PRECISE

SCIENCE AND TECHNOLOGY (PART - 1)

BASED ON TEXTBOOK AND BOARD PAPER PATTERN

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STD. X
(Eng. Med.)

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Based on the **Latest Board Paper Pattern** prescribed by the Maharashtra State Board of Secondary and Higher Secondary Education, Pune - 04

Precise

Science and Technology Part - 1

STD. X

Salient Features

- Written as per Latest Board Paper Pattern
- Ample numericals for thorough revision
- Memory maps provided for revision at a glance
- ‘Illustrative Examples’ provided for numerical elaboration
- ‘Reading between the lines’ provided for concept elaboration
- Includes solved Board questions of March and December 2020, March 2022
- Activity demonstration/concept explanation videos included wherever required
- Includes Board Activity Sheet of March 2023 (Solution in PDF format through QR code)

This book comprises of **QR Codes** at strategic touch points. You can simply scan this Code through your Smartphone camera and get a plethora of subject knowledge at your disposal. The QR Codes included herein would take you to videos that shall provide you a better understanding of ‘Activities’, ‘Experiments’, ‘Projects’ and ‘Try This’ section of the book. We hope students would maximize the use of this book with the aid of these videos.

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PREFACE

‘Precise Science and Technology Part-1, Std. X’ prepared as per Latest Board Paper Pattern which is a compact yet complete guide designed to boost students’ confidence and prepare them to face the conspicuous Std. X Board exam.

Every chapter begins with covering textual content in the format of Objectives, Question - Answers, Give Reasons, Numericals, Diagram-based questions, paragraph-based questions and a host of other Objective and Subjective type of questions. A series of ‘Intext Questions’ along with questions titled under ‘Use your brain power’, ‘Can you tell’ and various similar titles pave the way for a robust concept building. A detailed thinking process involved in solving numerical problems is explained in step wise manner in ‘Illustrative Examples.’ The solution to these examples is elaboration of the answer of the numerical and not the exact solution expected in examination.

For the students to grasp a better understanding of the concept lying behind the answer, ‘Reading between the lines’ *(not a part of the answer)* has been provided wherever necessary. Standard values of basic physical quantities are provided under the section ‘Values to remember.’ Questions that entail students to apply higher order thinking skills are marked *[HOTS]*. To enhance audio-visual learning, videos showing demonstration of activities / concept explanation are included wherever required. To keep students updated, solved questions from Board Activity Sheets of March 2019, July 2019, March 2020, December 2020 and March 2022 are included.

Wherever possible questions are allotted with marks in accordance with new marking scheme. The question can be modified as per the new marking scheme and asked in examination. Memory maps have been included wherever needed which provides a quick revision of the important topics of a chapter.

With absolute trust in our work, we hope, our holistic efforts towards making this book an ideal knowledge hub for students pays off.

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

Please write to us at: mail@targetpublications.org

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KEY FEATURES

Reading between The lines

'Reading between the lines' (not a part of the answer) helps students to grasp a better understanding of the concept lying behind the answer.

Latest Board Questions

Includes questions from Board Activity Sheets of March 2020, December 2020 and March 2022

New Question Types

Optimum coverage of new type of questions i.e., diagram based questions, paragraph based questions.

Memory Maps

Memory Maps summarize the key points in the chapter and provide chapter overview succinctly.

Numerical Section

Solved numerical questions segregated type wise are provided wherever applicable. For revision, list of all important formulae is provided at the beginning of the section.

Weightage of Marks

Wherever possible, questions are allotted with marks in accordance with new marking scheme.

Illustrative Examples

A detailed thinking process involved while solving numerical problems is explained in step wise manner in 'Illustrative Examples'.

QR Codes

QR code provides:

i. Access to a video/PDF in order to boost understanding of a concept or activity

ii. 'Solution' of Board Activity Sheet of March 2023.

PAPER PATTERN

- There will be separate question papers for Part 1 and Part 2 of 40 marks each.
- Duration of each paper will be 2 hours.

Question No.	Type of Questions	Total Marks
1.	(A) 5 Questions of 1 mark each (Multiple Choice Questions)	05
	(B) 5 Questions of 1 mark each (Objectives)	05
2.	(A) 3 Questions of 2 marks each (Scientific Reasoning) (Solve any 2)	04
	(B) 5 Questions of 2 marks each (Solve any 3)	06
3.	8 Questions of 3 marks each (Solve any 5)	15
4.	2 Questions of 5 marks each (Solve any 1)	05

Distribution of marks according to question type and aims

Sr. No.	Question type	Marks	Marks with option	% Marks
1.	Objective	10	10	25
2.	Very short answer	10	16	25
3.	Short answer	15	24	37.5
4.	Long answer	5	10	12.5
	Total	**40**	**60**	**100**

Sr. No.	Aims	Marks	Marks with option	% Marks
1.	Knowledge	10	15	25
2.	Understanding	10	15	25
3.	Application	16	24	40
4.	Skill	4	6	10
	Total	**40**	**60**	**100**

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

CONTENTS

Note: Textual exercise questions are represented by * mark.
Textual solved examples are represented by + mark.
Modified textual questions are represented by ♣ mark.

Exam Pointers

Students are expected to write the answers in their Examination as illustrated below.

Find out the correlation – Determine the correlation between two components and rewrite it.

1. In Fleming's right hand rule-Thumb: Motion of conductor :: In Fleming's right hand rule-Index finger: ________

Ans: In Fleming's right hand rule-Thumb: Motion of conductor :: In Fleming's right hand rule-Index finger: **Magnetic field**

MCQ – Write only the correct option while answering the MCQ.

2. When ________ is passed through fresh lime water, it turns milky.

(A) H_2 (B) CO_2

(C) CO (D) SO_2

Ans: 2. (B)

Numericals - Write the valid final answer along with the correct unit.

3. Calculate the escape velocity on the surface of the moon given the mass and radius of the moon to be 7.34×10^{22} kg and 1.74×10^{6} m respectively.

Ans: $v_{esc} = 2.372$ km/s

Reading between the lines

The explanation provided under 'Reading between the lines' is not expected to be a part of the answer. Its sole purpose is to provide a sound understanding of the concept behind the answer.

1. **What is the expected trend in the variation of nonmetallic character of elements from left to right in a period?**

Ans: The nonmetallic character increases from left to right in a period. } **Answer**

Reading between the lines

While going from left to right within a period, electrons get added in the same shell. At the same time, protons get added in the nucleus increasing the nuclear charge. This increases the effective nuclear charge experienced by valence electrons. As a result, the tendency to gain electrons increases. Thus, the nonmetallic character increases from left to right in a period. } **Not part of the answer**

1 Gravitation

Choose the correct alternative *[1 Mark each]*

1. A boy is whirling a stone tied to a string in a horizontal circular path. If the string breaks, the stone
   (A) will move along a straight line towards the centre of the circular path.
   (B) will move along a straight line perpendicular to the circular path away from the boy.
   (C) will move along a straight line tangential to the circular path.
   (D) will continue to move in circular path.

2. Law of gravitation gives the gravitational force between _______.
   (A) the earth and a point mass only
   (B) the earth and Sun only
   (C) any two bodies having some mass
   (D) two charged bodies only

3. The force of attraction between two unit point masses separated by a unit distance equals
   (A) gravitational potential.
   (B) acceleration due to gravity.
   (C) gravitational field.
   (D) universal gravitational constant.

4. According to Newton's law of gravitation, for two objects kept at a distance d from each other, if the distance between the objects is doubled, then the force between the two objects _______.
   (A) increases by a factor of 4
   (B) decreases by a factor of 4
   (C) decreases by a factor of 2
   (D) increases by a factor of 2

5. For bodies which are not spherical or having an irregular shape, the direction of the force is along the line joining their _______.
   (A) centre of masses (B) centres
   (C) nearest edges (D) both (A) and (B)

6. The tidal waves in the sea are primarily due to gravitational effect of
   (A) earth on the sea.
   (B) Sun on the earth.
   (C) earth on the moon.
   (D) moon on the earth.

7. The value of acceleration due to gravity
   (A) is same at the equator and poles.
   (B) is least at the poles.
   (C) is least at the equator.
   (D) is maximum at the centre of the earth.

8. For an object at infinite distance from the earth, the value of acceleration due to gravity (g) is
   (A) maximum (B) 9.8 m/s^2
   (C) 9.73 m/s^2 (D) zero

9. According to Newton's first law of motion, higher the mass _______ is the inertia.
   (A) lower (B) higher
   (C) zero (D) double

10. A spherical planet far out in space has a mass M_o and diameter D_o. A particle of mass m falling freely near the surface of this planet will experience acceleration due to gravity equal to
    (A) GM_o/D_0^2 (B) $4mGM_o/D_0^2$
    (C) $4GM_o/D_0^2$ (D) GmM_o/D_0^2

11. The value of g on moon is $1/6^{th}$ of its value on the earth. If a person weighs 14 N on the moon's surface, then the weight of the person on earth's surface is
    (A) 96 N (B) 84 N
    (C) 62 N (D) 54 N

12. The minimum velocity of the spacecraft to escape from earth's gravitational force must be _______. **[Dec 2020]**
    (A) 112 km/s (B) 11.2 km/s
    (C) 1.12 km/s (D) 0.112 km/s

Answers:

1.	(C)	2.	(C)	3.	(D)
4.	(B)	5.	(A)	6.	(D)
7.	(C)	8.	(D)	9.	(B)
10.	(C)	11.	(B)	12.	(B)

Complete the paragraph *[3 Marks]*

1. **Select the appropriate options and complete the following paragraph.**
   (velocity, independent, initial velocity, dependent, gravity, friction, final velocity, direction)
   The motion of any object under the influence of the force of _______ alone is called as free fall. During free fall, there will be no change in the _______ of motion of the object. But there will be a change in the magnitude of _______ of the object due to the gravitational pull of the earth. The acceleration that an object experiences

during free fall is _______ of the mass of the object undergoing motion. When a body is dropped freely from a height, its _______ is zero. Whereas when a body is thrown vertically upwards, its _______ is zero.

