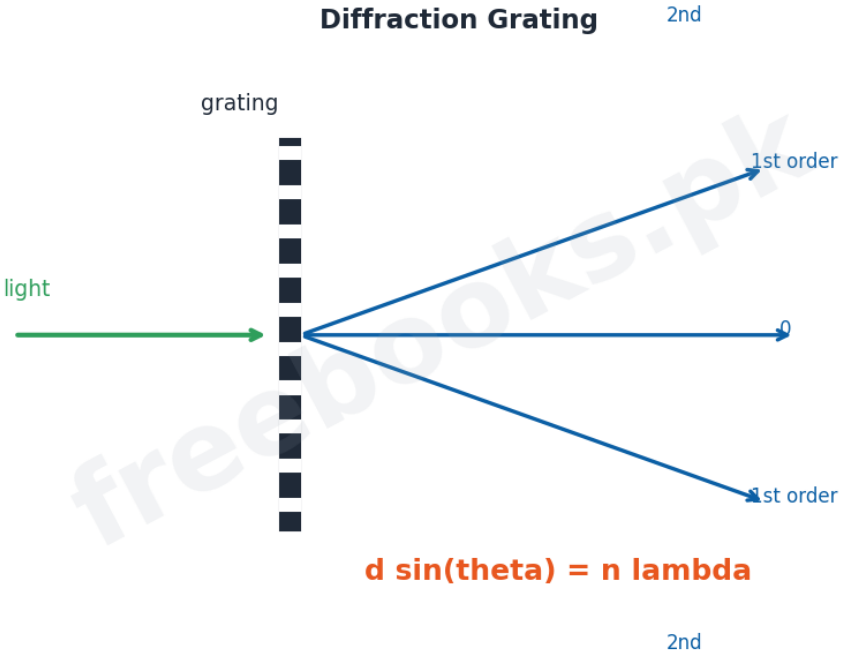
Diagrams & Illustrations

Young's double-slit experiment: light from a single source passing through two slits and forming alternate bright and dark interference fringes on a screen.



Young's double-slit experiment

Diffraction grating: a diffraction grating splitting an incoming beam into several sharp orders at angles given by d sin(theta) = n lambda.



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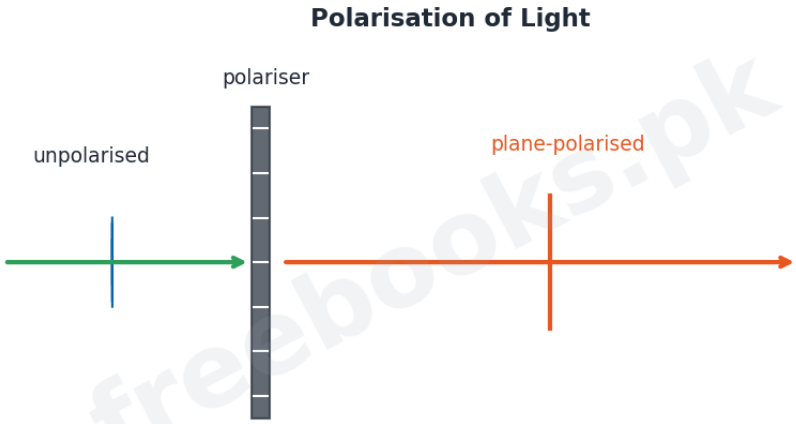
Diffraction grating

Polarisation of light: unpolarised light passing through a polariser and emerging as plane-polarised light vibrating in a single plane.



Polarisation of light

Solved Examples & Numericals

Grating equation

A grating with 5000 lines per cm has d = 1/(5000 x 100) m = 2 x 10^-6 m. For first-order (n=1) light of wavelength 5 x 10^-7 m, sin(theta) = n lambda / d = 5x10^-7 / 2x10^-6 = 0.25, so theta = 14.5 degrees.

Grating element

A grating has 2000 lines per centimetre. Its grating element is d = 1/2000 cm = 5 x 10^-4 cm = 5 x 10^-6 m.

Order of spectrum

Using d sin(theta) = n lambda, as n increases the angle theta increases, so higher orders are diffracted through larger angles.

Coherence

Two independent bulbs cannot produce steady interference because they are not coherent; that is why Young's experiment uses a single source split into two.

Short Questions & Answers

Q1. What is a wavefront?
Ans. A surface joining all points of a wave that are in the same phase.

Q2. State Huygens principle.

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Ans. Every point on a wavefront acts as a source of secondary wavelets, and the new wavefront is the surface touching all the wavelets.

Q3. What are coherent sources?

Ans. Sources that have the same frequency and a constant phase difference.

Q4. What is diffraction?

Ans. The bending or spreading of light as it passes an edge or a narrow opening.

Q5. Write the grating equation.

Ans. d sin(theta) = n lambda, where d is the grating element, theta the angle, n the order and lambda the wavelength.

Q6. What does polarisation prove about light?

Ans. That light is a transverse wave, since only transverse waves can be polarised.

Long Questions & Answers

Q1: Describe Young's double-slit experiment and explain how it demonstrates the wave nature of light.

