SAMPLE CONTENT

35 YEARS
1988 - 2022

1793 MCQs

PREVIOUS SOLVED PAPERS

Topic-wise & Subtopic-wise

NEET PHYSICS

INCLUDES SOLVED QUESTIONS OF 2022

A comprehensive collection of NEET & AIPMT Questions from past 35 Years

Target Publications® Pvt. Ltd.

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NEET PHYSICS

Salient Features

- A compilation of 35 years of AIPMT/NEET questions (1988-2022)
- Includes solved questions from NEET 2022
- Includes '1793' AIPMT/NEET MCQs
- Topic - wise and Subtopic - wise segregation of questions
- Year-wise flow of content concluded with the latest questions
- Relevant solutions provided
- Graphical analysis of questions : Topic - wise and Subtopic - wise

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PREFACE

Target's **'NEET Physics: PSP (Previous Solved Papers)'** is a compilation of questions asked in the past 35 years (1988-2022) in the National Eligibility cum Entrance Test (NEET), formerly known as the All India Pre-Medical Test (AIPMT).

The book consists of topic - wise categorization of questions. Each chapter is further segregated into subtopics and thereafter all the questions pertaining to a subtopic are arranged year-wise concluding with the latest year. To aid students, we have also provided detailed solutions for questions wherever deemed necessary.

A graphical (% wise) analysis of the subtopics for the past 35 years as well as 10 years (2013 onwards) has been provided at the onset of every topic. Both the graphs will help the students to understand and analyse each subtopic's distribution for NEET/AIPMT (35 years) and NEET-UG (10 Years).

We are confident that this book will comprehensively cater to needs of students and effectively assist them to achieve their goal.

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 on: mail@targetpublications.org

A book affects eternity; one can never tell where its influence stops.

Best of luck to all the aspirants!

Publisher

Edition: Third

Frequently Asked Questions

Why this book?	• This book acts as a go-to tool to find all the AIPMT/NEET questions since the past 35 years at one place. • The subtopic wise arrangement of questions provides the break-down of a chapter into its important components which will enable students to design an effective learning plan. • The graphical analysis guides students in ascertaining their own preparation of a particular topic.
Why the need for two graphs?	Admission for undergraduate and post graduate medical courses underwent a critical change with the introduction of NEET in 2013. Although it received a huge backlash and was criticised for the following two years, NEET went on to replace AIPMT in 2016. The introduction of NEET brought in a few structural differences in terms of how the exam was conducted. Although the syllabus has majorly remained the same, the chances of asking a question from a particular subtopic is seen to vary slightly with the inception of NEET. The two graphs will fundamentally help the students to understand that the (weightage) distribution of a particular topic can vary i.e., a particular subtopic having the most weightage for AIPMT may not necessarily be the subtopic with the most weightage for NEET.
How are the two graphs beneficial to the students?	• The two graphs provide a subtopic's weightage distribution over the past 35 years (for NEET/AIPMT) and over the past 10 years (for NEET-UG). • The students can use these graphs as a self-evaluation tool by analyzing and comparing a particular subtopic's weightage with their preparation of the subtopic. This exercise would help the students to get a clear picture about their strength and weakness based on the subtopics. • Students can also use the graphs as a source to know the most important as well as least important subtopics as per weightage of a particular topic which will further help them in planning the study structure of a particular chapter. *(Note: The percentage-wise weightage analysis of subtopics is solely for the knowledge of students and does not guarantee questions from subtopics having the most weightage, in the future exams.* *Question classification of a subtopic is done as per the authors' discretion and may vary with respect to another individual.)*

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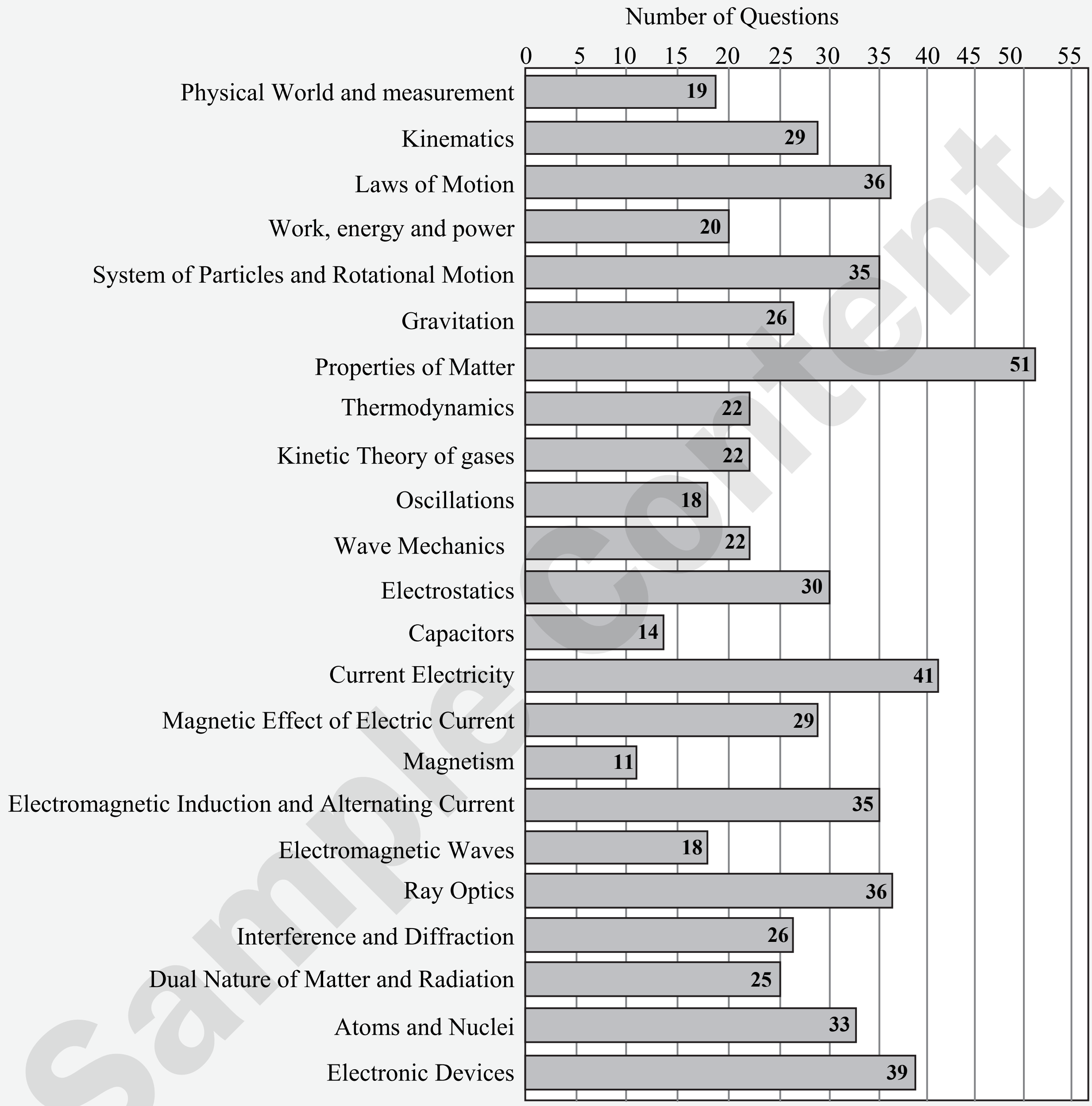
Topic-wise Weightage Analysis of past 10 Years (2013 Onwards)



Total No. of Questions: 637

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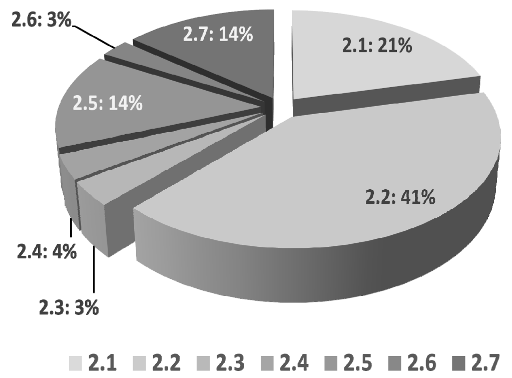
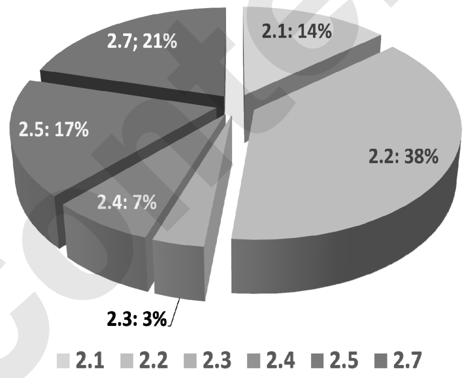
- 2.3 Position - time, velocity - time graphs
- 2.4 Relative velocity
- 2.5 Motion under gravity
- 2.6 Motion in a plane
- 2.7 Projectile motion