Answer:

The motion of any object under the influence of the force of **gravity** alone is called as free fall. During free fall, there will be no change in the **direction** of motion of the object. But there will be a change in the magnitude of **velocity** of the object due to the gravitational pull of the earth. The acceleration that an object experiences during free fall is **independent** of the mass of the object undergoing motion. When a body is dropped freely from a height, its **initial velocity** is zero. Whereas when a body is thrown vertically upwards, its **final velocity** is zero.

Name the following *[1 Mark each]*

1. Force which is directed towards the centre of the circle (centre seeking)
2. Amount of matter present in an object
3. According to Newton's first law, mass of any object is the measure of this quantity
4. Force with which the earth attracts an object
5. Scientist who was appointed as the royal mathematician in place of Brahe
6. Observatory constructed by scientists to detect the gravitational waves emitted by astronomical sources

Answers:

1. Centripetal force
2. Mass
3. Inertia
4. Weight of the object.
5. Johannes Kepler
6. LIGO-Laser Interferometric Gravitational Wave Observatory

True or False. If false, write the correct sentence *[1 Mark each]*

1. The orbit of a planet is an ellipse with the Sun at the centre.
2. Two planets move around the Sun. The periodic times and the mean radii of the orbits are T_1, T_2 and r_1, r_2 respectively. Then the ratio T_1/T_2 is equal to $(r_1/r_2)^{2/3}$.
3. Gravitational force is the strongest force in nature.
4. The centre of a mass of any object having uniform density is at its centroid.
5. According to Newton's third law of motion, a force acting on a body results in its acceleration.
6. Due to its rotation, the earth is flatter at the equator and bulges at the poles.
7. As we go above the earth's surface, the value of acceleration due to gravity increases.
8. The acceleration due to gravity at a given point on the earth is the same for all the objects.
9. The moon and the artificial satellites are all in free fall.
10. True free fall is possible only in air.
11. An object going vertically upwards will be free from the gravitational influence of the earth, if its initial velocity is equal to critical velocity of the earth.
12. The escape velocity is same for different planets.

Answers:

1. False.
   The orbit of a planet is an ellipse with the Sun at one of the foci.
2. False.
   Two planets move around the Sun. The periodic times and the mean radii of the orbits are T_1, T_2 and r_1, r_2 respectively. Then the ratio T_1/T_2 is equal to $(r_1/r_2)^{3/2}$.
3. False.
   Gravitational force is the weakest force in nature.
4. True.
5. False.
   According to Newton's second law of motion, a force acting on a body results in its acceleration.
6. False.
   Due to its rotation, the earth bulges at the equator and is flatter at the poles.
7. False.
   As we go above the earth's surface, the value of acceleration due to gravity decreases.
8. True.
9. True.
10. False
    True free fall is possible only in vacuum.
11. False.
    An object going vertically upwards will be free from the gravitational influence of the earth, if its initial velocity is equal to escape velocity of the earth.
12. False.
    The escape velocity is different for different planets.

Odd one out *[1 Mark each]*

1. Force, acceleration due to gravity, weight, mass.
2. $v = gt$, $h = \frac{1}{2}gt^2$, $v = u + at$, $v^2 = 2gh$
3. The orbit of a planet is an ellipse, line joining the planet and the sun sweeps equal areas in equal intervals of time, $F = \frac{Gm_1m_2}{r^2}$, $T^2 \propto R^3$

Answers:

1. Mass
   Mass is a scalar while other are vectors.

2. $v = u + at$
   $v = u + at$ is the fundamental kinematical equation of motion while others are kinematical equations for a freely falling body.
3. $F = \dfrac{Gm_1m_2}{r^2}$
   $F = \dfrac{Gm_1m_2}{r^2}$ is Newton's law of gravitation while others are Kepler's laws of planetary motion.

Complete the analogy *[1 Mark each]*

1. Gravitational constant: scalar quantity :: acceleration due to gravity : ________.
2. Kinetic energy of a body of mass m on the surface of the earth: $\frac{1}{2}mv_{esc}^2$ :: kinetic energy of a body of mass m at infinite distance from earth: ________.
3. Kepler's first law: orbit of a planet is an ellipse :: ________ : $T^2 \propto r^3$
   (T is orbital period of revolution of a planet and r is the mean distance of the planet from sun.)
4. Increase in altitude: value of g decreases :: at the centre of the earth: ________.

Answers:

1. vector quantity
   Gravitational constant is a scalar quantity and acceleration due to gravity is a vector quantity.
2. zero
   Kinetic energy of a body of mass m on the surface of the earth is $\frac{1}{2}mv_{esc}^2$ while kinetic energy of a body of mass m at infinite distance from earth is zero.
3. Kepler's third law
   Orbit of a planet is an ellipse is Kepler's first law while $T^2 \propto r^3$ is Kepler's third law.
4. value of g is zero.
   Value of g decreases with increase in altitude; while the value of g becomes zero at the centre of the earth.

Match the following

*1. **Study the entries in the following table and rewrite them putting the connected items in a single row.**

I	II	III
Mass	m/s^2	Zero at the centre
Weight	kg	Measure of inertia
Acceleration due to gravity	Nm^2/kg^2	Same in the entire universe
Gravitational constant	N	Depends on height

Ans:

I	II	III
Mass	kg	Measure of inertia
Weight	N	Zero at the centre
Acceleration due to gravity	m/s^2	Depends on height
Gravitational constant	Nm^2/kg^2	Same in the entire universe.

2. **Match the laws/physical quantities in column I with their corresponding formula/relation in column II.**

	Column I		Column II
i.	Kepler's third law	a.	$-\dfrac{GMm}{R+h}$
ii.	Law of gravitation	b.	$T^2 \propto r^3$
iii.	Gravitational Potential energy	c.	$F \propto \dfrac{m_1m_2}{r^2}$
iv.	Escape velocity	d.	$\sqrt{\dfrac{2GM}{R}}$
		e.	$\dfrac{GM}{R^2}$

Ans: (i – b), (ii – c), (iii – a), (iv – d)

Answer the following

*1. **What are (i) free fall (ii) acceleration due to gravity (iii) escape velocity (iv) centripetal force?** ***[1 Mark each]***

Ans:

i. **Free fall:**
   The motion of any object under the influence of the force of gravity alone is called as free fall.
ii. **Acceleration due to gravity:**
   The acceleration produced in a body under the influence of the force of gravity alone is called acceleration due to gravity.
iii. **Escape velocity:**
   The minimum velocity with which a body should be projected from the surface of a planet or moon, so that it escapes from the gravitational influence of the planet or moon is called as escape velocity.
iv. **Centripetal force:**
   The force acting on any object moving in a circle and directed towards the centre of the circle is called as centripetal force.

2. **Intext Question.** *(Textbook page no. 01)*
i. **If the force of gravitation acts on apples on the tree at different heights from the surface of the earth, can it also act on objects at even greater heights, much farther away from the earth, like for example, the moon?** ***[1 Mark]***

Ans: Yes, the gravitational force acts on objects at greater heights and farther away from the earth like the moon.

ii. Can it act on even farther objects like the other planets and the Sun? ***[1 Mark]***

Ans: Yes, the gravitational force acts on other planets and Sun.

3. Intext Question. *(Textbook page no. 02)*

i. Do you think some force is constantly acting on the moon?

ii. What must be the direction of this force?

iii. How would its motion have been if no such force acted on it?

iv. Do the other planets in the solar system revolve around the Sun in a similar fashion?

v. Is similar force acting on them? What must be its direction? *[HOTS]****[5 Marks]***

Ans:

i. There is a force constantly acting on the moon known as centripetal force.

ii. The force is directed towards the centre of the earth.

iii. If there was no force acting on the moon, it would have moved along a straight line which is the tangent to the circle.

iv. Yes, other planets revolve around the Sun in the similar fashion.

v. The other planets revolve around the Sun in the similar fashion due to the centripetal force exerted on them by the Sun. The direction of the force is towards the centre of the Sun.

Reading between the lines

'Centripetal' means centre seeking, i.e. the object tries to go towards the centre of the circle because of this force. Thus, the gravitational force that earth exerts on moon in this situation is termed as centripetal force.

*__4. Write the three laws given by Kepler. How did they help Newton to arrive at the inverse square law of gravity?__ ***[5 Marks]***

Ans: The three laws given by Kepler are:

i. **Kepler's first law:** The orbit of a planet is an ellipse with the sun at one of the foci.

ii. **Kepler's second law:** The line joining the planet and the sun sweeps equal areas in equal intervals of time.

iii. **Kepler's third law:** The square of orbital period of revolution of a planet around the Sun is directly proportional to the cube of the mean distance of the planet from the Sun.