In Young's double-slit experiment light from a single monochromatic source is first passed through a single narrow slit and then through two very narrow, closely spaced slits placed side by side. Because both sets of waves come from the same original source, the two slits behave as coherent sources, that is, they emit waves of the same frequency with a constant phase difference. The light spreading out from the two slits overlaps in the region beyond them and, by the principle of superposition, produces interference. On a screen placed in this region a pattern of equally spaced bright and dark bands, called interference fringes, is seen: bright fringes appear where the waves from the two slits arrive in phase (path difference a whole number of wavelengths, n lambda) and dark fringes appear where they arrive exactly out of phase (path difference (n + 1/2) lambda). Such a steady pattern of alternate bright and dark bands can only be explained if light travels as a wave; a stream of particles could not cancel out to give darkness. The experiment was therefore historic evidence for the wave nature of light, and measuring the fringe spacing allows the wavelength of the light to be found.

Q2: What is a diffraction grating? Derive/state its equation and describe its uses.

A diffraction grating is an optical plate on which a very large number of equally spaced, parallel slits (or lines) have been ruled, often several thousand per centimetre. When a parallel beam of light falls on the grating, each slit diffracts the light, and the many diffracted beams interfere. Reinforcement occurs only in certain sharply defined directions where the path difference between light from adjacent slits is a whole number of wavelengths, giving the grating equation d sin(theta) = n lambda, where d is the distance between the centres of neighbouring slits (the grating element), theta is the angle at which a bright beam is seen, n is the order of the spectrum (0, 1, 2, ...) and lambda is the wavelength. Because the angle depends on the wavelength, light of different colours is sent

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in different directions, so a grating spreads white light into a spectrum. Gratings are widely used in spectrometers to measure wavelengths very accurately and to study the composition of light from different sources.

Q3: Explain polarisation of light and describe how it shows that light is a transverse wave.

In an ordinary beam of light the electric-field vibrations take place in all possible directions at right angles to the direction in which the light travels; such light is said to be unpolarised. If, by some means, these vibrations are restricted so that they occur in only one plane, the light is called plane-polarised. Light can be polarised in several ways, the simplest being to pass it through a sheet of polarising material such as Polaroid, which transmits only the vibrations parallel to a particular direction and absorbs the rest; light can also be partly polarised by reflection from a surface such as water or glass. The crucial point is that polarisation is only possible for transverse waves, in which the vibrations are perpendicular to the direction of travel and so can be confined to a plane; longitudinal waves such as sound, whose vibrations are along the direction of travel, cannot be polarised. The fact that light can be polarised is therefore direct experimental proof that light is a transverse wave. Polarising materials are used in sunglasses and camera filters to cut down glare.

MCQs with Answers

1. A surface of points in the same phase is a:
(a) ray (b) wavefront (c) node (d) fringe
Correct Answer: (b) wavefront. A wavefront.

2. Sources with a constant phase difference are:
(a) coherent (b) incoherent (c) polarised (d) diffracted
Correct Answer: (a) coherent. Coherent.

3. Young's experiment demonstrates the ___ of light:
(a) particle nature (b) wave nature (c) speed (d) colour
Correct Answer: (b) wave nature. Wave nature.

4. Bright fringes occur where the path difference is:
(a) (n+1/2) lambda (b) n lambda (c) lambda/4 (d) zero only
Correct Answer: (b) n lambda. n lambda.

5. The bending of light around edges is:
(a) reflection (b) refraction (c) diffraction (d) dispersion
Correct Answer: (c) diffraction. Diffraction.

6. The grating equation is:
(a) d sin(theta) = n lambda (b) n d = lambda (c) d = n lambda tan (d) lambda = d cos
Correct Answer: (a) d sin(theta) = n lambda. d sin(theta) = n lambda.

7. Polarisation proves light is a ___ wave:
(a) longitudinal (b) transverse (c) stationary (d) sound
Correct Answer: (b) transverse. Transverse.

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8. Which cannot be polarised?

(a) light (b) radio waves (c) sound (d) X-rays

Correct Answer: (c) sound. Sound (longitudinal).

9. A diffraction grating is used to measure:

(a) mass (b) wavelength (c) current (d) temperature

Correct Answer: (b) wavelength. Wavelength.

10. Ordinary light is:

(a) polarised (b) unpolarised (c) coherent (d) monochromatic

Correct Answer: (b) unpolarised. Unpolarised.

Quick Revision Summary

- Wavefront = points in same phase; Huygens: each point emits secondary wavelets.
- Interference needs coherent sources; bright at n lambda, dark at (n+1/2) lambda.
- Young's double slit = proof of wave nature of light (fringes).
- Diffraction = bending around edges/openings ~ wavelength size.
- Grating: d sin(theta) = n lambda; disperses light, measures wavelength.
- Polarisation proves light is transverse; sound cannot be polarised. Notes by freebooks.pk.

Exam Tips

- Define wavefront and state Huygens principle.
- Explain why interference needs coherent sources.
- Remember bright = n lambda, dark = (n+1/2) lambda.
- Memorise the grating equation d sin(theta) = n lambda.
- State that polarisation proves light is transverse.
- Give a practical use of polarisation (sunglasses).

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FSc Part-I Physics — Punjab Board

CHAPTER 10

Optical Instruments

Key Concepts · Definitions · Short & Long Questions · MCQs · Diagrams · Exam Tips

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This chapter covers Optical Instruments from the 1st Year (FSc Part-I) Physics syllabus of the Punjab Curriculum and Textbook Board (PTB/PCTB). It explains magnifying power, the simple and compound microscope, the astronomical telescope, resolving power and the optical fibre. These notes are prepared by freebooks.pk.

Optical instruments use lenses (and total internal reflection) to help us see things that are too small or too far away for the unaided eye. This chapter explains how the common ones work.