35 Years NEET/AIPMT Analysis (Percentage-wise weightage of sub-topics)



10 Years NEET Analysis (2013 Onwards) (Percentage-wise weightage of sub-topics)



2.1 Scalars and vectors

1. The magnitude of vectors $\vec{A}$, $\vec{B}$ and $\vec{C}$ are 3, 4 and 5 units respectively. If $\vec{A} + \vec{B} = \vec{C}$, the angle between $\vec{A}$ and $\vec{B}$ is **[1988]**
   (A) $\pi/2$ (B) $\cos^{-1}(0.6)$
   (C) $\tan^{-1}(7/5)$ (D) $\pi/4$

2. The resultant of $\vec{A} \times 0$ will be equal to **[1992]**
   (A) zero (B) A
   (C) zero vector (D) unit vector

3. The angle between the two vectors $\vec{A} = 3\hat{i} + 4\hat{j} + 5\hat{k}$ and $\vec{B} = 3\hat{i} + 4\hat{j} - 5\hat{k}$ will be **[1994]**
   (A) 90° (B) 180°
   (C) zero (D) 45°

4. The position vector of a particle is $\vec{r} = (a \cos \omega t)\,\hat{i} + (a \sin \omega t)\hat{j}$. The velocity of the particle is **[1995]**
   (A) parallel to the position vector
   (B) perpendicular to the position vector
   (C) directed towards the origin
   (D) directed away from the origin

5. Identify the vector quantity among the following **[1997]**
   (A) distance
   (B) angular momentum
   (C) heat
   (D) energy

6. What is the value of linear velocity, if $\vec{r} = 3\hat{i} - 4\hat{j} + \hat{k}$ and $\vec{\omega} = 5\hat{i} - 6\hat{j} + 6\hat{k}$? **[1999]**
   (A) $4\hat{i} - 13\hat{j} + 6\hat{k}$ (B) $18\hat{i} + 13\hat{j} - 2\hat{k}$
   (C) $6\hat{i} + 2\hat{j} - 3\hat{k}$ (D) $6\hat{i} - 2\hat{j} + 8\hat{k}$

7. If a unit vector is represented by $0.5\hat{i} - 0.8\hat{j} + c\hat{k}$ then the value of c is **[1999]**
   (A) $\sqrt{0.01}$ (B) $\sqrt{0.11}$
   (C) 1 (D) $\sqrt{0.39}$

8. If $|\vec{A} + \vec{B}| = |\vec{A}| + |\vec{B}|$ then angle between A and B will be **[2001]**
   (A) 90° (B) 120° (C) 0° (D) 60°

9. The vector sum of two forces is perpendicular to their vector differences. In this case, the forces **[2003]**
   (A) are equal to each other in magnitude.
   (B) are not equal to each other in magnitude.
   (C) cannot be predicted.
   (D) are equal to each other in direction.

10. If $|\vec{A}\times\vec{B}| = \sqrt{3}\,\vec{A}\cdot\vec{B}$ then the value of $|\vec{A}+\vec{B}|$ is **[2004]**
(A) $(A^2 + B^2 + AB)^{1/2}$
(B) $\left(A^2 + B^2 + \frac{AB}{\sqrt{3}}\right)^{1/2}$
(C) $A + B$
(D) $\left(A^2 + B^2 + \sqrt{3}AB\right)^{1/2}$

11. If the angle between the vectors $\vec{A}$ and $\vec{B}$ is θ, the value of the product $(\vec{B}\times\vec{A})\cdot\vec{A}$ is equal to **[2005,1989]**
(A) $BA^2\sin\theta$ (B) $BA^2\cos\theta$
(C) $BA^2\sin\theta\cos\theta$ (D) Zero.

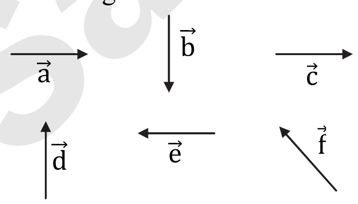
12. If a vector $2\hat{i} + 3\hat{j} + 8\hat{k}$ is perpendicular to the vector $4\hat{j} - 4\hat{i} + \alpha\hat{k}$, then the value of α is **[2005]**
(A) 1/2 (B) – 1/2
(C) 1 (D) – 1.

13. The vectors $\vec{A}$ and $\vec{B}$ are such that $|\vec{A}+\vec{B}| = |\vec{A}-\vec{B}|$. The angle between the two vectors is **[2006, 1996, 1991]**
(A) 45° (B) 90°
(C) 60° (D) 75°

14. $\vec{A}$ and $\vec{B}$ are two vectors and θ is the angle between them, if $|\vec{A}\times\vec{B}| = \sqrt{3}(\vec{A}\cdot\vec{B})$, the value of θ is **[2007]**
(A) 45° (B) 30°
(C) 90° (D) 60°

15. A particle has initial velocity $(3\hat{i} + 4\hat{j})$ and has acceleration $(0.4\hat{i} + 0.3\hat{j})$. Its speed after 10 s is **[2010]**
(A) 7 units (B) $7\sqrt{2}$ units
(C) 8.5 units (D) 10 units

16. Six vectors, $\vec{a}$ through $\vec{f}$ have the magnitudes and directions indicated in the figure. Which of the following statements is true? **[2010]**



(A) $\vec{b}+\vec{c}=\vec{f}$ (B) $\vec{d}+\vec{c}=\vec{f}$
(C) $\vec{d}+\vec{e}=\vec{f}$ (D) $\vec{b}+\vec{e}=\vec{f}$

17. A particle has initial velocity $(2\vec{i}+3\vec{j})$ and acceleration $(0.3\vec{i}+0.2\vec{j})$. The magnitude of velocity after 10 seconds will be **[2012]**
(A) $9\sqrt{2}$ units (B) $5\sqrt{2}$ units
(C) 5 units (D) 9 units

18. The position vector of a particle $\vec{R}$ as a function of time is given by $\vec{R} = 4\sin(2\pi t)\,\hat{i} + 4\cos(2\pi t)\,\hat{j}$ Where R is in metres, t is in seconds and $\hat{i}$ and $\hat{j}$ denote unit vectors along x and y-directions, respectively. Which one of the following statements is wrong for the motion of particle? **[Re - Test 2015]**
(A) Path of the particle is a circle of radius 4 metre.
(B) Acceleration vectors is along $-\vec{R}$.
(C) Magnitude of acceleration vector is $\frac{v^2}{R}$ where v is the velocity of particle.
(D) Magnitude of the velocity of particle is 8 metre/second.

19. If vectors $\vec{A} = \cos\omega t\ \hat{i} + \sin\omega t\ \hat{j}$ and $\vec{B} = \cos\frac{\omega t}{2}\hat{i} + \sin\frac{\omega t}{2}\hat{j}$ are functions of time, then the value of t at which they are orthogonal to each other is **[Re-Test 2015]**
(A) $t = 0$ (B) $t = \frac{\pi}{4\omega}$
(C) $t = \frac{\pi}{2\omega}$ (D) $t = \frac{\pi}{\omega}$

20. A particle moves so that its position vector is given by $\vec{r} = \cos\omega t\ \hat{x} + \sin\omega t\ \hat{y}$, where ω is a constant. Which of the following is true? **[Phase - I 2016]**
(A) Velocity is perpendicular to $\vec{r}$ and acceleration is directed towards the origin.
(B) Velocity is perpendicular to $\vec{r}$ and acceleration is directed away from the origin.
(C) Velocity and acceleration both are perpendicular to $\vec{r}$.
(D) Velocity and acceleration both are parallel to $\vec{r}$.

21. If the magnitude of sum of two vectors is equal to the magnitude of difference of the two vectors, the angle between these vectors is **[Phase - I 2016]**
(A) 45° (B) 180°
(C) 0° (D) 90°

2.2 Speed, velocity and acceleration

1. A car is moving along a straight road with a uniform acceleration. It passes through two points P and Q separated by a distance with velocity 30 km/h and 40 km/h respectively. The velocity of the car midway between P and Q is **[1988]**
(A) 33.3 km/h (B) $20\sqrt{2}$ km/h
(C) $25\sqrt{2}$ km/h (D) 35 km/h

2. A bus is moving on a straight road towards north with a uniform speed of 50 km/hour then it turns left through 90°. If the speed remains unchanged after turning, the increase in the velocity of bus in the turning process is **[1989]**
(A) 70.7 km/hr along south-west direction
(B) Zero
(C) 50km/hr along west
(D) 70.7 km/hr along north-west direction

3 A car covers the first half of the distance between two places at 40 km/h and another half at 60 km/h. The average speed of the car is **[1990]**
(A) 40 km/h (B) 48 km/h
(C) 50 km/h (D) 60 km/h

4 A bus travelling the first one-third distance at a speed of 10 km/h, the next one-third at 20 km/h and last one-third at 60 km/h. The average speed of the bus is **[1991]**
(A) 9 km/h (B) 16 km/h
(C) 18 km/h (D) 48 km/h

5. A car moves a distance of 200 m. It covers the first half of the distance at speed 40 km/h and the second half of distance at speed v. The average speed is 48 km/h, The value of v is **[1991]**
(A) 56 km/h (B) 60 km/h
(C) 50 km/h (D) 48 km/h.