Derivation of inverse square law of gravity with the help of Kepler's law:

i. The centripetal force acting on a planet of mass m and velocity v, revolving at a distance of r from the Sun, is given as,

$$F = \frac{mv^2}{r} \quad \text{....(1)}$$

ii. Let T be the period of revolution of the planet and $2\pi r$ be the distance travelled by the planet in one revolution. Then the speed of the planet is given as,

$$\text{speed (v)} = \frac{\text{distance travelled}}{\text{time taken}}$$

$$= \frac{2\pi r}{T} \quad \text{....(2)}$$

iii. Substituting equation (2) in (1), we get,

$$F = \frac{m\left(\frac{2\pi r}{T}\right)^2}{r} = \frac{4m\pi^2 r}{T^2}$$

iv. Multiplying and dividing by r^2, we get,

$$F = \frac{4m\pi^2 r^3}{r^2 T^2} = \frac{4m\pi^2}{r^2}\left(\frac{r^3}{T^2}\right) \quad \text{....(3)}$$

v. But, According to Kepler's third law,

$T^2 \propto r^3$

$$\therefore \frac{T^2}{r^3} = \text{constant (K)} \quad \text{....(4)}$$

Substituting equation (4) in (3), we get,

$$F = \frac{4m\pi^2}{r^2 K}$$

But, $\frac{4m\pi^2}{K} = \text{constant}$

$$\therefore F \propto \frac{1}{r^2}$$

Thus, with the help of Kepler's third law, Newton concluded that the centripetal force acting on the planet must be inversely proportional to the square of the distance between the planet and the Sun and hence, postulated the inverse square law of gravitation.

*__5. Let the period of revolution of a planet at a distance R from a star be T. Prove that if it was at a distance of 2R from the star, its period of revolution will be $\sqrt{8}$ T.__ ***[2 Marks]***

Ans:

i. According to Kepler's third law, the square of orbital period of revolution T of a planet around a star is directly proportional to the cube of the mean distance R of the planet from the star.

$T^2 \propto R^3$

$$\therefore T^2 = k(R)^3 \quad \text{....(1)}$$

Where, k is constant of proportionality.

ii. When the planet is at a distance of 2R from the star, then its period of revolution T′ will be,

$T'^2 \propto (2R)^3$

$$\therefore T'^2 = k(2R)^3 \quad \text{....(2)}$$

iii. Dividing equations (1) and (2), we get,

$$\frac{T^2}{T'^2} = \frac{(R)^3}{(2R)^3}$$

$\therefore \quad \frac{T^2}{T'^2} = \frac{1}{8}$

$\therefore \quad T' = \sqrt{8}\,T$

Thus, for a planet at a distance of 2R from the star, its period of revolution will be $\sqrt{8}$ T.

6. Define value of Gravitational constant. ***[1 Mark]***

Ans: The gravitational force acting between unit masses kept at a unit distance away from each other gives the value of gravitational constant (G).

7. Use your brain power! ***(Textbook page no. 04)***
Show that in SI units, the unit of G is newton m^2 kg^{-2}. ***[2 Marks]***

Ans:

i. According to Newton's law of gravitation,

$$F = \frac{Gm_1m_2}{r^2}$$

$$\therefore \quad G = \frac{Fr^2}{m_1m_2} \quad \quad ....(1)$$

ii. In SI system, force is measured in newton (N), distance is measured in metre (m) and mass is measured in kilogram (kg).

iii. Substituting in equation (1), we get, unit of G as,

$$\frac{\text{newton} \times (\text{metre})^2}{\text{kg} \times \text{kg}}$$

iv. Thus, in SI system,

Unit of G = $\frac{Nm^2}{kg^2}$ or newton m^2 kg^{-2}

8. Intext Question. ***(Textbook page no. 05)***
Why did Newton assume inverse square dependence on distance in his law of gravitation?

Ans: Newton had assumed inverse square dependence on distance in his law of gravitation by considering Kepler's third law which states that, 'The square of orbital period of revolution of a planet around the sun is directly proportional to the cube of the mean distance of the planet from the sun' i.e., $T^2 \propto r^3$

9. Use your brain power! ***(Textbook page no. 05)***
Is there a gravitational force between two objects kept on a table or between you and your friend sitting next to you? If yes, why don't the two move towards each other?

Ans:

i. Yes, there exists a gravitational force between two different objects kept on the table or between me and my friend sitting beside each other.

ii. The gravitational force between any two objects is given by, $F = \frac{Gm_1m_2}{r^2}$

Where,
F = force between any two objects in newtons
G = universal gravitational constant taken as 6.67×10^{-11} N-m^2 /kg^2
m_1 and m_2 = mass of the two objects in kg
r = distance between the two objects in metres (m)

iii. Thus, any two objects attract each other. But due to their small masses, they exert a force on each other, which is too small as compared to the gravitational force of the earth. Hence, two different objects kept on the table or me and my friend don't move towards each other.

10. Use your brain power! ***(Textbook page no. 07)***
According to Newton's law of gravitation, every object attracts every other object. Thus, if the earth attracts an apple towards itself, the apple also attracts the earth towards itself with the same force. Why then does the apple fall towards the earth, but the earth does not move towards the apple? ***[2 Marks]***

Ans:

i. The apple attracts the earth with the same force with which the earth attracts the apple.

ii. According to Newton's third law, these two forces are equal and opposite in direction.

iii. For same magnitude of force, the acceleration produced in a body is inversely proportional to its mass.

iv. As the mass of the earth is very large compared to that of the apple, the acceleration of the earth is too small compared to the acceleration of the apple that it cannot be noticed.

Hence, the apple falls towards the earth while the earth does not move towards the apple.

11. Intext Question. ***(Textbook page no. 07)***
The moon and the artificial satellites orbit the earth. The earth attracts them towards itself but unlike a falling apple, they do not fall on the earth, why?

Ans: Even though the moon and the artificial satellites are attracted towards the earth, the velocity of the moon and the satellites is such that it prevents them from falling on the earth.

12. Intext Question. ***(Textbook page no. 07)***
Will the velocity of a stone thrown vertically upwards remain constant or will it change with time? How will it change? Why doesn't the stone move up all the time? Why does it fall down after reaching a certain height? What does its maximum height depend on?

Ans:

i. The velocity of a stone thrown vertically upwards decreases with time till it becomes zero.

ii. When a stone is thrown vertically up, it is acted upon by the gravitational force of the earth which constantly tries to pull the stone down. Due to the constant downward pull, the velocity of the stone becomes zero after reaching a certain height. Once the velocity becomes zero, the gravitational force acting on the stone causes it to start moving vertically downwards.

iii. The maximum height the stone can achieve depends on the initial velocity with which the stone is thrown vertically upwards.

13. What is acceleration due to gravity? Derive an expression for acceleration due to gravity on the earth's surface. ***[3 Marks]***

Ans: Acceleration due to gravity:

The acceleration produced in a body under the influence of the force of gravity alone is called acceleration due to gravity. It is denoted by 'g'.

Expression for acceleration due to gravity:

i. Suppose an object of mass 'm' is situated at a distance 'R' from the centre of the earth.

ii. Let 'M' be the mass of the earth, then the gravitational force of attraction F between the object and the earth is given by,

$$F = G\frac{Mm}{R^2}$$

Where, G = constant of gravitation

$$\therefore \frac{F}{m} = G\frac{M}{R^2} \quad \text{....(1)}$$

iii. But acceleration is given by acceleration due to gravity.

$$g = \frac{\text{force}}{\text{mass}} = \frac{F}{m} \quad \text{....(2)}$$

iv. From equations (1) and (2), we have, acceleration due to gravity on the earth's surface,

$$g = \frac{GM}{R^2}$$

v. From the above relation, acceleration due to gravity on earth's surface depends upon the mass of the earth (M) and distance (R) of the object from the centre of the earth i.e., the radius of the earth.

14. Explain the factors affecting the value of gravitational acceleration of the earth 'g'. ***[3 Marks]***

Ans: The following factors affect the value of gravitational acceleration of the earth 'g':

i. Shape of the earth:

a. The shape of the earth is not perfectly spherical. It is slightly flattened at the poles and bulged at the equator.

b. As a result, the radius of the earth at the poles is less than that at the equator.

c. Hence, the value of 'g' is highest at the poles (9.832 m/s^2) and decreases slowly with decreasing latitude. It is the lowest at the equator (9.78 m/s^2).

ii. Height:

a. As the height of an object from the surface of the earth increases, the distance between the object and the centre of the earth (r) increases.

b. As a result, the value of 'g' decreases with increase in height.

iii. Depth:

a. The value of g is maximum on the surface of the earth.

b. As depth of an object increases, the distance between the object and the centre of the earth (r) decreases.

c. Along with the distance, the part of the earth which contributes towards the gravitational force felt by the object (M) also decreases.

d. Thus, due to the combined effect of changing value of r and M, the value of 'g' decreases.

e. At the centre of the earth, the value of 'g' becomes zero.

15. Intext Question. ***(Textbook page no. 08)***

Will the value of g be the same everywhere on the surface of the earth? ***[1 Mark]***

Ans: No, the value of g will not be same everywhere on the surface of earth.