Learning Objectives

- Define least distance of distinct vision and magnifying power.
- Explain the working of a simple and a compound microscope.
- Explain the working of an astronomical telescope.
- State what is meant by resolving power.
- Describe the optical fibre and total internal reflection.

Key Concepts

Magnifying Power and Least Distance of Distinct Vision

The least distance of distinct vision is the closest distance at which a normal eye can see an object clearly without strain, taken as 25 cm. The magnifying power (or angular magnification) of an instrument is the ratio of the angle subtended at the eye by the image seen through the instrument to the angle subtended by the object when placed at the least distance of distinct vision. It tells us how much larger an object appears through the instrument.

The Simple Microscope

A simple microscope, or magnifying glass, is a single convex lens of short focal length. When an object is placed inside the focal length of the lens, the lens forms an enlarged, erect, virtual image on the same side as the object. Its magnifying power is $M = 1 + d/f$, where $d = 25$ cm is the least distance of distinct vision and f is the focal length of the lens; a shorter focal length gives a greater magnification.

The Compound Microscope

A compound microscope uses two convex lenses: an objective of very short focal length near the object and an eyepiece near the eye. The objective forms a real, magnified image of the object, and the eyepiece then acts as a magnifying glass to further enlarge this image, producing a large, virtual final image. Because the magnification takes place in two stages, a compound microscope gives much greater magnification than a simple one and is used to view tiny objects such as cells.

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The Astronomical Telescope

An astronomical (refracting) telescope is used to view distant objects such as stars and planets. It has an objective lens of large focal length that collects light from the distant object and forms a real image of it, and an eyepiece of short focal length that magnifies this image. In normal adjustment the final image is formed at infinity and the magnifying power is M = f_o / f_e, the ratio of the focal lengths of the objective and the eyepiece; a long objective and a short eyepiece give high magnification.

Resolving Power

The resolving power of an instrument is its ability to show two closely spaced objects as separate. A microscope or telescope with high resolving power can distinguish fine detail. Resolving power increases with the size (aperture) of the objective and decreases with the wavelength of the light used, which is one reason large telescopes have large objective lenses or mirrors.

The Optical Fibre

An optical fibre is a thin, flexible strand of very pure glass (or plastic) that carries light along its length. Light entering one end strikes the walls at an angle greater than the critical angle and is repeatedly reflected by total internal reflection, so it travels along the fibre with very little loss even when the fibre is bent. Optical fibres are used to carry telephone and internet signals as pulses of light and in medical endoscopes to look inside the body.

Important Definitions

Term	Definition
Least distance of distinct vision	The nearest distance (25 cm) at which a normal eye sees clearly without strain.
Magnifying power	The ratio of the angle subtended by the image to that subtended by the object at 25 cm.
Simple microscope	A single convex lens used as a magnifying glass.
Compound microscope	An instrument using an objective and eyepiece to give large magnification.
Astronomical telescope	An instrument using two lenses to view distant objects.
Resolving power	The ability of an instrument to show two close objects as separate.
Optical fibre	A thin glass strand that guides light by total internal reflection.
Total internal reflection	Complete reflection of light at a boundary when the angle exceeds the critical angle.

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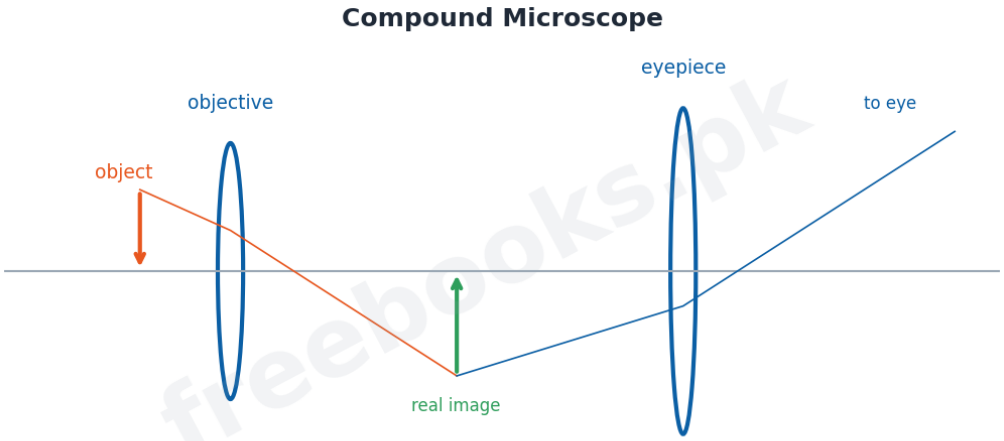
Formulas & Rules

Item	Fact
Least distance of distinct vision	d = 25 cm
Simple microscope	M = 1 + d/f
Compound microscope	M = M_objective x M_eyepiece
Astronomical telescope (normal adjustment)	M = f_o / f_e