6. A body starts from rest. What is the ratio of the distance travelled by the body during the 4th and 3rd second? **[1993]**
(A) $\frac{7}{3}$ (B) $\frac{7}{5}$ (C) $\frac{5}{7}$ (D) $\frac{3}{7}$

7. A boat is sent across a river with a velocity of 8 km h^{-1}. If the resultant velocity of boat is 10 km h^{-1}, then velocity of river is **[1994, 1993]**
(A) 12.8 km h^{-1} (B) 6 km h^{-1}
(C) 8 km h^{-1} (D) 10 km h^{-1}

8. A satellite in force-free space sweeps stationary interplanetary dust at a rate $dM/dt = \alpha v$ where M is the mass, v is the velocity of the satellite and α is a constant. What is the deceleration of the satellite? **[1994]**
(A) $-2\alpha v^2/M$ (B) $-\alpha v^2/M$
(C) $+\alpha v^2/M$ (D) $-\alpha v^2$

9. The velocity of train increases uniformly from 20 km/h to 60 km/h in 4 hours. The distance travelled by the train during this period is **[1994]**
(A) 160 km (B) 180 km
(C) 100 km (D) 120 km

10. A car accelerates from rest at a constant rate α for some time, after which it decelerates at a constant rate β and comes to rest. If the total time elapsed is t, then the maximum velocity acquired by the car is **[1994]**
(A) $\left(\frac{\alpha^2+\beta^2}{\alpha\beta}\right)t$ (B) $\left(\frac{\alpha^2-\beta^2}{\alpha\beta}\right)t$
(C) $\frac{(\alpha+\beta)t}{\alpha\beta}$ (D) $\frac{\alpha\beta t}{\alpha+\beta}$

11. A particle moves along a straight line such that its displacement at any time t is given by $s = (t^3 - 6t^2 + 3t + 4)$ metres. The velocity when the acceleration is zero is **[1994]**
(A) 3 m/s (B) 42 m/s
(C) –9 m/s (D) – 15 m/s

12. The acceleration of a particle is increasing linearly with time t as bt. The particle starts from origin with an initial velocity v_0. The distance travelled by the particle in time t will be **[1995]**
(A) $v_0t + \frac{1}{3}bt^2$ (B) $v_0t + \frac{1}{2}bt^2$
(C) $v_0t + \frac{1}{6}bt^3$ (D) $v_0t + \frac{1}{3}bt^3$

13. If a car at rest accelerates uniformly to a speed of 144 km/h in 20s, it covers a distance of **[1997]**
(A) 1440 cm (B) 2980 cm
(C) 20 m (D) 400 m

14. The position x of a particle varies with time, (t) as $x = at^2 - bt^3$. The acceleration will be zero at time t is equal to **[1997]**
(A) $\frac{a}{3b}$ (B) Zero (C) $\frac{2a}{3b}$ (D) $\frac{a}{b}$

15. A car moving with a speed of 40 km/hr can be stopped by applying brakes after at least 2 m. If the same car is moving with a speed of 80 km/hr, what is the minimum stopping distance? **[1998]**
(A) 8 m (B) 2 m (C) 4 m (D) 6 m

16. A person aiming to reach exactly opposite point on the bank of a stream is swimming with a speed of 0.5 m/s at an angle of 120° with the direction of flow of water. The speed of water in the stream, is **[1999]**
(A) 0.25 m/s (B) 0.5 m/s
(C) 1.0 m/s (D) 0.433 m/s

17. The width of river is 1 km. The velocity of boat is 5 km/hr. The boat covered the width of river in shortest time 15 min. Then the velocity of river stream is **[2000, 1998]**
(A) 3 km/hr (B) 4 km/hr
(C) $\sqrt{29}$ km/hr (D) $\sqrt{41}$ km/hr

18. Motion of a particle is given by equation $s = (3t^3 + 7t^2 + 14t + 8)$ m. The value of acceleration of the particle at t = 1s is **[2000]**
(A) 10 m/s^2 (B) 32 m/s^2
(C) 23 m/s^2 (D) 16 m/s^2

19. An object of mass 3 kg is at rest. Now a force of $\vec{F} = 6t^2\,\hat{i} + 4t\,\hat{j}$ is applied on the object then velocity of object at t = 3 s. is **[2002]**
(A) $18\hat{i} + 3\hat{j}$ (B) $18\hat{i} + 6\hat{j}$
(C) $3\hat{i} + 18\hat{j}$ (D) $18\hat{i} + 4\hat{j}$

20. Two boys are standing at the ends A and B of a ground where AB = a. The boy at B starts running in a direction perpendicular to AB with velocity v_1. The boy at A starts running simultaneously with velocity v and catches the other in a time t, where t is **[2005]**
(A) $\dfrac{a}{\sqrt{v^2 + v_1^2}}$ (B) $\dfrac{a}{v + v_1}$
(C) $\dfrac{a}{v - v_1}$ (D) $\sqrt{\dfrac{a^2}{v^2 - v_1^2}}$

21. The displacement x of a particle varies with time t, $x = ae^{-\alpha t} + be^{\beta t}$, where a, b, α and β are positive constants. The velocity of the particle will **[2005]**
(A) go on decreasing with time
(B) be independent of α and β
(C) drop to zero when $\alpha = \beta$
(D) go on increasing with time

22. A car runs at a constant speed on a circular track of radius 100 m, taking 62.8 seconds for every circular lap. The average velocity and average speed for each circular lap respectively is **[2006]**
(A) 10 m/s, 0 (B) 0, 0
(C) 0, 10 m/s (D) 10 m/s, 10 m/s.

23. A particle moves along a straight line OX. At a time t (in seconds) the distance x (in metres) of the particle from O is given by $x = 40 + 12t - t^3$. How long would the particle travel before coming to rest? **[2006]**
(A) 16 m (B) 24 m
(C) 40 m (D) 56 m

24. A car moves from X to Y with a uniform speed v_u and returns to Y with a uniform speed v_d. The average speed for this round trip is **[2007]**
(A) $\sqrt{v_u v_d}$ (B) $\dfrac{v_d v_u}{v_d + v_u}$
(C) $\dfrac{v_u + v_d}{2}$ (D) $\dfrac{2v_d v_u}{v_d + v_u}$

25. The position x of a particle with respect to time t along x-axis is given by $x = 9t^2 - t^3$ where x is in metres and t in seconds. What will be the position of this particle when it achieves maximum speed along the +x direction? **[2007]**
(A) 54 m (B) 81 m
(C) 24 m (D) 32 m

26. A particle moving along x-axis has acceleration f, at time t, given by $f = f_0\left(1 - \frac{t}{T}\right)$ where f_0 and T are constants. The particle at t = 0 has zero velocity. In the time interval between t = 0 and the instant when f = 0, the particle's velocity (v_x) is **[2007]**
(A) $\frac{1}{2} f_0 T^2$ (B) $f_0 T^2$
(C) $\frac{1}{2} f_0 T$ (D) $f_0 T$

27. The distance travelled by a particle starting from rest and moving with an acceleration $\frac{4}{3}$ m s^{-2}, in the third second is **[2008]**
(A) $\frac{10}{3}$ m (B) $\frac{19}{3}$ m
(C) 6 m (D) 4 m

28. A particle moves in a straight line with a constant acceleration. It changes its velocity from 10 ms^{-1} to 20 ms^{-1} while passing through a distance 135 m in t second. The value of t is **[2008]**
(A) 12 (B) 9 (C) 10 (D) 1.8

29. A particle starts its motion from rest under the action of a constant force. If the distance covered in first 10 seconds is S_1 and that covered in the first 20 seconds is S_2, then **[2009]**
(A) $S_2 = 3S_1$ (B) $S_2 = 4S_1$
(C) $S_2 = S_1$ (D) $S_2 = 2S_1$

30. A particle moves a distance x in time t according to equation $x = (t + 5)^{-1}$. The acceleration of particle is proportional to **[2010]**
(A) $(\text{velocity})^{3/2}$ (B) $(\text{distance})^2$
(C) $(\text{distance})^{-2}$ (D) $(\text{velocity})^{2/3}$

31. A body is moving with velocity 30 m/s towards east. After 10 seconds its velocity becomes 40 m/s towards north. The average acceleration of the body is **[2011]**
(A) 1 m/s^2 (B) 7 m/s^2
(C) $\sqrt{7}$ m/s^2 (D) 5 m/s^2