16. Think about it. ***(Textbook page no. 09)***

i. Will the direction of the gravitational force change as we go inside the earth? ***[1 Mark]***

Ans: There will be no change in the direction of the gravitational force. Gravitational force always acts downwards, towards the centre of the earth.

ii. What will be the value of g at the centre of the earth? ***[1 Mark]***

Ans: The value of g at the centre of the earth is zero.

17. Use your brain power!

(Textbook page no. 10)

Will your weight remain constant as you go above the surface of the earth? ***[2 Marks]***

Ans: No, our weights will not remain constant if we move away from the surface of the earth. Weight is the product of mass and gravitational acceleration. When we move away from the surface of the earth, mass remains the same but the value of gravitational acceleration decreases. Thus, weight decreases as we move away from the surface of the earth.

18. On what factors does acceleration due to gravity (g) on earth's surface depend on? ***[1 Mark]***

Ans: On earth's surface, acceleration due to gravity (g) depends on mass and radius of the Earth.

***19. Will the mass and weight of an object on the earth be same as their values on Mars? Why?**
[2 Marks]

Ans:

i. Mass is a fundamental quantity whose value remains same everywhere. Hence, the mass of an object on earth will be same as its value on Mars.

ii. Weight of an object is product of mass and gravitational acceleration, i.e., $W = F = mg$

iii. As the weight depends on the value of acceleration due to gravity (g) which changes from place-to-place, and is different for earth and Mars, the weight of the object on earth will be different than its value on Mars.

***20. A stone thrown vertically upwards with initial velocity u reaches a height 'h' before coming down. Show that the time taken to go up is same as the time taken to come down.**
[3 Marks]

Ans:

i. Consider a stone thrown vertically upwards with initial velocity 'u'. It reaches a height 'h' before coming down.

ii. The kinematical equations of motion are given as,

$v = u + at$ ….(1)

$s = ut + \frac{1}{2}at^2$ ….(2)

$v^2 - u^2 = 2as$ ….(3)

iii. For upward motion of the stone,

$a = -g$ (negative sign indicates the direction of force is opposite to that of velocity.)

$v = 0$ ($\because$ at the highest point velocity becomes zero).

Substituting this in equation (1), the time t_1 taken by the stone to reach the maximum height is given as,

$\therefore$ $0 = u - gt_1$

$\therefore$ $t_1 = \frac{u}{g}$ ….(4)

Similarly, substituting the values of a and v in equation (3), the maximum height h which the stone reaches is given as,

$0^2 - u^2 = -2gh$

$\therefore$ $h = \frac{u^2}{2g}$ ….(5)

iv. For downward motion of the stone,

$a = g$

$u = 0$ ($\because$ at maximum height, initial velocity is zero.)

Substituting this in equation (2), the time t_2 taken by the stone to come down is given as,

$h = 0 + \frac{1}{2}gt_2^2$

$\therefore$ $t_2^2 = \frac{2h}{g}$

$\therefore$ $t_2 = \sqrt{\frac{2h}{g}}$ ….(6)

v. Substituting equation (5) in (6),

$t_2 = \sqrt{\frac{2}{g} \times \frac{u^2}{2g}}$

$\therefore$ $t_2 = \frac{u}{g}$ ….(7)

Thus, from equations (4) and (7), we can conclude that the time taken by the stone to go up is same as the time taken to come down.

21. Using the law of conservation of energy, derive an expression for the escape velocity of an object from the surface of the earth.
[3 Marks]

Ans: Expression for escape velocity:

i. Consider an object of mass m moving with initial velocity equal to escape velocity v_{esc} on the surface of the earth.

The kinetic energy of the object is given as,

$K.E = \frac{1}{2}mv_{esc}^2$

The potential energy of the object is given as,

Potential energy $= -\frac{GMm}{R}$

$\therefore$ Total energy $= E_1 = K.E + P.E$

$= \frac{1}{2}mv_{esc}^2 - \frac{GMm}{R}$ ….(1)

ii. The object escapes the gravitational force of the earth and comes to rest at infinite distance from the earth.

The kinetic energy of the object is given as,

$K.E = 0$

The potential energy of the object is given as,

Potential energy $= -\frac{GMm}{\infty} = 0$

$\therefore$ Total energy $= E_2 = K.E + P.E$

$= 0$ ….(2)

iii. From the principle of conservation of energy, $E_1 = E_2$

$\frac{1}{2}mv_{esc}^2 - \frac{GMm}{R} = 0$

$\therefore$ $v_{esc}^2 = \frac{2GM}{R}$

$\therefore$ $v_{esc} = \sqrt{\frac{2GM}{R}}$ ….(3)

iv. Also, we know, acceleration due to gravity is given as,

$g = \frac{GM}{R^2}$

$\therefore$ $GM = gR^2$ ….(4)

v. Substituting equation (4) in (3), we get,

$$v_{esc} = \sqrt{\frac{2gR^2}{R}} = \sqrt{2gR} \quad \ldots(5)$$

Equations (3) and (5) represent the equations for escape velocity from the surface of the earth.

22. What is the cause of weightlessness of space travellers in a spacecraft? ***[1 Mark]***

Ans: Space travellers being in a state of free fall is the cause of their weightlessness in a spacecraft.

Give reasons *[2 Marks each]*

1. Intext Question. *(Textbook page no. 01)*
Why all apples fall vertically downward and not at an angle to the vertical. Why do they not fly off in a horizontal direction?

Ans:
i. The force with which earth attracts any object is directed towards the centre of the earth.
ii. At any given position of a falling object, the direction from the falling object to the centre of the earth is vertically downward.

Hence, any object on earth will fall vertically downward and not at an angle to the vertical; nor will the object fly off in a horizontal direction.

2. Use your brain power! *(Textbook page no. 12)*
According to Newton's law of gravitation, earth's gravitational force is higher on an object of larger mass. Why doesn't that object fall down with higher velocity as compared to an object with lower mass?

Ans:
i. The acceleration produced in a body under the influence of the force of gravity alone is called acceleration due to gravity. It is given by,

$$g = \frac{GM}{R^2}$$

ii. The value of g depends upon mass and radius of the earth (planet due to which there is a gravitational pull).
iii. It is independent of the shape, size, mass etc of the body which is falling. Hence, the object with greater mass and the object with comparatively less mass, both will fall with the same velocity.

***3. Explain why the value of g is zero at the centre of the earth.**

Ans:
i. The acceleration due to gravity (g) on earth's surface is given as,

$$g = \frac{GM}{R^2}$$

The value of g depends on the mass M of the earth and the radius R of the earth.
ii. As we go inside the earth, our distance from the centre of the earth decreases and no longer remains equal to the radius of the earth (R).
iii. Along-with the distance, the part of the earth which contributes towards the gravitational force felt also decreases, decreasing the value of (M).
iv. Due to combined result of change in R and M, value of g becomes zero at the centre of the earth.

4. Explain why value of g changes if we go inside the earth. **[July 2019]**

Ans:
i. The acceleration due to gravity (g) on earth's surface is given as, $g = \frac{GM}{R^2}$.

The value of g depends on the mass M of the earth and the radius R of the earth.
ii. As we go inside the earth, our distance from the centre of the earth decreases and no longer remains equal to the radius of the earth (R).
iii. Along-with the distance, the part of the earth which contributes towards the gravitational force felt also decreases, decreasing the value of (M).
iv. Due to combined result of change in R and M, value of g decreases as we go inside the earth and becomes zero at the centre of the earth.

***5. If the value of g suddenly becomes twice its value, it will become two times more difficult to pull a heavy object along the floor. Why?**

Ans:
i. The weight of an object is defined as the force with which the earth attracts the object. It is given as,
W = F = mg
ii. The weight of an object depends on the mass of the object and the value of acceleration due to gravity.
iii. If the value of g doubles, the force with which the earth attracts the object also becomes twice.
iv. Thus, the object becomes twice as heavier, making it harder to be pulled along the floor.

6. A body weighs more at poles and less at equator.

Ans:
i. The weight of an object is defined as the force with which the earth attracts the object. It is given as, W = F = mg
ii. The weight of an object depends on the mass of the object and the value of acceleration due to gravity.
iii. On the surface of the earth, the value of g is highest at the poles and decreases slowly with decreasing latitude becoming lowest at the equator.

Hence, a body weighs more at the poles and less at equator.

7. The weight of an object changes from place to place though its mass is constant.
[Mar 2020] ***[2 Marks]***

Ans: *Refer Answer the following Q.19*

8. Intext Question. ***(Textbook page no. 14)***
Space travellers as well as objects in the spacecraft appear to be floating. Why does this happen?

Ans:

i. In space, the only force that acts on a spacecraft is the gravitational force of the earth. Therefore, the spacecraft is in a state of free fall.

ii. The velocity in free fall is independent of the properties of an object and thus is the same for the spacecraft, the travellers and the objects in the space craft.

iii. The free fall leads to weightlessness of space travellers as well as object in the spacecraft.

Being weightless, space travellers as well as objects in the spacecraft appear to be floating.