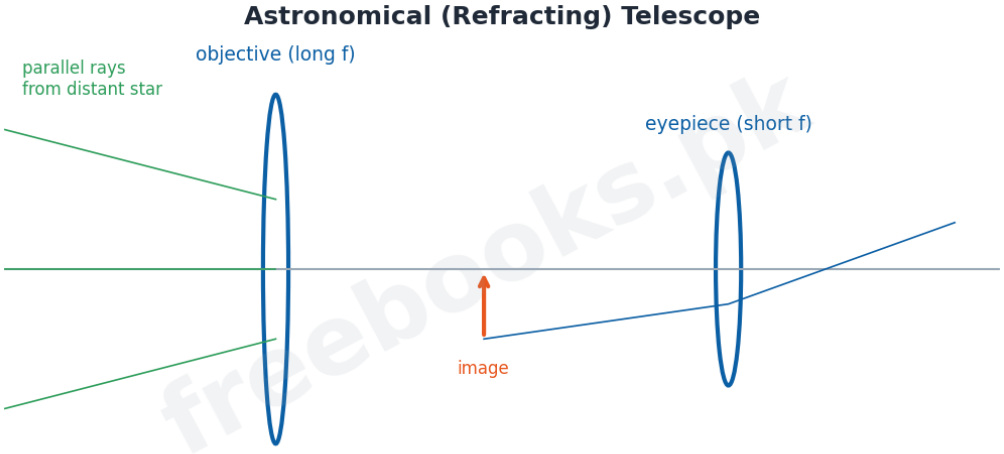
Diagrams & Illustrations

Compound microscope: a compound microscope with an objective forming a real image and an eyepiece magnifying it to give a large virtual final image.



Compound microscope

Astronomical telescope: an astronomical telescope with a long-focus objective and a short-focus eyepiece viewing a distant object.



Astronomical telescope

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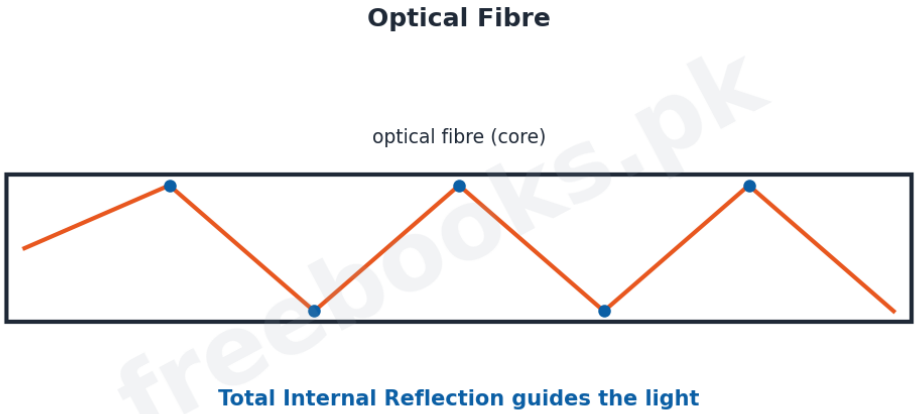
Optical fibre: light travelling along an optical fibre by repeated total internal reflection at its walls.



Optical fibre

Solved Examples & Numericals

Simple microscope

A magnifying glass has focal length 5 cm. Its magnifying power is M = 1 + d/f = 1 + 25/5 = 1 + 5 = 6.

Telescope

A telescope has an objective of focal length 100 cm and an eyepiece of focal length 5 cm. Its magnifying power is M = f_o/f_e = 100/5 = 20.

Length of telescope

In normal adjustment the length of a telescope is about f_o + f_e = 100 + 5 = 105 cm for the example above.

Effect of focal length

For a simple microscope a smaller focal length gives a larger M; a 2.5 cm lens gives M = 1 + 25/2.5 = 11.

Short Questions & Answers

Q1. What is the least distance of distinct vision?
Ans. The closest distance, about 25 cm, at which a normal eye can see an object clearly without strain.

Q2. What is a simple microscope?
Ans. A single convex lens of short focal length used as a magnifying glass; M = 1 + d/f.

Q3. How does a compound microscope give high magnification?

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Ans. It magnifies in two stages: the objective forms a real magnified image which the eyepiece magnifies again.

Q4. Write the magnifying power of a telescope in normal adjustment.

Ans. M = f_o / f_e, the ratio of the focal lengths of the objective and eyepiece.

Q5. What is resolving power?

Ans. The ability of an instrument to show two closely placed objects as separate.

Q6. How does light travel along an optical fibre?

Ans. By repeated total internal reflection at the walls of the fibre.

Long Questions & Answers

Q1: Describe the construction and working of a compound microscope and write its magnifying power.

A compound microscope is used to view very small objects and consists of two convex lenses mounted at the ends of a tube. The lens nearer the object is the objective and has a very short focal length; the lens nearer the eye is the eyepiece and has a somewhat longer focal length. The object to be examined is placed just outside the focal length of the objective, which therefore forms a real, inverted and magnified image inside the tube. This real image lies within the focal length of the eyepiece, so the eyepiece acts as a simple magnifying glass and forms a still larger, virtual image which the observer sees. Because the magnification is produced in two stages, one by the objective and one by the eyepiece, the overall magnifying power is the product of the two, M = M_objective x M_eyepiece, and is much greater than that of a single lens. This is why a compound microscope can reveal fine detail such as the structure of cells.

Q2: Describe the astronomical telescope and derive/state its magnifying power in normal adjustment.

An astronomical telescope is used to view distant objects such as stars, planets and the Moon. It consists of two convex lenses: an objective of large aperture and long focal length facing the object, and an eyepiece of short focal length near the eye. Light from the distant object arrives as an almost parallel beam, and the objective brings it to a focus, forming a small, real, inverted image just inside its focal point. This real image is arranged to lie at the focal point of the eyepiece, so that the eyepiece produces a final image at infinity, which the relaxed eye can view without strain; this arrangement is called normal adjustment. In normal adjustment the magnifying power is the ratio of the focal length of the objective to that of the eyepiece, M = f_o / f_e. Therefore a telescope with a long objective focal length and a short eyepiece focal length gives high magnification, and its overall length is about f_o + f_e.