32. A particle covers half of its total distance with speed v_1 and the rest half distance with speed v_2. Its average speed during the complete journey is **[2011]**
(A) $\dfrac{v_1 + v_2}{2}$ (B) $\dfrac{v_1 v_2}{v_1 + v_2}$
(C) $\dfrac{2v_1 v_2}{v_1 + v_2}$ (D) $\dfrac{v_1^2 v_2^2}{v_1^2 + v_2^2}$

33. The motion of a particle along a straight line is described by equation $x = 8 + 12t - t^3$ where x is in metre and t in second. The retardation of the particle when its velocity becomes zero is **[2012]**
(A) 24 m s^{-2} (B) zero
(C) 6 m s^{-2} (D) 12 m s^{-2}

34. A particle is moving such that its position coordinates (x, y) are (2m, 3m) at time t = 0; (6m, 7m) at time t = 2 s and (13m, 14m) at time t = 5 s. Average velocity vector $\vec{v}_{av}$ from t = 0 to t = 5 s is **[2014]**
(A) $\frac{1}{5}(13\hat{i}+14\hat{j})$ (B) $\frac{7}{j}(\hat{i}+\hat{j})$
(C) $2(\hat{i}+\hat{j})$ (D) $\frac{11}{5}(\hat{i}+\hat{j})$

35. A particle of unit mass undergoes one-dimensional motion such that its velocity varies according to $v(x) = \beta x^{-2n}$, where β and n are constants and x is the position of the particle. The acceleration of the particle as a function of x, is given by **[2015]**
(A) $-2n\beta^2 x^{-2n-1}$ (B) $-2n\beta^2 x^{-4n-1}$
(C) $-2\beta^2 x^{-2n+1}$ (D) $-2n\beta^2 x^{-4n+1}$

36. If the velocity of a particle is $v = At + Bt^2$, where A and B are constants, then the distance travelled by it between 1 s and 2 s is **[Phase-I 2016]**
(A) $\frac{3}{2}A + \frac{7}{3}B$ (B) $\frac{A}{2}+\frac{B}{3}$
(C) $\frac{3}{2}A + 4B$ (D) 3A + 7B

37. Two cars P and Q start from a point at the same time in a straight line and their positions are represented by $x_P(t) = at + bt^2$ and $x_Q(t) = ft - t^2$. At what time do the cars have the same velocity? **[Phase-II 2016]**
(A) $\frac{f-a}{2(1+b)}$ (B) $\frac{a-f}{1+b}$
(C) $\frac{a+f}{2(b-1)}$ (D) $\frac{a+f}{2(1+b)}$

38. Preeti reached the metro station and found that the escalator was not working. She walked up the stationary escalator in time t_1. On other days, if she remains stationary on the moving escalator, then the escalator takes her up in time t_2. The time taken by her to walk up on the moving escalator will be: **[2017]**
(A) $\frac{t_1+t_2}{2}$ (B) $\frac{t_1t_2}{t_2-t_1}$
(C) $\frac{t_1t_2}{t_2+t_1}$ (D) $t_1 - t_2$

39. The x and y co-ordinates of the particle at any time are $x = 5t - 2t^2$ and $y = 10t$ respectively, where x and y are in metres and t in seconds. The acceleration of the particle at t = 2s is: **[2017]**
(A) 0 (B) $5\ m/s^2$
(C) $-4\ m/s^2$ (D) $-8\ m/s^2$

40. A toy car with charge q moves on a frictionless horizontal plane surface under the influence of a uniform electric field $\vec{E}$. Due to the force $q\vec{E}$, its velocity increases from 0 to 6 m/s in one second duration. At that instant the direction of the field is reversed. The car continues to move for two more seconds under the influence of this field. The average velocity and the average speed of the toy car between 0 to 3 seconds are respectively **[2018]**
(A) 2 m/s, 4 m/s (B) 1 m/s, 3 m/s
(C) 1 m/s, 3.5 m/s (D) 1.5 m/s, 3 m/s

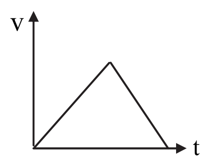
41. The speed of swimmer in still water is 20 m/s. The speed of river water is 10 m/s and is flowing due east. If he is standing on the south bank and wishes to cross the river along the shortest path, the angle at which he should make his strokes w.r.t. north is given by: **[2019]**
(A) 60° west (B) 45° west
(C) 30° west (D) 0°

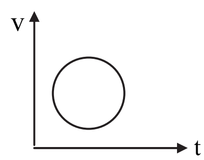
42. A person travelling in a straight line moves with a constant velocity v_1 for certain distance 'x' and with a constant velocity v_2 for next equal distance. The average velocity v is given by the relation **[Odisha 2019]**
(A) $v = \sqrt{v_1 v_2}$ (B) $\frac{1}{v} = \frac{1}{v_1} + \frac{1}{v_2}$
(C) $\frac{2}{v} = \frac{1}{v_1} + \frac{1}{v_2}$ (D) $\frac{v}{2} = \frac{v_1+v_2}{2}$

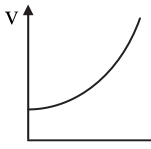
43. A small block slides down on a smooth inclined plane, starting from rest at time t = 0. Let S_n be the distance travelled by the block in the interval t = n − 1 to t = n. Then, the ratio $\frac{S_n}{S_{n+1}}$ is: **[2021]**
(A) $\frac{2n-1}{2n+1}$ (B) $\frac{2n+1}{2n-1}$
(C) $\frac{2n}{2n-1}$ (D) $\frac{2n-1}{2n}$

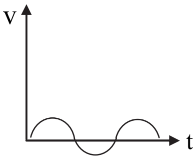
44. A car starts from rest and accelerates at $5\ m/s^2$. At t = 4 s, a ball is dropped out of a window by a person sitting in the car. What is the velocity and acceleration of the ball at t = 6 s? (Take $g = 10\ m/s^2$) **[2021]**
(A) 20 m/s, 0
(B) $20\sqrt{2}$ m/s, 0
(C) $20\sqrt{2}$ m/s, $10\ m/s^2$
(D) 20 m/s, $5\ m/s^2$

2.3 Position - time, velocity - time graphs

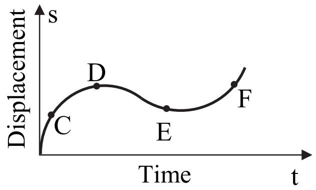
1. Which of the following curve does not represent motion in one dimension? **[1992]**
(A)


(B)


(C)


(D)


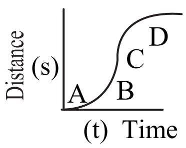
2. The displacement-time graph of moving particle is shown below



The instantaneous velocity of the particle is negative at the point **[1994]**

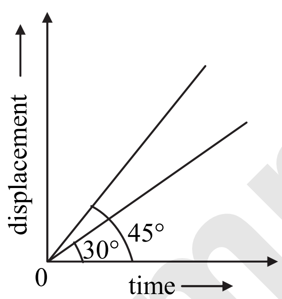
(A) D (B) F (C) C (D) E

3. A particle shows distance- time curve as given in this figure. The maximum instantaneous velocity of the particle is around the point **[2008]**



(A) D (B) A (C) B (D) C

4. The displacement-time graphs of two moving particles make angles of 30° and 45° with the x-axis as shown in the figure. The ratio of their respective velocity is: **[2022]**



(A) 1 : 2 (B) $1 : \sqrt{3}$

(C) $\sqrt{3} : 1$ (D) 1 : 1

2.4 Relative velocity

1. A train of 150 metre length is going towards north direction at a speed of 10 m/s. A parrot flies at the speed of 5 m/s towards south direction parallel to the railway track. The time taken by the parrot to cross the train is **[1998]**

(A) 7 s (B) 8 s (C) 9 s (D) 10 s

2. A bus is moving with a speed of 10 ms^{-1} on a straight road. A scooterist wishes to overtake the bus in 100 s. If the bus is at a distance of 1 km from the scooterist, with what speed should the scooterist chase the bus? **[2009]**

(A) 40 $m\ s^{-1}$ (B) 25 $m\ s^{-1}$

(C) 10 $m\ s^{-1}$ (D) 20 $m\ s^{-1}$

3. A ship A is moving westwards with a speed of 10 km h^{-1} and a ship B 100 km south of A, is moving northwards with a speed of 10 km h^{-1}. The time after which the distance between them becomes shortest, is **[2015]**

(A) 0 h (B) 5 h

(C) $5\sqrt{2}$ h (D) $10\sqrt{2}$ h

4. Two particles A and B, move with constant velocities $\vec{v}_1$ and $\vec{v}_2$. At the initial moment their position vectors are $\vec{r}_1$ and $\vec{r}_2$ respectively. The condition for particle A and B for their collision is **[Re-Test 2015]**