Distinguish between *[2 Marks]*

***1. What is the difference between mass and weight of an object?**

Ans:

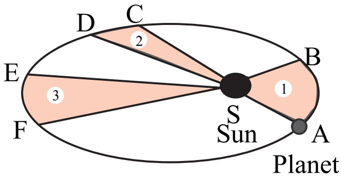
	Mass	Weight
i.	Mass is the quantity of matter contained in an object.	Weight is the force with which the earth attracts an object.
ii.	Mass remains same everywhere.	Weight of a body keeps on changing from place to place.
iii.	Mass is measured in kilogram (kg).	Weight is measured in newton (N).
iv.	Mass is a scalar quantity.	Weight is a vector quantity.
v.	Mass of an object can never be zero.	Weight of an object becomes zero at the centre of the earth.

Questions based on diagram

1. State the laws related to the given diagram: **[Mar 2022]**

OR

Observe the given figure showing the orbit of a planet moving around the Sun and write the *three* laws related to it: **[Mar 2020] *[3 Marks]***



The orbit of a planet moving around the Sun

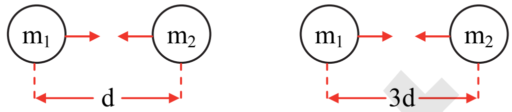
Ans:

i. Kepler's first law: The orbit of a planet is an ellipse with the sun at one of the foci.

ii. Kepler's second law: The line joining the planet and the sun sweeps equal areas in equal intervals of time.

iii. Kepler's third law: The square of orbital period of revolution of a planet around the Sun is directly proportional to the cube of the mean distance of the planet from the Sun.

2. Write proper answer in the box:



If $F = \frac{Gm_1m_2}{d^2}$ then F = [ ]

[Mar 2019] *[1 Mark]*

Ans: $\frac{Gm_1m_2}{9d^2}$

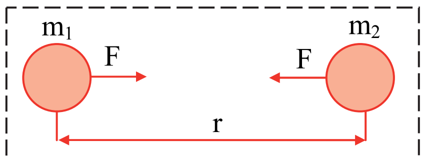
Reading between the lines

As, $F = \frac{Gm_1m_2}{d^2}$, $F \propto \frac{1}{d^2}$

$\therefore$ for d = 3d,

$F = \frac{Gm_1m_2}{(3d)^2} = \frac{Gm_1m_2}{9d^2}$

3. Observe the following diagram and answer the questions. ***[5 Marks]***



i. Which law do we understand from the above diagram? State the law.

ii. State the mathematical equation for the law.

iii. In case the two bodies are not spherical, then in which direction is the force directed?

iv. How will the value of force F change if the mass m_2 is increased to $4m_2$?

v. How will the value of force F change if the distance r is doubled? *[HOTS]*

Ans:

i. From the given diagram, we understand Newton's law of gravitation.
Statement: Gravitational force between two bodies in the universe is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

ii. The mathematical equation for the law is given as, $F = G\frac{m_1m_2}{r^2}$

iii. If the two bodies are not spherical, then the direction of force is along the line joining their centres of mass.

iv. Gravitational force between the two bodies is given by, $F = \frac{Gm_1m_2}{r^2}$

The mass m_2 is increased to $4m_2$, then the force F′ will be,

$$F' = \frac{Gm_1(4m_2)}{(r)^2} = 4\frac{Gm_1m_2}{r^2} = 4F$$

∴ Force becomes **four times** the initial force.

v. Gravitational force between the two bodies is given by, $F = \frac{Gm_1m_2}{r^2}$

When distance between the objects is doubled, the force F′ will be,

$$F' = \frac{Gm_1 m_2}{(2r)^2} = \frac{Gm_1m_2}{4r^2} = \frac{1}{4}F$$

∴ Force becomes **one fourth** the initial force.

Numerical Section

Formulae

1. Kepler's third law:

i. $T^2 \propto r^3$

Where,
T = the period of revolution of a body,
r = the radius of orbit in which the body is revolving.

ii. $\left(\frac{T_1}{T_2}\right)^2 = \left(\frac{r_1}{r_2}\right)^3$

Where T_1, T_2 and r_1, r_2 are periodic times and mean radii of the orbits of two planets around the Sun respectively.

2. Gravitational force between two bodies:

$$F = \frac{Gm_1m_2}{r^2}$$

Where, m_1 and m_2 = masses of two bodies,
r = distance of separation between them,
G = universal gravitational constant

3. Universal gravitational constant:

$$G = \frac{Fr^2}{m_1m_2}$$

4. Acceleration due to gravity:

On the earth surface, $g = \frac{GM}{R^2}$

Where, M = mass of the earth,
R = radius of the earth.

5. Kinematical equations of motion:

i. $v = u + at$ ii. $s = ut + \frac{1}{2}at^2$

iii. $v^2 = u^2 + 2as$

For a freely falling body:

i. $v = gt$ ii. $h = \frac{1}{2}gt^2$

iii. $v^2 = 2gh$

For a body thrown upwards:

i. $u = -gt$
(negative sign indicates velocity is decreasing)

ii. $h = ut - \frac{1}{2}gt^2$

iii. $u^2 = 2gh$

Where, u = initial velocity,
v = final velocity,
g = acceleration due to gravity,
h = distance of the body from the surface of the earth

6. Potential energy of a body:

i. On the earth's surface, $P.E. = \frac{-GMm}{R}$

ii. At a height h from surface of earth,

$$P.E. = \frac{-GMm}{R+h}$$

where, m = mass of the body.

7. Escape velocity of a body (On the surface of the earth):

$$v_{esc} = \sqrt{\frac{2GM}{R}} = \sqrt{2gR}$$

Values to remember

1. **Gravitational constant (G)** $= 6.7 \times 10^{-11}$ Nm^2/kg^2
2. **Acceleration due to gravity (g)** = 9.8 m/s^2
3. **Mass of the earth** = 6×10^{24} kg
4. **Radius of the earth** = 6.4×10^6 m

Solve the following problems

Type I Gravitational force between two bodies

Formulae:

i. $F = \frac{Gm_1m_2}{r^2}$ ii. $G = \frac{Fr^2}{m_1m_2}$

+1. **Mahendra and Virat are sitting at a distance of 1 metre from each other. Their masses are 75 kg and 80 kg respectively. What is the gravitational force between them?** ***[2 Marks]***

Solution:

Given: Distance (r) = 1 m, mass (m_1) = 75 kg, mass (m_2) = 80 kg, gravitational constant (G) $= 6.67 \times 10^{-11}$ Nm^2/kg^2

To find: Gravitational force (F)

Formula: $F = \frac{Gm_1m_2}{r^2}$

Calculation: From formula,

$$F = \frac{6.67\times10^{-11}\times75\times80}{1^2}$$

$\therefore$ F = **4.002 × 10^{-7} N**

Ans: The gravitational force between Mahendra and Virat is **4.002 × 10^{-7} N**.

+2. **Calculate the gravitational force due to the earth on Mahendra who has mass of 75 kg. [Mass of the earth = 6 × 10^{24} kg, Radius of the earth = 6.4 × 10^{6} m, Gravitational constant (G) = 6.67 × 10^{-11} Nm^2/kg^2]** ***[2 Marks]***

Solution:

Given: Mass of the earth (m_1) = 6 × 10^{24} kg,
Radius of the earth (R) = 6.4 × 10^{6} m,
Mahendra's mass (m_2) = 75 kg,
Gravitational constant (G)
= 6.67 × 10^{-11} Nm^2/kg^2

To find: Gravitational force (F)

Formula: $F = \frac{Gm_1m_2}{R^2}$

Calculation: From formula,

$$F = \frac{6.67\times10^{-11}\times75\times6\times10^{24}}{\left(6.4\times10^{6}\right)^2}$$

$$= \frac{6.67\times75\times6}{6.4\times6.4}\times10$$

= **733 N**

Ans: The gravitational force due to the earth on Mahendra is **733 N**.

*3. **The masses of the earth and moon are 6 × 10^{24} kg and 7.4 × 10^{22} kg, respectively. The distance between them is 3.84 × 10^{5} km. Calculate the gravitational force of attraction between the two. Use G = 6.7 × 10^{-11} Nm^2 kg^{-2}** ***[2 Marks]***

Solution:

Given: Mass of the earth (M_e) = 6 × 10^{24} kg,
Mass of the moon (M_m) = 7.4 × 10^{22} kg,
Distance (r) = 3.84 × 10^{5} km
= 3.84 × 10^{8} m,
Gravitational constant (G)
= 6.7 × 10^{-11} Nm^2/kg^2

To find: Gravitational force (F)

Formula: $F = \frac{Gm_1m_2}{r^2}$

Calculation: From formula,

$$F = \frac{(6.7\times10^{-11})\times(6\times10^{24})\times(7.4\times10^{22})}{\left(3.84\times10^{8}\right)^2}$$

$$= \frac{6.7\times6\times7.4}{3.84\times3.84}\times10^{19}$$

$\therefore$ F = **2 × 10^{20} N**

Ans: The gravitational force between the earth and the moon is **2 × 10^{20} N**.