Q3: Explain the optical fibre and the principle of total internal reflection on which it works, and give its uses.

An optical fibre is a very thin, flexible thread of extremely pure glass (or transparent plastic) used to guide light from one end to the other. Its working depends on total internal

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reflection, which occurs when light inside a denser medium meets the boundary with a less dense medium at an angle of incidence greater than a certain critical angle; instead of passing out, all the light is reflected back into the denser medium. In an optical fibre light entering one end strikes the walls at angles greater than the critical angle and so is completely reflected again and again, zig-zagging along the fibre with almost no loss of energy even when the fibre is curved. Because they carry information as fast, low-loss pulses of light, optical fibres are the backbone of modern telephone and internet communication, carrying far more data than ordinary wires. They are also used in medical endoscopes, which let doctors see inside the body, and in decorative and lighting applications.

MCQs with Answers

1. The least distance of distinct vision is about:
(a) 25 cm (b) 2.5 cm (c) 1 m (d) infinity
Correct Answer: (a) 25 cm. About 25 cm.

2. A simple microscope is a:
(a) convex lens (b) concave lens (c) prism (d) mirror
Correct Answer: (a) convex lens. A single convex lens.

3. The magnifying power of a simple microscope is:
(a) 1 + d/f (b) f/d (c) d/f only (d) f_o/f_e
Correct Answer: (a) 1 + d/f. M = 1 + d/f.

4. A compound microscope uses:
(a) one lens (b) two convex lenses (c) a mirror (d) a prism
Correct Answer: (b) two convex lenses. Objective and eyepiece.

5. The objective of a compound microscope has a ___ focal length:
(a) very long (b) very short (c) infinite (d) zero
Correct Answer: (b) very short. Very short.

6. The magnifying power of a telescope (normal adjustment) is:
(a) f_o/f_e (b) f_e/f_o (c) f_o x f_e (d) 1 + d/f
Correct Answer: (a) f_o/f_e. M = f_o/f_e.

7. A telescope objective has a ___ focal length:
(a) short (b) long (c) zero (d) negative
Correct Answer: (b) long. Long.

8. Light travels along an optical fibre by:
(a) refraction (b) diffraction (c) total internal reflection (d) dispersion
Correct Answer: (c) total internal reflection. Total internal reflection.

9. The ability to see two close objects separately is:
(a) magnifying power (b) resolving power (c) focal power (d) refractive index
Correct Answer: (b) resolving power. Resolving power.

10. Optical fibres are mainly used in:

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(a) cooking (b) communication (c) weighing (d) heating
Correct Answer: (b) communication. Communication.

Quick Revision Summary

- Least distance of distinct vision d = 25 cm; magnifying power = angle ratio.
- Simple microscope (convex lens): M = 1 + d/f.
- Compound microscope: objective (real image) + eyepiece (magnifies); M = product.
- Astronomical telescope (normal adjustment): M = f_o/f_e; length ~ f_o + f_e.
- Resolving power = ability to separate close objects; larger aperture is better.
- Optical fibre guides light by total internal reflection; used in communication. Notes by freebooks.pk.

Exam Tips

- Remember d = 25 cm for the least distance of distinct vision.
- Learn M = 1 + d/f for the simple microscope.
- State the two-stage magnification of a compound microscope.
- Learn M = f_o/f_e for the telescope.
- Optical fibre works by total internal reflection.
- Link resolving power to aperture size.

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CHAPTER 11

Heat and Thermodynamics

Key Concepts · Definitions · Short & Long Questions · MCQs · Diagrams · Exam Tips

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This chapter covers Heat and Thermodynamics from the 1st Year (FSc Part-I) Physics syllabus of the Punjab Curriculum and Textbook Board (PTB/PCTB). It treats the kinetic theory of gases, internal energy, the first law of thermodynamics, isothermal and adiabatic processes, molar specific heats, the second law and the Carnot engine. These notes are prepared by freebooks.pk.

Thermodynamics is the study of heat and its transformation into work and other forms of energy. It underlies engines, refrigerators and much of modern technology.

Learning Objectives

- State the postulates of the kinetic theory of gases.
- Explain internal energy and the first law of thermodynamics.
- Distinguish isothermal and adiabatic processes.
- Define the molar specific heats of a gas.
- State the second law of thermodynamics.
- Describe the Carnot engine and its efficiency.

Key Concepts

Kinetic Theory of Gases

According to the kinetic theory, a gas consists of a very large number of tiny molecules in rapid, random motion. The molecules are far apart compared with their size, they exert no force on one another except during collisions, and their collisions with each other and with the walls of the container are perfectly elastic. The pressure of a gas is produced by these molecules striking the walls, and the absolute temperature of the gas is a measure of the average kinetic energy of its molecules.

Internal Energy

The internal energy of a system is the total energy of all its molecules, that is, the sum of their kinetic and potential energies. For an ideal gas the internal energy depends only on the temperature, so heating a gas raises its internal energy. Internal energy is a state function: it depends only on the state of the system, not on how that state was reached.