(A) $\vec{r}_1 - \vec{r}_2 = \vec{v}_1 - \vec{v}_2$

(B) $\dfrac{\vec{r}_1 - \vec{r}_2}{|\vec{r}_1 - \vec{r}_2|} = \dfrac{\vec{v}_2 - \vec{v}_1}{|\vec{v}_2 - \vec{v}_1|}$

(C) $\vec{r}_1 \cdot \vec{v}_1 = \vec{r}_2 \cdot \vec{v}_2$

(D) $\vec{r}_1 \times \vec{v}_1 = \vec{r}_2 \times \vec{v}_2$

2.5 Motion under gravity

1. What will be the ratio of the distance moved by a freely falling body from rest in 4th and 5th seconds of journey? **[1989]**

(A) 4 : 5 (B) 7 : 9

(C) 16 : 25 (D) 1 : 1

2. A body dropped from top of a tower falls through 40 m during the last two seconds of its fall. The height of tower is ($g = 10\ m/s^2$) **[1992]**

(A) 60 m (B) 45 m

(C) 80 m (D) 50 m

3. Water drops fall at regular intervals from a tap which is 5 m above the ground. The third drop leaves the tap at the instant the first drop touches the ground. How far above the ground is the second drop at that instant?
[$g = 10\ ms^{-2}$] **[1995]**

(A) 1.25 m (B) 3.75 m

(C) 4.00 m (D) 4.25 m

4. A body dropped from a height h with initial velocity zero, strikes the ground with a velocity 3 m/s. Another body of same mass is dropped from the same height h with an initial velocity of 4 m/s. The final velocity of second mass with which it strikes the ground is **[1996]**

(A) 5 m/s (B) 12 m/s

(C) 3 m/s (D) 4 m/s

5. A particle is thrown vertically upward. Its velocity at half of the height is 10 m/s, then the maximum height attained by it ($g = 10\ m/s^2$) **[2001]**

(A) 8 m (B) 20 m

(C) 10 m (D) 16 m

6. If a ball is thrown vertically upward with speed u, the distance covered during the last t seconds of its ascent is **[2003]**
(A) ut (B) $\frac{1}{2}gt^2$
(C) $ut - \frac{1}{2}gt^2$ (D) (u + gt) t.

7. A man throws balls with the same speed vertically upwards one after the other at an interval of 2 seconds. What should be the speed of the throw so that more than two balls are in the sky at any time?
(Given g = 9.8 m/s^2) **[2003]**
(A) more than 19.6 m/s
(B) at least 9.8 m/s
(C) any speed less than 19.6 m/s
(D) only with speed 19.6 m/s.

8. A ball is thrown vertically upward. It has a speed of 10 m when it has reached one half of its maximum height. How high does the ball rise? (Take g = 10 m/s^2.) **[2005]**
(A) 10 m (B) 5 m
(C) 15 m (D) 20 m.

9. Two bodies A (of mass 1 kg) and B (of mass 3 kg) are dropped from heights of 16 m and 25 m, respectively. The ratio of the time taken by them to reach the ground is **[2006]**
(A) 4/5 (B) 5/4
(C) 12/5 (D) 5/12

10. A ball is dropped from a high rise platform at t = 0 starting from rest. After 6 seconds another ball is thrown downwards from the same platform with a speed v. The two balls meet at t = 18 s. What is the value of v?
(Take g = 10 m/s^2) **[2010]**
(A) 75 m/s (B) 55 m/s
(C) 40 m/s (D) 60 m/s

11. A boy standing at the top of a tower of 20 m height drops a stone. Assuming g = 10 m s^{-2}, the velocity with which it hits the ground is **[2011]**
(A) 10.0 m/s (B) 20.0 m/s
(C) 40.0 m/s (D) 50.0 m/s

12. A stone falls freely under gravity. It covers distances h_1, h_2 and h_3 in the first 5 seconds, the next 5 seconds and the next 5 seconds respectively. The relation between h_1, h_2 and h_3 is **[2013]**
(A) $h_1 = 2h_2 = 3h_3$
(B) $h_1 = \frac{h_2}{3} = \frac{h_3}{5}$
(C) $h_2 = 3h_1$ and $h_3 = 3h_2$
(D) $h_1 = h_2 = h_3$

13. A person standing on the floor of an elevator drops a coin. The coin reaches the floor in time t_1 if the elevator is at rest and in time t_2 if the elevator is moving uniformly. Then **[Odisha 2019]**
(A) $t_1 = t_2$
(B) $t_1 < t_2$ or $t_1 > t_2$ depending upon whether the lift is going up or down
(C) $t_1 < t_2$
(D) $t_1 > t_2$

14. A ball is thrown vertically downward with a velocity of 20 m/s from the top of a tower. It hits the ground after some time with a velocity of 80 m/s. The height of the tower is: (g = 10 m/s^2) **[Phase-I 2020]**
(A) 340 m (B) 320 m
(C) 300 m (D) 360 m

15. A person sitting in the ground floor of building notices through the window, of height 1.5 m, a ball dropped from the roof of the building crosses the window in 0.1 s. What is the velocity of the ball when it is at the topmost point of the window? (g =10 m/s^2) **[Phase-II 2020]**
(A) 20 m/s (B) 15.5 m/s
(C) 14.5 m/s (D) 4.5 m/s

16. The ratio of the distances travelled by a freely falling body in the 1^{st}, 2^{nd}, 3^{rd} and 4^{th} second: **[2022]**
(A) 1 : 3 : 5 : 7 (B) 1 : 1 : 1 : 1
(C) 1 : 2 : 3 : 4 (D) 1 : 4 : 9 : 16

2.6 Motion in a plane

1. A body of mass 5 kg at rest explodes into three fragments with masses in the ratio 1 : 1 : 3. The fragments with equal masses fly in mutually perpendicular directions with speeds of 21 m/s. The velocity of the heaviest fragment in m/s will be **[1989]**
(A) $7\sqrt{2}$ (B) $5\sqrt{2}$ (C) $3\sqrt{2}$ (D) $\sqrt{2}$

2. A particle starting from the origin (0, 0) moves in a straight line in the (x, y) plane. Its coordinates at a later time are $(\sqrt{3}, 3)$. The path that the particle makes with the x-axis is at an angle of **[2007]**
(A) 45° (B) 60° (C) 0° (D) 30°

3. A particle moves in x – y plane according to rule x = asin ωt and y = acos ωt. The particle follows: **[2010]**
(A) an elliptical path
(B) a circular path
(C) a parabolic path
(D) a straight line path inclined equally to x – axes and y – axes

2.7 Projectile motion

1. The maximum range of a gun of horizontal terrain is 16 km. If $g = 10\ ms^{-2}$, then muzzle velocity of a shell must be **[1990]**
(A) $160\ ms^{-1}$ (B) $200\sqrt{2}\ ms^{-1}$
(C) $400\ ms^{-1}$ (D) $800\ ms^{-1}$

2. If a body A of mass M is thrown with velocity v at an angle of 30° to the horizontal and another body B of the same mass is thrown with the same speed at an angle of 60° to the horizontal, the ratio of horizontal range of A to B will be **[1992, 1990]**
(A) 1 : 3 (B) 1 : 1
(C) $1 : \sqrt{3}$ (D) $\sqrt{3} : 1$

3. Two projectiles of same mass and with same velocity are thrown at an angle 60° and 30° with the horizontal, then which will remain same? **[2000]**
(A) time of flight
(B) range of projectile
(C) maximum height acquired
(D) all of them.

4. A particle A is dropped from a height and another particle B is projected in horizontal direction with speed of 5 m/s from the same height then correct statement is **[2002]**
(A) particle A will reach ground first with respect to particle B.
(B) particle B will reach ground first with respect to particle A.
(C) both particles will reach ground simultaneously.
(D) both particles will reach ground with same speed.