*4. **The mass of the earth is 6 × 10^{24} kg. The distance between the earth and the Sun is 1.5 × 10^{11} m. If the gravitational force between the two is 3.5 × 10^{22} N, what is the mass of the Sun? Use G = 6.7 × 10^{-11} Nm^2/kg^2.** ***[2 Marks]***

Solution:

Given: Mass of the earth (M_e) = 6 × 10^{24} kg,
Gravitational force (F) = 3.5 × 10^{22} N,
Distance (r) = 1.5 × 10^{11} m,
Gravitational constant (G)
= 6.7 × 10^{-11} Nm^2/kg^2

To find: Mass of Sun (M_s)

Formula: $F = \frac{Gm_1m_2}{r^2}$

Calculation: From formula, $M_s = \frac{Fr^2}{GM_e}$

$$\therefore \quad M_s = \frac{(3.5\times10^{22})\times(1.5\times10^{11})^2}{6.7\times10^{-11}\times6\times10^{24}}$$

$$= \frac{7.88\times10^{44}}{40.2\times10^{13}} = \mathbf{1.96\times10^{30}\ kg}$$

Ans: The mass of the Sun is **1.96 × 10^{30} kg**.

5. **A spaceship is 10^{14} km away from a massive star. The gravitational force between them is 70 N. Calculate the distance between them, if the force between them is increased to 7 × 10^{5} N.** ***[2 Marks]***

Solution:

Given: Force (F_1) = 70 N,
distance (r_1) = 10^{14} km = 10^{17} m,
force (F_2) = 7 × 10^{5} N

To find: Distance (r_2)

Formula: $F = \frac{Gm_1m_2}{r^2}$

Calculation: From formula,
For r_1 = 10^{17} m:

$$F_1 = \frac{Gm_1m_2}{r_1^2}$$

$$70 = \frac{Gm_1m_2}{\left(10^{17}\right)^2} \quad ....(1)$$

For r_2:

$$F_2 = \frac{Gm_1m_2}{r_2^2}$$

$$7\times10^5 = \frac{Gm_1m_2}{r_2^2} \quad ....(2)$$

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

$$\frac{70}{7\times10^5} = \frac{r_2^2}{\left(10^{17}\right)^2}$$

$$\therefore \quad r_2^2 = \frac{70}{7\times10^5}\times10^{34} = 10^{30}$$

$\therefore$ r_2 = 10^{15} m = **10^{12} km**

Ans: The distance between the spaceship and the star is **10^{12} km**.

Type II Kinematical equations of motion

Formulae:

i. Kinematical equations of motion:

1. $v = u + at$ 2. $s = ut + \frac{1}{2}at^2$ 3. $v^2 = u^2 + 2as$

ii. For a freely falling body:

1. $v = gt$ 2. $h = \frac{1}{2}gt^2$ 3. $v^2 = 2gh$

iii. For a body thrown upwards:

1. $u = -gt$ (negative sign indicates velocity is decreasing)
2. $h = ut - \frac{1}{2}gt^2$ 3. $u^2 = 2gh$

Illustrative Example:

+ **An iron ball of mass 3 kg is released from a height of 125 m and falls freely to the ground. Assuming that the value of g is 10 m/s^2, calculate**

i. time taken by the ball to reach the ground
ii. velocity of the ball on reaching the ground
iii. the height of the ball at half the time it takes to reach the ground.

Analyse

Step 1: Read the problem and make a list of what is given or can be inferred from the problem.
From the information given, we come to know that the iron ball is in a state of free fall.
Mass (m) of the ball = 3 kg, distance travelled by the ball (s) = 125 m,
The iron ball is released from a height means initial velocity of the ball (u) = 0,
During free fall, acceleration $a = g = 10\ m/s^2$.

Step 2: Make a note of all the quantities which are required to be found.
i. Time taken (t) ii. Final velocity (v) iii. Height (h)

Solve

Step 3: Based on the information provided and the quantity to be found, identify which kinematical equation of motion best fits the situation.

To find the time taken by the ball to reach the ground.
An equation that includes distance (s), initial velocity (u), acceleration (a) and time (t) i.e, $s = ut + \frac{1}{2}at^2$ fits the given situation.

Step 4: Substitute known values into the equation and use appropriate algebraic steps to solve for the unknown quantity.

$125 = 0t + 12 \times 10 \times t^2 = 5t^2$

$\therefore \quad t^2 = \frac{125}{5} = 25$

$\therefore \quad t =$ **5 s**

Step 5: Check the final answer in terms of its magnitude, sign and unit.

To find the velocity of the ball on reaching the ground.
Repeat step (3) for above case.
An equation that includes final velocity (v), initial velocity (u), acceleration (a) and time (t) i.e., $v = u + at$ fits the given situation.
Repeat step (4).
$v = 0 + 10 \times 5 =$ **50 m/s**
Repeat step (5).

To find the height of the ball at half the time it takes to reach the ground.

Repeat step (3) for above case.

An equation that includes distance (s), initial velocity (u), acceleration (a) and time (t) i.e., $s = ut + \frac{1}{2}at^2$ fits the given situation.

We consider the ball's distance from top as 's'

Take note of any conditions given in the problem, in this case the height to be found is at half the time.

Half time = $t' = \frac{5}{2} = 2.5$ s

Repeat step (4).

$s = ut' + \frac{1}{2}at'^2$ $\quad\therefore\quad s = 0 + \frac{1}{2} \times 10 \times (2.5)^2 = 31.25$ m.

Thus, the distance of the ball from the top is 31.25 m.

To get the height of the ball at half time,

h = 125 – 31.25 = **93.75 m**

Repeat step (5).

6. An iron ball of mass 3 kg is released from a height of 125 m and falls freely to the ground. Assuming that the value of 'g' is 10 m/s^2, calculate:

i. Time taken by the ball to reach the ground.

ii. Velocity of the ball on reaching the ground.

[Dec 2020] ***[3 Marks]***

Ans: *Refer Illustrative example (i, ii.)*

7. A metal ball of mass 5 kg falls from a height of 490 m. How much time will it take to reach the ground? (g = 9.8 m/s^2)

[Mar 2019] ***[2 Marks]***

Solution:

Given: Mass (M) = 5 kg, height (s) = 490 m, gravitational acceleration (g) = 9.8 m/s^2

To find: Time taken (t)

Formula: $s = ut + \frac{1}{2}gt^2$

Calculation: From formula,

$490 = (0 \times t) + (\frac{1}{2} \times 9.8 \times t^2)$

$\therefore\ 490 = 4.9\ t^2$

$\therefore\ t^2 = \frac{490}{4.9} = 100$

$\therefore\ t = \mathbf{10\ s}$

Ans: The metal ball will take **10 s** to reach the ground.

***8. An object takes 5 s to reach the ground from a height of 5 m on a planet. What is the value of g on the planet?**

[Mar 2022; Dec 2020]***[2 Marks]***

Solution:

Given: Time (t) = 5 s, height (s) = 5 m

To find: Gravitational acceleration (g)

Formula: $s = ut + \frac{1}{2}gt^2$

Calculation: From formula,

$5 = 0 \times t + \frac{1}{2}g(5)^2$

$\therefore\ 5 = \frac{1}{2}g \times 25$

$\therefore\ g = \frac{2}{5} = \mathbf{0.4\ m/s^2}$

Ans: The gravitational acceleration of the planet is **0.4 m/s^2**.

9. Use your brain power! ***(Textbook page no. 06)***

How long will Mahendra take to move 1 cm towards Virat, if a constant acceleration of 5.34×10^{-9} m/s^2 is produced in Mahendra?

[2 Marks]

Solution:

Given: Height (s) = 1 cm = 0.01 m, initial velocity (u) = 0 m/s, acceleration (a) = 5.34×10^{-9} m/s^2

To find: Time taken (t)

Formula: $s = ut + \frac{1}{2}at^2$

Calculation: From formula,

$0.01 = \frac{1}{2} \times 5.34 \times 10^{-9} \times t^2$

$\therefore\ 0.01 = 2.67 \times 10^{-9} \times t^2$

$\therefore\ t^2 = \frac{0.01}{2.67 \times 10^{-9}} = 3.75 \times 10^6$

$\therefore\ t = \mathbf{1936\ s}$

Ans: With constant acceleration, Mahendra takes **1936 s** to move 1 cm towards Virat.

10. A stone is released from the top of a tower of height 19.6 m. Calculate its final velocity just before touching the ground. ***[2 Marks]***

Solution:

Given: Height (h) = 19.6 m, Initial velocity (u) = 0 m/s,

To find: Final velocity (v)

Formula: $v^2 = u^2 + 2as$

Calculation: For downward motion,

$a = g, s = h, u = 0$

From formula,

$v^2 = 2 \times 9.8 \times 19.6$

$\therefore$ $v^2 = 384.16$

$\therefore$ $v = \mathbf{19.6\ m/s}$

Ans: Final velocity of the stone just before touching the ground is **19.6 m/s**.

+**11. A gravitational force of 4.002 × 10^{-7} N is acting between Mahendra (75 kg) and Virat (80 kg). Assuming that the bench on which Mahendra is sitting is frictionless, starting with zero velocity, what will be Mahendra's velocity of motion towards Virat after 1 s? Will this velocity change with time and how?** ***[3 Marks]***

Solution:

Given: Force on Mahendra (F) = 4.002×10^{-7} N, Mahendra's mass (m) = 75 kg

To find: Velocity (v)

Formulae: i. $F = ma$

ii. $v = u + at$

Calculation: From formula (i),

$a = \frac{F}{m} = \frac{4.002 \times 10^{-7}}{75} = 5.34 \times 10^{-9}\ m/s^2$

As Mahendra is sitting on the bench, his initial velocity is zero (u = 0)

Assuming the bench to be frictionless,

From formula (ii),

$v = 0 + 5.34 \times 10^{-9} \times 1$

$\therefore$ $v = \mathbf{5.34 \times 10^{-9}\ m/s}$

As Mahendra is moving towards Virat, the distance between them decreases causing an increase in gravitational force.