First Law of Thermodynamics

The first law of thermodynamics is the law of conservation of energy applied to heat. It states that the heat Q supplied to a system is used partly to increase the internal energy of the system (delta U) and partly to do external work W: Q = delta U + W. This law tells us that energy can be transferred as heat or work but can never be created or destroyed.

Isothermal and Adiabatic Processes

In an isothermal process the temperature is kept constant (the system is in good thermal contact with its surroundings and changes slowly), so for an ideal gas the internal energy

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does not change and all the heat supplied is converted into work. In an adiabatic process no heat enters or leaves the system (Q = 0, the system is well insulated or the change is very rapid), so any work done by the gas is at the expense of its internal energy, and the gas cools when it expands.

Molar Specific Heats

A gas has two principal molar specific heats: the molar specific heat at constant volume, C_v, and the molar specific heat at constant pressure, C_p. C_p is always greater than C_v, because when a gas is heated at constant pressure some of the heat supplied is used to do work in expanding the gas, in addition to raising its internal energy. The two are related by C_p - C_v = R, where R is the general gas constant.

Second Law and the Carnot Engine

The second law of thermodynamics recognises that heat flows naturally from a hot body to a cold body and that no heat engine can convert all the heat it takes in into work; some heat must always be rejected to a cold reservoir. A heat engine takes heat Q1 from a hot reservoir, converts part of it into work W and rejects the rest Q2 to a cold reservoir. The most efficient possible engine is the ideal Carnot engine, whose efficiency depends only on the temperatures of the two reservoirs: efficiency = 1 - T2/T1, where the temperatures are on the absolute (kelvin) scale.

Important Definitions

Term	Definition
Kinetic theory of gases	The model that treats a gas as many tiny molecules in rapid random motion.
Internal energy	The total kinetic and potential energy of all the molecules of a system.
First law of thermodynamics	Q = delta U + W; conservation of energy for heat.
Isothermal process	A change at constant temperature.
Adiabatic process	A change in which no heat enters or leaves the system (Q = 0).
Molar specific heat	The heat needed to raise the temperature of one mole of gas by one kelvin.
Second law of thermodynamics	Heat cannot be completely converted into work; some is always rejected.
Carnot engine	An ideal heat engine of maximum possible efficiency 1 - T2/T1.

Formulas & Rules

Item	Fact
First law	Q = delta U + W

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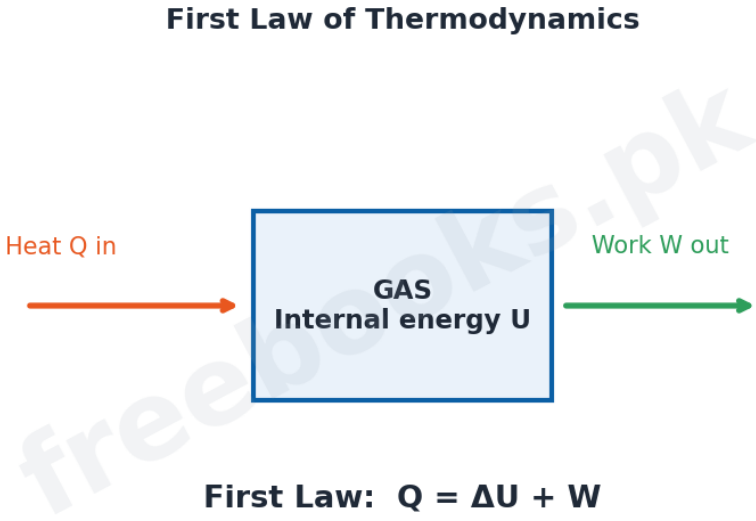
Item	Fact
Molar specific heats	C_p - C_v = R
Isothermal process	delta U = 0, so Q = W
Adiabatic process	Q = 0, so delta U = -W
Carnot efficiency	efficiency = 1 - T2/T1 (T in kelvin)

Diagrams & Illustrations

First law of thermodynamics: heat Q entering a gas, part raising its internal energy U and part leaving as work W, illustrating Q = delta U + W.



First law of thermodynamics

Heat engine: a heat engine taking heat Q1 from a hot reservoir, doing work W and rejecting Q2 to a cold reservoir, with efficiency 1 - T2/T1.

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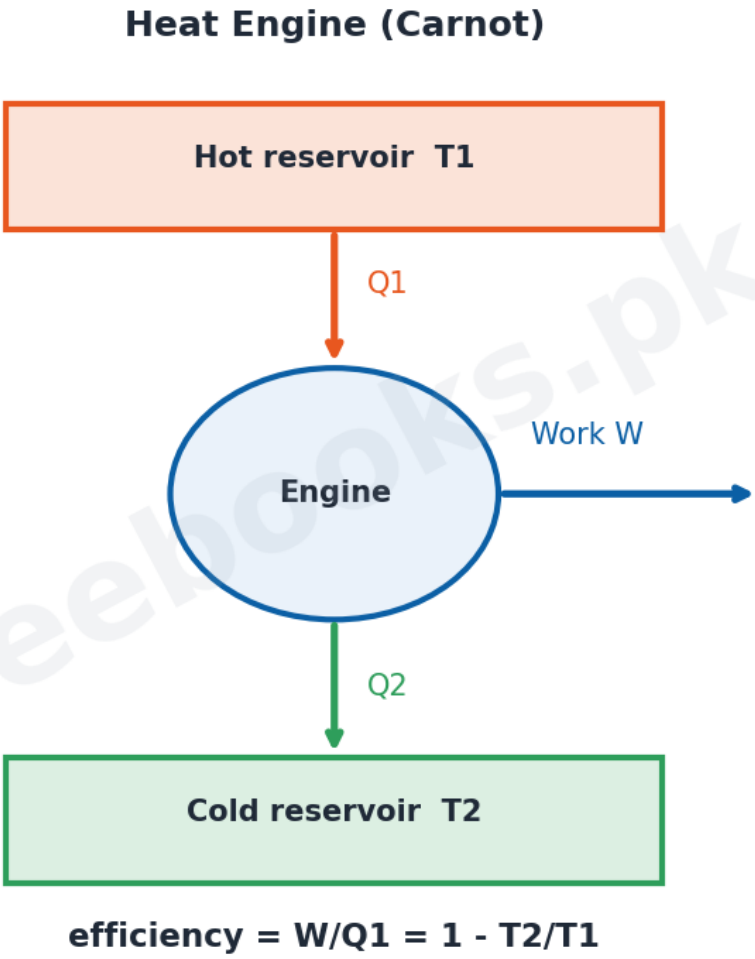