5. For angles of projection of a projectile at angle (45° – θ) and (45° + θ), the horizontal range described by the projectile are in the ratio of **[2006]**
(A) 2 : 1 (B) 1 : 1
(C) 2 : 3 (D) 1 :2

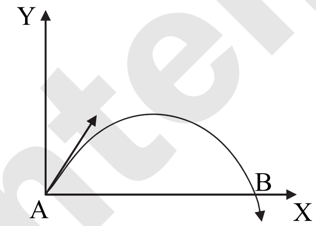
6. The speed of a projectile at its maximum height is half of its initial speed. The angle of projection is **[2010]**
(A) 60° (B) 15°
(C) 30° (D) 45°

7. A projectile is fired at an angle of 45° with the horizontal. Elevation angle of the projectile at its highest point as seen from the point of projection, is **[2011]**
(A) 45° (B) 60°
(C) $\tan^{-1}\left(\frac{1}{2}\right)$ (D) $\tan^{-1}\left(\frac{\sqrt{3}}{2}\right)$

8. A missile is fired for maximum range with an initial velocity of 20 m/s. If $g = 10\ m/s^2$, the range of the missile is **[2011]**
(A) 40 m (B) 50 m
(C) 60 m (D) 20 m

9. The horizontal range and the maximum height of a projectile are equal. The angle of projection of the projectile is **[2012]**
(A) $\theta = \tan^{-1}\left(\frac{1}{4}\right)$ (B) $\theta = \tan^{-1}(4)$
(C) $\theta = \tan^{-1}(2)$ (D) $\theta = 45°$

10. The velocity of a projectile at the initial point A is $(2\hat{i} + 3\hat{j})$ m/s. Its velocity (in m/s) at point B is **[2013]**



(A) $-2\hat{i} - 3\hat{j}$ (B) $-2\hat{i} + 3\hat{j}$
(C) $2\hat{i} - 3\hat{j}$ (D) $2\hat{i} + 3\hat{j}$

11. A projectile is fired from the surface of the earth with a velocity of $5\ m\ s^{-1}$ and angle θ with the horizontal. Another projectile fired from another planet with a velocity of $3\ m\ s^{-1}$ at the same angle follows a trajectory which is identical with the trajectory of the projectile fired from the earth. The value of the acceleration due to gravity on the planet is (in $m\ s^{-2}$) (given $g = 9.8\ m\ s^{-2}$) **[2014]**
(A) 3.5 (B) 5.9
(C) 16.3 (D) 110.8

12. When an object is shot from the bottom of a long smooth inclined plane kept at an angle 60° with horizontal, it can travel a distance x_1 along the plane. But when the inclination is decreased to 30° and the same object is shot with the same velocity, it can travel x_2 distance. Then $x_1 : x_2$ will be : **[2019]**
(A) $1 : \sqrt{3}$ (B) $1 : 2\sqrt{3}$
(C) $1 : \sqrt{2}$ (D) $\sqrt{2} : 1$

13. Two bullets are fired horizontally and simultaneously towards each other from roof tops of two buildings 100 m apart and of same height of 200 m, with the same velocity of 25 m/s. When and where will the two bullets collide? ($g = 10\ m/s^2$) **[Odisha 2019]**
(A) They will not collide
(B) After 2 s at a height of 180 m
(C) After 2 s at a height of 20 m
(D) After 4 s at a height of 120 m

14. A particle moving in a circle of radius R with a uniform speed takes a time T to complete one revolution. If this particle were projected with the same speed at an angle 'θ' to the horizontal, the maximum height attained by it equals 4R. The angle of projection, θ, is then given by: **[2021]**

(A) $\theta = \cos^{-1}\left(\dfrac{\pi^2 R}{gT^2}\right)^{1/2}$

(B) $\theta = \sin^{-1}\left(\dfrac{\pi^2 R}{gT^2}\right)^{1/2}$

(C) $\theta = \sin^{-1}\left(\dfrac{2gT^2}{\pi^2 R}\right)^{1/2}$

(D) $\theta = \cos^{-1}\left(\dfrac{gT^2}{\pi^2 R}\right)^{1/2}$

15. A ball is projected with a velocity, 10 ms^{-1}, at an angle of 60° with the vertical direction. Its speed at the highest point of its trajectory will be: **[2022]**

(A) 5 ms^{-1} (B) 10 ms^{-1}

(C) Zero (D) $5\sqrt{3}\ ms^{-1}$

Answers to MCQ's

2.1 :	1.	(A)	2.	(C)	3.	(A)	4.	(B)	5.	(B)	6.	(B)	7.	(B)	8.	(C)	9.	(A)	10.	(A)
	11.	(D)	12.	(B)	13.	(B)	14.	(D)	15.	(B)	16.	(C)	17.	(B)	18.	(D)	19.	(D)	20.	(A)
	21.	(D)																		
2.2 :	1.	(C)	2.	(A)	3	(B)	4.	(C)	5.	(B)	6.	(B)	7.	(B)	8.	(C)	9.	(A)	10.	(D)
	11.	(C)	12.	(C)	13.	(D)	14.	(A)	15.	(A)	16.	(A)	17.	(A)	18.	(B)	19.	(B)	20.	(D)
	21.	(D)	22.	(C)	23.	(A)	24.	(D)	25.	(A)	26.	(C)	27.	(A)	28.	(B)	29.	(B)	30.	(A)
	31.	(D)	32.	(C)	33.	(D)	34.	(D)	35.	(B)	36.	(A)	37.	(A)	38.	(C)	39.	(C)	40.	(B)
	41.	(C)	42.	(C)	43.	(A)	44.	(C)												
2.3 :	1.	(B)	2.	(D)	3.	(D)	4.	(B)												
2.4 :	1.	(D)	2.	(D)	3.	(B)	4.	(B)												
2.5 :	1.	(B)	2.	(B)	3.	(B)	4.	(A)	5.	(C)	6.	(B)	7.	(A)	8.	(A)	9.	(A)	10.	(A)
	11.	(B)	12.	(B)	13.	(A)	14.	(C)	15.	(C)	16.	(A)								
2.6 :	1.	(A)	2.	(B)	3.	(B)														
2.7 :	1.	(C)	2.	(B)	3.	(B)	4.	(C)	5.	(B)	6.	(A)	7.	(C)	8.	(A)	9.	(B)	10.	(C)
	11.	(A)	12.	(A)	13.	(B)	14.	(C)	15.	(D)										

Hints to MCQ's

2.1 Scalars and vectors

1. $\vec{A} + \vec{B} = \vec{C}$,

$\therefore$ $(\vec{A} + \vec{B})\cdot(\vec{A} + \vec{B}) = \vec{C}\cdot\vec{C}$

$\vec{A}\,.\,\vec{A} + \vec{A}.\,\vec{B} + \vec{B}.\,\vec{A} + \vec{B}\,.\,\vec{B} = \vec{C}\,.\,\vec{C}$

$A^2 + 2AB\cos\theta + B^2 = C^2$

$9 + 2AB\cos\theta + 16 = 25$

$\therefore$ $2AB\cos\theta = 0$

$\therefore$ $\cos\theta = 0$

$\therefore$ $\theta = 90°$

2. The cross product of two vectors is the zero vector if either one or both the inputs is a zero vector.

In case 0 is a scalar, the product is zero and (scalar × vector) is also a vector.

3. $\cos\theta = \dfrac{\vec{A}\cdot\vec{B}}{|\vec{A}||\vec{B}|}$

$= \dfrac{(3\hat{i} + 4\hat{j} + 5\hat{k})\cdot(3\hat{i} + 4\hat{j} - 5\hat{k})}{\left[\sqrt{(3)^2+(4)^2+(5)^2}\right]\times\left[\sqrt{(3)^2+(4)^2+(5)^2}\right]}$

$= \dfrac{9 + 16 - 25}{50}$

$\therefore$ $\cos\theta = 0$

$\therefore$ $\theta = \cos^{-1}(0)$

$\therefore$ $\theta = 90°$

4. $\vec{r} = (a\cos\omega t)\,\hat{i} + (a\sin\omega t)\,\hat{j}$

$\therefore$ $\vec{v} = \dfrac{d\vec{r}}{dt} = -a\omega\sin\omega t\,\hat{i} + a\omega\cos\omega t\,\hat{j}$

As $\vec{r}\cdot\vec{v} = 0$, therefore velocity of the particle is perpendicular to the position vector.

5. Angular momentum has both magnitude and direction, therefore is a vector quantity

6. $\vec{v} = \vec{\omega} \times \vec{r} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 5 & -6 & 6 \\ 3 & -4 & 1 \end{vmatrix}$

$= (-24 + 6)\hat{i} - (18 - 5)\,\hat{j} + (-18 + 20)\,\hat{k}$

$= 18\hat{i} + 13\,\hat{j} - 2\hat{k}$

7. Magnitude of vector = 1

$\sqrt{a_x^2 + a_y^2 + a_z^2} = 1$

$\therefore$ $\sqrt{0.5^2 + 0.8^2 + c^2} = 1$

$\sqrt{c^2 + 0.89} = 1$

$\therefore$ $c^2 = 0.11$

$\therefore$ $c = \sqrt{0.11}$

8. $|\vec{A} + \vec{B}| = |\vec{A}| + |\vec{B}|$ when $(\vec{A} \| \vec{B})$.

$\therefore$ $\theta = 0°$.