For a given mass, gravitational force being directly proportional to acceleration, acceleration increases.

$a = \frac{F}{m}$

As acceleration increases, the velocity **increases**.

Ans: Mahendra's velocity after 1 s towards Virat will be **5.34 × 10^{-9} m/s** and will **increase** with time.

+**12. The gravitational force of 733 N acts on Mahendra who has mass of 75 kg. Starting from rest, what will be Mahendra's velocity after one second if he is falling down due to the gravitational force of the earth?** ***[2 Marks]***

Solution:

Given: Initial velocity (u) = 0, force (F) = 733 N, Mahendra's mass (m) = 75 kg, time (t) = 1 s

To find: Velocity (v)

Formulae: i. $F = ma$

ii. $v = u + at$

Calculation: Mahendra's acceleration

From formula (i),

$a = \frac{F}{m} = \frac{733}{75} = 9.77\ m/s^2$

Mahendra's velocity after 1 second,

From formula (ii),

$v = 0 + 9.77 \times 1 = \mathbf{9.77\ m/s}$

Ans: Mahendra's velocity after one second, if he is falling down due to the gravitational force of the earth is **9.77 m/s**.

13. A ball falls off a table and reaches the ground in 1 s. Assuming g = 10 m/s², calculate its speed on reaching the ground and the height of the table.** ***[2 Marks]

Solution:

Given: Initial velocity (u) = 0, acceleration due to gravity(g) = 10 m/s², time (t) = 1 s

To find: Height (s), velocity (v)

Formulae: i. $s = ut + \frac{1}{2} gt^2$

ii. $v^2 = u^2 + 2\,gs$

Calculation: From formula (i),

$s = 0 \times t + \frac{1}{2} \times 10 \times 1^2 = \mathbf{5\ m}$

From formula (ii),

$v^2 = 0 + 2 \times 10 \times 5$

$\therefore$ $v^2 = 100$

$\therefore$ $v = \mathbf{10\ m/s}$

Ans: i. The velocity of the ball when it reaches the ground is **10 m/s**.

ii. The height of the table is **5 m**.

***14. An object thrown vertically upwards reaches a height of 500 m. What was its initial velocity? How long will the object take to come back to the earth? Assume g = 10 m/s².**

[July 2019] ***[3 Marks]***

Solution:

Given: Height (s) = 500 m, acceleration due to gravity (g) = 10 m/s²

To find: i. Initial velocity (u),

ii. Total time taken

Formulae: i. $v^2 = u^2 + 2\,as$

ii. $s = ut + \frac{1}{2} at^2$

Calculation: For upward motion of the ball,

(v) = 0.

$a = -g = -10\ m/s^2$

From formula (i),

$0 = u^2 + 2\,(-10) \times 500$

$\therefore$ $u^2 = 10000$

$\therefore$ $u = \mathbf{100\ m/s}$

For downward motion of the ball, (u) = 0.
$a = g = 10\ m/s^2$
From formula (ii),
$500 = 0 + \frac{1}{2} \times 10\ t^2$
$\therefore\ t^2 = \frac{500}{5} = 100$
$\therefore\ t = 10\ s$
Time for upward journey of the ball will be the same as time for downward journey i.e., 10 s.
$\therefore$ Total time taken = 2 × t = 2 × 10 = **20 s**

Ans: i. The initial velocity of the object is **100 m/s**.
ii. The total time taken by the object to reach the height and come down is **20 s**.

+15. **A tennis ball is thrown up and reaches a height of 4.05 m before coming down. What was its initial velocity? How much total time will it take to come down? Assume $g = 10\ m/s^2$.** ***[3 Marks]***

Solution:

Given: Distance travelled by the ball (s) = 4.05 m,
acceleration $a = g = 10\ m/s^2$

To find: i. Initial velocity (u)
ii. Time taken (t)

Formulae: i. $v^2 = u^2 + 2\ as$
ii. $s = ut + \frac{1}{2}\ at^2$

Calculation: For upward motion of the ball,
v = 0.
$a = -g = -10\ m/s^2$
From formula (i),
$0 = u^2 + 2\ (-10) \times 4.05$
$\therefore\ u^2 = 81$
$\therefore$ u = **9 m/s**
For downward motion of the ball, u = 0.
$a = g = 10\ m/s^2$
From formula (ii),
$4.05 = 0 + \frac{1}{2} \times 10\ t^2$
$\therefore\ t^2 = \frac{4.05}{5} = 0.81$
$\therefore\ t = 0.9\ s$
Time for upward journey of the ball will be the same as time for downward journey i.e., 0.9 s.
$\therefore$ Total time taken = 2 × 0.9 = **1.8 s**

Ans: i. The initial velocity of the ball is **9 m/s**.
ii. The total time taken by the ball to reach the ground is **1.8 s**.

Type III **Acceleration due to gravity (g)**

Formula: On the earth surface, $g = \frac{GM}{R^2}$

*16. **The mass and weight of an object on earth are 5 kg and 49 N respectively. What will be their values on the moon? Assume that the acceleration due to gravity on the moon is 1/6th of that on the earth.** ***[2 Marks]***

Solution:

Given: Mass on earth (m_e) = 5 kg, weight on earth (W_e) = 49 N,
acceleration due to gravity on moon (g_m) = 9.8/6 = 1.63 m/s^2

To find: Mass (m_m), weight (W_m) on moon

Formula: $W_m = m_m g_m$

Calculation: The mass of the object is independent of gravity and remains unchanged i.e., **5 kg**.
From formula,
$W_m = 5 \times 1.63$
$\therefore\ W_m =$ **8.15 N**

Ans: On moon, the mass of the object is **5 kg** and weight is **8.15 N**.

17. **Can you tell?** ***(Textbook page no. 08)***
What would be the value of g on the surface of the earth if its mass was twice as large and its radius half of what it is now?
[Mar 2019] ***[3 Marks]***

Solution:

Given: Mass of the earth M′ = 2M, radius of the earth $R' = \frac{R}{2}$

To find: gravitational acceleration (g′)

Formula: $g = \frac{GM}{R^2}$

Calculation: From formula,
$$g' = \frac{G \times M'}{(R')^2}$$
$$= \frac{G \times 2M}{\left(\frac{R}{2}\right)^2}$$
$$g' = \frac{G \times 2M \times 4}{R^2}$$
$\therefore\ g' = 8g = 8 \times 9.8$
$\therefore$ g = **78.4 m/s^2** i.e., 8 times the original value of g.

Ans: The value of g would be **78.4 m/s^2** on the surface of the earth if its mass was twice as large and its radius half of the present value.

18. The radius of planet A is half the radius of planet B. If the mass of A is M_A, what must be the mass of B so that the value of g on B is half that of its value on A?** ***[2 Marks]

Solution:

Given: For planet A:

mass = M_A, radius $R_A = \frac{R_B}{2}$,

acceleration due to gravity = g_A

For planet B:

radius = R_B,

acceleration due to gravity $g_B = \frac{g_A}{2}$

To find: Mass of planet B (M_B)

Formula: $g = \frac{GM}{R^2}$

Calculation: From formula,

$$\frac{M_A}{M_B} = \frac{g_A R_A^2}{G} \times \frac{G}{g_B R_B^2}$$

$$= \frac{g_A R_B^2}{4} \times \frac{2}{g_A R_B^2}$$

.... [Substituting for R_A and g_B]

$\therefore \frac{M_A}{M_B} = \frac{1}{2}$

$\therefore M_B = \mathbf{2M_A}$

Ans: The mass of planet B is $\mathbf{2M_A}$.

+19. If a person weighs 750 N on earth, how much would be his weight on the moon given that moon's mass is $\frac{1}{81}$ of that of the earth and its radius is $\frac{1}{3.7}$ of that of the earth? ***[2 Marks]***

Solution:

Given: Weight on earth = 750 N, Ratio of mass of the earth (M_E) to mass of the moon (M_M) = $\frac{M_E}{M_M} = 81$

Ratio of radius of the earth (R_E) to radius of moon (R_M) = $\frac{R_E}{R_M} = 3.7$

To find: Weight (W)

Formula: weight = mg = $\frac{mGM}{R^2}$

Calculation: Weight on the earth,

$mg = 750 = \frac{mGM_E}{R_E^2}$

$\therefore m = \frac{750 R_E^2}{(GM_E)}$ ....(i)

Weight on Moon

$W_{moon} = \frac{mGM_M}{R_M^2}$ ....(ii)

Substituting equation (i) in equation (ii),

$$W_{moon} = \frac{750 R_E^2}{(GM_E)} \times \frac{GM_M}{R_M^2} = 750 \frac{R_E^2}{R_M^2} \times \frac{M_M}{M_E}$$

$$= 750 \times (3.7)^2 \times \frac{1}{81}$$

$\therefore W_{moon} = \mathbf{126.8\ N}$

Ans: The weight of the person on moon will be **126.8 N**.