Heat engine

Isothermal and adiabatic curves: a P-V diagram comparing the gentler isothermal curve with the steeper adiabatic curve.

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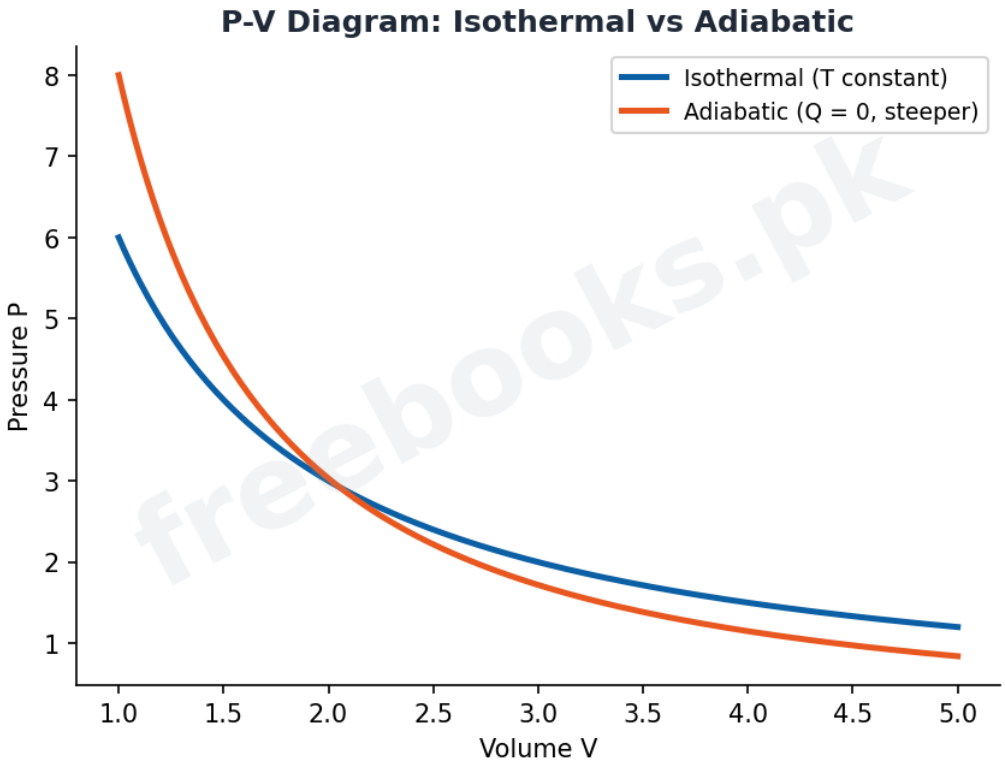

Isothermal and adiabatic curves

Solved Examples & Numericals

First law

A gas absorbs 200 J of heat and does 80 J of work. The increase in its internal energy is delta U = Q - W = 200 - 80 = 120 J.

Isothermal process

In an isothermal expansion delta U = 0, so if a gas absorbs 150 J of heat it does 150 J of work.

Carnot efficiency

An engine works between 400 K and 300 K. Its maximum efficiency is 1 - 300/400 = 1 - 0.75 = 0.25 or 25%.

Specific heats

For a gas C_p = 29 J/mol K and R = 8.3 J/mol K, so C_v = C_p - R = 29 - 8.3 = 20.7 J/mol K.

Short Questions & Answers

Q1. State the first law of thermodynamics.
Ans. The heat supplied to a system equals the increase in its internal energy plus the work done by it: Q = delta U + W.

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Q2. What is an isothermal process?

Ans. A process carried out at constant temperature; for an ideal gas delta U = 0 and Q = W.

Q3. What is an adiabatic process?

Ans. A process in which no heat enters or leaves the system (Q = 0), so delta U = -W.

Q4. Why is C_p greater than C_v?

Ans. Because at constant pressure some heat is used to do work in expanding the gas, as well as to raise its internal energy.

Q5. State the second law of thermodynamics.

Ans. Heat cannot be completely converted into work; some heat must always be rejected to a cold reservoir.

Q6. Write the efficiency of a Carnot engine.

Ans. efficiency = 1 - T2/T1, where T1 and T2 are the absolute temperatures of the hot and cold reservoirs.

Long Questions & Answers

Q1: State and explain the first law of thermodynamics and apply it to isothermal and adiabatic processes.