9. Let the two forces be $\vec{F}_1$ and $\vec{F}_2$

$\therefore$ according to given condition we have,

$(\vec{F}_1 + \vec{F}_2) \cdot (\vec{F}_1 - \vec{F}_2) = 0$

….(orthogonality condition)

$\therefore$ $(\vec{F}_1 \cdot \vec{F}_1) - (\vec{F}_1 \cdot \vec{F}_2) + (\vec{F}_2 \cdot \vec{F}_1) - (\vec{F}_2 \cdot \vec{F}_2) = 0$

$\therefore$ $(\vec{F}_1 \cdot \vec{F}_1) - (\vec{F}_2 \cdot \vec{F}_2) = 0$

$\therefore$ $\vec{F}_1 \cdot \vec{F}_1 = \vec{F}_2 \cdot \vec{F}_2$

$\therefore$ $F_1^2 \cos\theta = F_2^2 \cos\theta$

$\therefore$ $F_1^2 = F_2^2$

$\therefore$ $F_1 = F_2$

10. $|\vec{A} \times \vec{B}| = \sqrt{3}\,\vec{A} \cdot \vec{B}$

$\therefore$ $|\vec{A}||\vec{B}| \sin\theta = \sqrt{3}\,|\vec{A}||\vec{B}| \cos\theta$

$\therefore$ $\tan\theta = \sqrt{3}$

$\therefore$ $\theta = 60°$

Now $|\vec{A} + \vec{B}| = \sqrt{|\vec{A}|^2 + |\vec{B}|^2 + 2|\vec{A}||\vec{B}|\cos\theta}$

$= (A^2 + B^2 + AB)^{1/2}$

11. Let $(\vec{B} \times \vec{A})\,.\,\vec{A} = \vec{C} \cdot \vec{A}$

$\vec{C} = \vec{B} \times \vec{A}$ which is perpendicular to both vectors $\vec{A}$ and $\vec{B}$

$\therefore$ $\vec{C} \cdot \vec{A} = 0$.

12. Since, $\vec{a} \perp \vec{b} \Rightarrow \vec{a} \cdot \vec{b} = 0$

$\therefore$ $(2\hat{i} + 3\hat{j} + 8\hat{k}) \cdot (4\hat{j} - 4\hat{i} + \alpha\hat{k}) = 0$

$\therefore$ $-8 + 12 + 8\alpha = 0$

$\therefore$ $4 + 8\alpha = 0$

$\therefore$ $\alpha = -1/2$.

13. $|\vec{A} + \vec{B}| = |\vec{A} - \vec{B}|$

$\therefore$ $|\vec{A} + \vec{B}|^2 = |\vec{A} - \vec{B}|^2$

$\therefore$ $(\vec{A} + \vec{B}) \cdot (\vec{A} + \vec{B}) = (\vec{A} - \vec{B}) \cdot (\vec{A} - \vec{B})$

$\therefore$ $\vec{A} \cdot \vec{A} + \vec{A} \cdot \vec{B} + \vec{B} \cdot \vec{A} + \vec{B} \cdot \vec{B}$

$= \vec{A} \cdot \vec{A} - \vec{A} \cdot \vec{B} - \vec{B} \cdot \vec{A} + \vec{B} \cdot \vec{B}$

$\therefore$ $4AB\cos\theta = 0$

$\therefore$ $\cos\theta = 0°$

$\therefore$ $\theta = 90°$

14. $|\vec{A} \times \vec{B}| = \sqrt{3}(\vec{A} \cdot \vec{B})$

$\therefore$ $AB \sin\theta = \sqrt{3}\,AB\cos\theta$

$\therefore$ $\tan\theta = \sqrt{3}$

$\therefore$ $\theta = \tan^{-1}\sqrt{3} = 60°$

15. $\vec{u} = (3\hat{i} + 4\hat{j})$, $\vec{a} = 0.4\hat{i} + 0.3\hat{j}$, $t = 10$ s

$\vec{v} = \vec{u} + \vec{a}t$

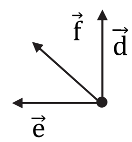
$\therefore$ $\vec{v} = (3\hat{i} + 4\hat{j}) + (0.4\hat{i} + 0.3\hat{j})(10)$

$= 3\hat{i} + 4\hat{j} + 4\hat{i} + 3\hat{j} = 7\hat{i} + 7\hat{j}$

Speed of the particle after 10 s

$= |\vec{v}| = \sqrt{(7)^2 + (7)^2} = 7\sqrt{2}$ units

16. Two non – zero vectors $(\vec{d}$ and $\vec{e})$ are represented by two adjacent sides of a parallelogram, then the resultant $(\vec{f})$ is the diagonal of the parallelogram passing through the point of intersection of two vectors.



17. Here, $\vec{u} = 2\hat{i} + 3\hat{j}$, $\vec{a} = 0.3\hat{i} + 0.2\hat{j}$, $t = 10$s

$\vec{v} = \vec{u} + \vec{a}t$

$\therefore$ $\vec{v} = (2\hat{i} + 3\hat{j}) + (0.3\hat{i} + 0.2\hat{j}) \times 10$

$= 2\hat{i} + 3\hat{j} + 3\hat{i} + 2\hat{j} = 5\hat{i} + 5\hat{j}$

$|\vec{v}| = \sqrt{(5)^2 + (5)^2} = 5\sqrt{2}$ units

18. $\vec{R} = 4\sin(2\pi t)\,\hat{i} + 4\cos 2\pi t\,\hat{j}$

$\vec{v} = \frac{d\vec{R}}{dt} = 8\pi\cos 2\pi t\hat{i} - 8\pi\sin 2\pi t\hat{j}$

$|\vec{v}| = \sqrt{v_x^2 + v_y^2}$

$= \sqrt{(8\pi\cos 2\pi t)^2 + (-8\pi\sin 2\pi t)^2}$

$= 8\pi$ m/s

19. Vectors are orthogonal

i.e. $\vec{A} \cdot \vec{B} = 0$

$\therefore$ $\cos\omega t \cos\left(\frac{\omega t}{2}\right) + \sin\omega t \sin\left(\frac{\omega t}{2}\right) = 0$

$\therefore$ $\cos\left[\omega t - \frac{\omega t}{2}\right] = 0$

$\therefore$ $\cos\left(\frac{\omega t}{2}\right) = 0$

$\therefore$ $\frac{\omega t}{2} = \frac{\pi}{2}$

$\therefore$ $t = \frac{\pi}{\omega}$

20. $\vec{r} = \cos\omega t\,\hat{x} + \sin\omega t\hat{y}$

$\therefore$ $\vec{v} = \frac{d\vec{r}}{dt} = -\omega\sin\omega t\hat{x} + \omega\cos\omega t\hat{y}$

$\therefore$ $\vec{a} = \frac{d\vec{v}}{dt} = -\omega^2\cos\omega t\hat{x} + \omega^2\sin\omega t\hat{y} = -\omega^2\,\vec{r}$

Now, the position vector $(\vec{r})$ is directed away from the origin,

$\therefore$ acceleration is directed towards the origin.

$\vec{r}\cdot\vec{v} = (\cos\omega t\hat{x}+\sin\omega t\hat{y}).(-\omega\sin\omega t\hat{x}+\omega\cos\omega t\hat{y})$

$= -\omega\sin\omega t\cos\omega t + \omega\sin\omega t\cos\omega t = 0$

$\therefore$ $\vec{r} \perp \vec{v}$

21. As $|\vec{A}+\vec{B}| = |\vec{A}-\vec{B}|$,

$\therefore$ $A^2 + B^2 + 2AB\cos\theta = A^2 + B^2 - 2AB\cos\theta$

$\therefore$ $4AB\cos\theta = 0$, i.e. $\cos\theta = 0 = \cos 90°$

$\therefore$ $\theta = 90°$

2.2 Speed, velocity and acceleration

1. $v_p = 30$ km/h

$V_q = 40$ km/h

Let 's' be the distance between 'P' and 'Q'

From, third equation of motion, we get,

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

$(40)^2 - (30)^2 = 2as$

$\therefore$ $2as = 700$

$\therefore$ $as = 350$ ....(i)

Let velocity at midpoint of PQ be 'v_{mid}'

$\therefore$ $v_{mid}{}^2 = v_p^2 + 2a(s/2)$

$\therefore$ $v_{mid}{}^2 = 900 + 350 = 1250$

$\therefore$ $v_{mid} = 25\sqrt{2}$ km/h.

2. $v_1 = 50$ km/hr due north

$v_2 = 50$ km/hr due west

$-v_1 = 50$ km/hr due south

Magnitude of change in velocity

$= |\vec{v}_2 - \vec{v}_1| = |\vec{v}_2 + (-\vec{v}_1)|$

$= \sqrt{v_2^2 + (-v_1)^2} = \sqrt{(50)^2 + (50)^2}$

$= 70.7$ km/hr

Direction of resultant velocity,

$\theta = \tan^{-1}\left(\frac{-50}{-50}\right)$

$= \tan^{-1}(1)$

$\therefore$ $\theta = 45°$

$\therefore$ Car will move in south-west direction.