20. Use your brain power! *(Textbook page no. 10)*
Suppose you are standing on a tall ladder. If your distance from the centre of the earth is 2R, what will be your weight? ***[2 Marks]***

Solution:

Given: h = R ($\because$ distance from centre of the earth is 2R)

To find: Weight (W)

Formulae:
i. On earth's surface, $W = mg = \frac{GMm}{R^2}$

ii. At a height (h) above earth's surface, $W = \frac{GMm}{(R+h)^2}$

Calculation: On earth's surface,

From formula (i),

$W = \frac{GMm}{R^2}$ ....(1)

At a distance of 2R from centre of the earth,

From formula (ii),

$W' = \frac{GMm}{(R+R)^2} = \frac{GMm}{4R^2}$ ....(2)

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

$\frac{W'}{W} = \frac{R^2}{4R^2}$

$\therefore W' = \frac{1}{4} W$

Ans: The person's weight at a distance of 2R from the centre of the earth, would reduce to $\frac{1}{4}^{th}$ the weight on the surface of the earth.

Type IV Escape velocity

Formula: $v_{esc} = \sqrt{\frac{2GM}{R}} = \sqrt{2gR}$

+21. Calculate the escape velocity on the surface of the moon given the mass and radius of the moon to be 7.34×10^{22} kg and 1.74×10^6 m respectively. ***[2 Marks]***

Solution:

Given: Gravitational constant (G) = 6.67×10^{-11} Nm^2/kg^2, Mass of the moon (M) = 7.34×10^{22} kg, radius of the moon (R) = 1.74×10^6 m.

To find: Escape velocity (v_{esc})

Formula: $v_{esc} = \sqrt{\frac{2GM}{R}}$

Calculation: From formula,

$$v_{esc} = \sqrt{\frac{2 \times 6.67 \times 10^{-11} \times 7.34 \times 10^{22}}{1.74 \times 10^{6}}}$$

$$= \sqrt{\frac{97.9 \times 10^{5}}{1.74}}$$

$\therefore$ v_{esc} = 2372 m/s = **2.372 km/s**

Ans: Escape velocity on the moon is **2.372 km/s**.

22. The escape velocity of a body from the earth's surface is 11.2 km/s. The mass of the Moon is $(1/81)^{th}$ of that of earth. The radius of the moon is $(1/3.7)^{th}$ that of earth. Find the escape velocity from Moon's surface. ***[2 Marks]***

Solution:

Given: Escape velocity on earth's surface (v_{esc}) = 11.2 km/s,
ratio of moon and earth's mass (M_m/M_e) = 1/81,
ratio of moon and earth's radius (R_m/R_e) = 1/3.7

To find: Escape velocity $(v_e)_m$

Formulae: i. $v_{esc} = \sqrt{\frac{2GM_e}{R_e}}$

ii. $(v_{esc})_m = \sqrt{\frac{2GM_m}{R_m}}$

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

$$\frac{(v_{esc})_m}{v_{esc}} = \sqrt{\frac{M_m \times R_e}{M_e \times R_m}} = \sqrt{\frac{1}{81} \times 3.7} = 0.214$$

$\therefore$ $(v_{esc})_m = v_{esc} \times 0.214 = 11.2 \times 0.214$
= **2.39 km/s**

Ans: The escape velocity from Moon's surface is **2.39 km/s**.

Practice Problems

1. The masses of earth and Jupiter are 6×10^{24} kg and 1.9×10^{27} kg, respectively. The distance between them is 6.2×10^{11} m. Calculate the gravitational force of attraction between the two. Use $G = 6.7 \times 10^{-11}$ Nm^2 kg^{-2} ***[2 Marks]***

Ans: 1.98×10^{18} N

2. The mass of a planet is 6 times the mass of earth and its radius is 3 times that of the earth. Considering acceleration due to gravity on earth to be 9.8 m/s^2, calculate the value of 'g' on the other planet. ***[2 Marks]***

Ans: 6.53 m/s^2

3. An object takes 15 s to reach the ground from a height of 40 m on a planet. What is the value of g on the planet? ***[2 Marks]***

Ans: 0.35 m/s^2

4. A ball falls off a table and reaches the ground in 10 s. Assuming g = 10 m/s^2, calculate its speed on reaching the ground and the height of the table. ***[2 Marks]***

Ans: 100 m/s, 500m

5. An object thrown vertically upwards reaches a height of 320 m. What was its initial velocity? How long will the object take to come back to the earth? Assume g = 10 m/s^2. ***[3 Marks]***

Ans: 80 m/s, 16 s

6. An object is thrown vertically upwards and rises to a height of 10 m. Calculate
i. the velocity with which the object was thrown upwards and
ii. the time taken by the object to reach the highest point. (g = 9.8 m/s^2) ***[3 Marks]***

Ans: i. 14 ms^{-1} ii. 1.43 s

7. Calculate the maximum height attained by the body thrown vertically upward with a velocity of 9.8 m/s. (g = 9.8 m/s^2) ***[2 Marks]***

Ans: 4.9 m

8. An apple of mass 0.15 kg falls from a tree. What is the acceleration of the apple towards the earth? Also calculate the acceleration of the earth towards the apple. [Given: Mass of earth = 6×10^{24} kg, Radius of earth = 6.4×10^{6} m, $G = 6.67 \times 10^{-11}$ Nm^2 kg^{-2}.] ***[3 Marks]***

Ans: 9.8 m/s^2, 2.44×10^{-25} m/s^2

9. A body weighs 400 N on the surface of earth. How much will it weigh on the surface of a planet whose mass is $\frac{1}{6}^{th}$ and radius $\frac{1}{2}$ that of the earth? ***[2 Marks]***

Ans: 266.7 N

10. Find the escape speed of a body from the surface of Mars. [Radius of Mars = 3392 km, g_{Mars} = 3.724 m/s^2] ***[2 Marks]***

Ans: 5 km/s

Apply your Knowledge

1. Try this. ***(Textbook page no. 02)***
Tie a stone to one end of a string. Take the other end in your hand and rotate the string so that the stone moves along a circle as shown in the figure 1.2 (a) of your textbook.

i. Are you applying any force on the stone?
ii. In which direction is this force acting?
iii. How will you stop this force from acting?
iv. What will be the effect on the stone?

Ans:
i. Yes, I am applying a force on the stone.
ii. The force is acting in the direction towards the centre of the circle along which the stone is rotated.
iii. The force can be stopped from acting by releasing the string.

iv. The stone will fly off along a straight line tangential to the circle at the position of the stone, when the string is released.

[Note: Students are expected to refer the accompanying Q. R. code in *Quill – The Padhai App* for demonstration of the activity.**]**

2. Use your brain power! ***(Textbook page no. 04)***
If the area ESF given in figure 1.4 of your textbook is equal to area ASB, what will you infer about EF?

Ans: According to Kepler's second law, if area of ESF = area of ASB, then AB and EF are distances covered by planet in the same time.

3. Think about it. ***(Textbook page no. 08)***

i. What would happen if there were no gravity?

Ans: If gravitational force ceased to exist on earth, then:

a. All the objects will no longer be drawn towards each other and the earth. Objects not being attracted to the earth along-with humans would float off into space away from the surface of the earth.
b. The important constituents of the earth including the atmosphere and the water from the ocean, seas etc would also float into space.
c. The moon would stop orbiting the earth and would drift in space.

ii. What would happen if the value of G was twice as large?

Ans: If the value of G were to be doubled, then:

a. the value of acceleration due to gravity(g) would become double.
b. Weight of all the objects on the earth will become double making simple tasks like picking an object difficult.
c. The atmospheric air pressure would increase leading to various climatic changes. To counter this change in air pressure, the blood pressure of human body will increase making it hard to survive on earth.
d. The earth's orbit around the Sun will be affected which will result in catastrophic climatic changes.

4. Try This. ***(Textbook page no. 11)***
Take a small stone. Hold it in your hand. Which forces are acting on the stone? Now release the stone. What do you observe? What are the forces acting on the stone after you release it?

Ans:

i. When a stone is held in our hands, it experiences the gravitational force exerted on it by the earth pulling it downward and the force of the hand pushing it upwards.
ii. When the stone is released, it falls down.
iii. Once the stone is released, the forces acting on the stone are gravitational force and an upward force opposing the gravitational force.
iv. If the medium in which the stone is released is air, frictional force due to air also acts on the stone opposing its motion.

[Note: Students are expected to refer the accompanying Q. R. code in *Quill – The Padhai App* for understanding of the concept.**]**

Memory Map

Kepler's laws of planetary motion

Law of orbit
- Planets orbit is an ellipse with Sun at one of the foci.

Law of areas
- Line joining planet and Sun sweeps equal areas in equal time interval

Law of period
- Square of orbital revolution of planet around Sun is directly proportional to cube of mean distance of the planet from sun.
- $T^2 \propto R^3$

helped in formulating

Newton's law of Gravitation

Formulates

Gravitational force
- $F = G\dfrac{Mm}{r^2}$

To escape its influence

Escape velocity
- $v_{esc} = \sqrt{\dfrac{2GM}{R}} = \sqrt{2gR}$

Gives rise to

Gravitational acceleration
- $g = \dfrac{GM}{r^2}$

Varies

Due to shape of the earth
- Value of 'g' is highest at poles and lowest at equator.

With height
- Value of 'g' decreases with increase in height

With depth
- Value of 'g' decreases with increase in depth

Gives rise to

Weight
- $W = mg$

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