The first law of thermodynamics is simply the principle of conservation of energy applied to systems in which heat is involved. It states that when an amount of heat Q is supplied to a system, part of it is used to increase the internal energy of the system by an amount delta U and the remainder is used by the system to do external work W on its surroundings, so that Q = delta U + W. Energy is therefore neither created nor destroyed, only transferred between heat, internal energy and work. The law takes simple forms in two important cases. In an isothermal process the temperature, and hence for an ideal gas the internal energy, stays constant, so delta U = 0 and the whole of the heat supplied appears as work, Q = W. In an adiabatic process the system is thermally insulated so that no heat enters or leaves it, giving Q = 0; then delta U = -W, which means that when the gas does work by expanding it does so at the cost of its internal energy and therefore cools, while compressing it warms it up.

Q2: Distinguish between the two molar specific heats of a gas and derive the relation C_p - C_v = R.

A gas can be heated in two different ways, and these lead to two distinct molar specific heats. The molar specific heat at constant volume, C_v, is the heat required to raise the temperature of one mole of the gas by one kelvin while its volume is held fixed; since the gas does no external work in this case, all the heat goes to increase the internal energy. The molar specific heat at constant pressure, C_p, is the heat required to raise the temperature of one mole by one kelvin while the pressure is kept constant; now the gas expands and does external work as well as gaining internal energy. Because heating at constant pressure has to supply this extra work in addition to the same rise in internal energy, C_p is always larger than C_v. Applying the first law to one mole heated at constant pressure, the extra

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heat compared with the constant-volume case equals the work of expansion, which for one mole and a one-kelvin rise is equal to the general gas constant R; hence C_p - C_v = R. This important result links the two specific heats to the gas constant.

Q3: State the second law of thermodynamics and describe the Carnot engine and its efficiency.

The second law of thermodynamics expresses the one-way nature of heat flow and the limits on converting heat into work. In one common form it states that heat flows of its own accord only from a hotter body to a colder body, and in another (Kelvin's form) that it is impossible to build an engine that, working in a cycle, converts all the heat it takes in completely into work; some heat must always be discharged to a cold reservoir. A heat engine works between two reservoirs: it absorbs heat Q1 from a hot reservoir at temperature T1, converts a part of it into useful work W, and rejects the remaining heat Q2 to a cold reservoir at temperature T2, its efficiency being W/Q1. The French engineer Carnot devised an ideal engine, working through a reversible cycle of two isothermal and two adiabatic changes, which has the greatest efficiency any engine working between the two temperatures can have. This Carnot efficiency depends only on the two absolute temperatures and is given by efficiency = 1 - T2/T1. It shows that no engine can be perfectly efficient unless the cold reservoir is at absolute zero, which is unattainable, and that a larger temperature difference gives a higher efficiency.

MCQs with Answers

1. The pressure of a gas is due to molecules striking the:
(a) each other (b) walls (c) light (d) nothing
Correct Answer: (b) walls. The walls of the container.

2. The absolute temperature measures the average ___ of molecules:
(a) mass (b) kinetic energy (c) charge (d) size
Correct Answer: (b) kinetic energy. Average kinetic energy.

3. The first law of thermodynamics is:
(a) Q = delta U + W (b) Q = W - U (c) F = ma (d) PV = nRT
Correct Answer: (a) Q = delta U + W. Q = delta U + W.

4. In an isothermal process:
(a) Q = 0 (b) delta U = 0 (c) W = 0 (d) T changes
Correct Answer: (b) delta U = 0. delta U = 0 (constant temperature).

5. In an adiabatic process:
(a) Q = 0 (b) delta U = 0 (c) T constant (d) W = 0
Correct Answer: (a) Q = 0. Q = 0 (no heat exchange).

6. For a gas, C_p is ___ C_v:
(a) less than (b) equal to (c) greater than (d) zero
Correct Answer: (c) greater than. Greater than.

7. C_p - C_v equals:

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(a) R (b) zero (c) 2R (d) R/2

Correct Answer: (a) R. The gas constant R.

8. No engine can convert all heat into work is the:

(a) first law (b) second law (c) zeroth law (d) third law

Correct Answer: (b) second law. The second law.

9. Carnot efficiency is:

(a) 1 - T2/T1 (b) T2/T1 (c) 1 - T1/T2 (d) T1 - T2

Correct Answer: (a) 1 - T2/T1. 1 - T2/T1.

10. The internal energy of an ideal gas depends only on its:

(a) pressure (b) volume (c) temperature (d) shape

Correct Answer: (c) temperature. Temperature.

Quick Revision Summary

- Kinetic theory: gas = many molecules in random motion; pressure from wall collisions; T = average KE.
- Internal energy = total molecular energy; for ideal gas depends only on temperature.
- First law: Q = delta U + W (conservation of energy).
- Isothermal: delta U = 0, Q = W. Adiabatic: Q = 0, delta U = -W.
- Specific heats: C_p > C_v; C_p - C_v = R.
- Second law: heat not fully convertible to work; Carnot efficiency = 1 - T2/T1. Notes by freebooks.pk.

Exam Tips

- Memorise the first law Q = delta U + W and its sign convention.
- Isothermal: temperature constant. Adiabatic: no heat exchange.
- Explain why C_p > C_v (extra work at constant pressure).
- Learn C_p - C_v = R.
- State the second law in words.
- Use kelvin temperatures in the Carnot efficiency formula.

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