3 Total distance covered be s

Total time taken $= \frac{s/2}{40} + \frac{s/3}{60} = \frac{5s}{240} = \frac{s}{48}$

Average speed $= \frac{\text{total distance covered}}{\text{total time taken}}$

$= \frac{s}{\left(\frac{s}{48}\right)} = 48$ km/h.

4. Total distance covered be s

Total time taken $= \frac{s/3}{10} + \frac{s/3}{20} + \frac{s/3}{60}$

$= \frac{s}{30} + \frac{s}{60} + \frac{s}{180} = \frac{s}{18}$

Average speed $= \frac{\text{Total distance travelled}}{\text{total time taken}}$

$= \frac{s}{s/18} = 18$ km/hr.

5. Total distance travelled = 200 m

Total time taken $= \frac{100}{40} + \frac{100}{v}$

Average speed $= \frac{\text{Total distance travelled}}{\text{total time taken}}$

$\therefore$ $48 = \frac{200}{\left(\frac{100}{40} + \frac{100}{v}\right)}$

$\therefore$ $48 = \frac{2}{\left(\frac{1}{40} + \frac{1}{v}\right)}$

$\therefore$ $\frac{1}{40} + \frac{1}{v} = \frac{1}{24}$

$\therefore$ $\frac{1}{v} = \frac{1}{24} - \frac{1}{40} = \frac{1}{60}$

$\therefore$ $v = 60$ km/hr

6. $S_n = u + \frac{a}{2}(2n - 1)$

As $u = 0$,

Now, $s_4 = \frac{a}{2}(2 \times 4 - 1) = \frac{7a}{2}$

$s_3 = \frac{a}{2}(2 \times 3 - 1) = \frac{5a}{2}$

$\therefore$ $\frac{S_4}{S_3} = \frac{7}{5}$

7. Resultant velocity $= \sqrt{v_B^2 + v_R^2 + 2v_Bv_R\cos\theta}$

$(10) = \sqrt{v_B^2 + v_R^2 + 2v_Bv_R\cos 90°}$

$(10) = \sqrt{(8)^2 + v_R^2}$

$\therefore$ $(10)^2 = (8)^2 + v_R^2$

$v_R^2 = 100 - 64$

$\therefore$ $v_R = 6$ km/hr

8. $F = \frac{dp}{dt} = v\left(\frac{dM}{dt}\right) = \alpha v^2$

$\therefore$ $a = \frac{F}{M} = \frac{\alpha v^2}{M}$

9. $v = u + at$

$u = 20$ km/h; $v = 60$ km/h, $t = 4$ hours.

$\therefore$ $60 = 20 + a(4)$

$\therefore$ $a = \frac{60-20}{4} = 10$ km/h^2.

distance travelled in 4 hours,

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

$= (20 \times 4) + \frac{1}{2} \times 10 \times (4)^2 = 160$ km.

10. Let the car accelerate at rate α for time t_1. Then maximum velocity attained,

$v = 0 + \alpha t_1 = \alpha t_1$

Now, the car decelerates at a rate β for time $(t - t_1)$ and finally comes to rest. Then,

$0 = v - \beta(t - t_1)$

$\therefore$ $0 = \alpha t_1 - \beta t + \beta t_1$

$\therefore$ $t_1 = \frac{\beta}{\alpha+\beta}t$

Multiplying by α on both sides, we get,

$\therefore$ $v = \frac{\alpha\beta}{\alpha+\beta}t$

11. $s = t^3 - 6t^2 + 3t + 4$ metres

$v = \frac{ds}{dt} = 3t^2 - 12t + 3$

$\therefore$ $a = \frac{dv}{dt} = 6t - 12.$

When a = 0, we get t = 2 seconds

$\therefore$ $v = 3 \times (2)^2 - (12 \times 2) + 3 = -9$ m/s.

12. Acceleration $\frac{d^2x}{dt^2} = bt$

Integrating, $\frac{dx}{dt} = \frac{bt^2}{2} + C$

Initially, $t = 0$, $dx/dt = v_0$

Therefore, $\frac{dx}{dt} = \frac{bt^2}{2} + v_0$

Integrating again, $x = \frac{bt^3}{6} + v_0 t + C$

When the particle starts from origin,

$t = 0$, $x = 0$

$\therefore$ $C = 0$.

i.e., distance travelled by the particle in time t

$= v_0 t + \frac{bt^3}{6}$

13. Using $v = u + at$

$u = 0$, $v = 144$ km/h $= \frac{5}{18} \times 144 = 40$ m/s,

$t = 20$ s

$\therefore$ $a = v/t = 2$ m/s^2

Now, $s = ut + \frac{1}{2} at^2 = \frac{1}{2} \times 2 \times (20)^2 = 400$ m.

14. $x = at^2 - bt^3$

$\therefore$ $v = \frac{dx}{dt} = \frac{d}{dt}(at^2 - bt^3) = 2at - 3bt^2$

$\therefore$ $a = \frac{dv}{dt} = \frac{d}{dt}(at^2 - 3bt^3) = 2a - 6bt = 0$

$\therefore$ $t = \frac{2a}{6b} = \frac{a}{3b}$

15. $S \propto u^2 \Rightarrow \frac{S_1}{S_2} = \left(\frac{u_1}{u_2}\right)^2$

$\therefore$ $\frac{2}{S_2} = \frac{1}{4} \Rightarrow S_2 = 8$ m

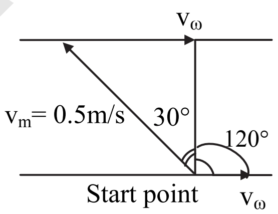
16. $\sin 30 = \frac{v_\omega}{v_m}$

$\therefore$ $\sin 30° = \frac{v_\omega}{0.5}$

$\therefore$ $v_\omega = 0.5 \sin 30°$

$= 0.5 \times (1/2)$

$= 0.25$ m/s.



17. distance = 1 km, time $= \frac{15}{60} = \frac{1}{4}$ hr

velocity along shortest path,

$v = \frac{1\text{km}}{1/4\text{hr}} = 4$ km/hr

$\therefore$ velocity of river stream,

$v_{\text{River stream}} = \sqrt{5^2 - 4^2} = 3$ km/hr

18. $s = 3t^3 + 7t^2 + 14t + 8$

$\therefore$ $\frac{ds}{dt} = 9t^2 + 14t + 14$

$\therefore$ $a = \frac{d^2s}{dt^2} = 18\,t + 14$

At t = 1s,

$a_{t=1} = 18 \times (1) + 14 = 32$ m/s^2

19. $\vec{F} = ma$

$\therefore$ $a = F/m = \frac{6t^2\hat{i} + 4t\hat{j}}{3} = 2t^2\,\hat{i} + \frac{4}{3}\,t\,\hat{j}$

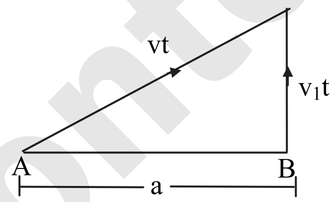
$\therefore$ $a = \frac{dv}{dt} = 2t^2\,\hat{i} + \frac{4}{3}\,t\,\hat{j}$

$\therefore$ $dv = \left(2t^2\,\hat{i} + \frac{4}{3}t\,\hat{j}\right) dt$

$\therefore$ $v = \int_0^3 \left(2t^2\,\hat{i} + \frac{4}{3}t\,\hat{j}\right) dt$

$= \frac{2}{3}t^3\hat{i} + \frac{4}{6}t^2\hat{j}\Big|_0^3 = 18\hat{i} + 6\hat{j}$

20.



From figure we have,

$(vt)^2 = a^2 + (v_1t)^2$

$\therefore$ $t^2(v^2 - v_1^2) = a^2$

$\therefore$ $t = \frac{a}{\sqrt{v^2 - v_1^2}}$

21. $x = ae^{-\alpha t} + be^{\beta t}$

$\therefore$ Velocity, $v = \frac{dx}{dt} = \frac{d}{dt}(ae^{-\alpha t} + be^{\beta t})$

$= a.e^{-\alpha t}(-\alpha) + be^{\beta t}.\,\beta$

$= -a\alpha e^{-\alpha t} + b\beta e^{\beta t}$

Acceleration $= \frac{dv}{dt}$

Acceleration $= -a\alpha e^{-\alpha t}(-\alpha) + b\,\beta e^{\beta t}\cdot\beta$

$= a\alpha^2 e^{-\alpha t} + b\beta^2 e^{\beta t}$

Acceleration is positive so velocity goes on increasing with time.

22. Distance travelled in one rotation = $2\pi r$

$\therefore$ Average speed $= \frac{\text{distance}}{\text{time}} = \frac{2\pi r}{t}$

$= \frac{2 \times 3.14 \times 100}{62.8} = 10$ m /s

Net displacement in one rotation = 0

Average velocity $= \frac{\text{net displacement}}{\text{time}} = \frac{0}{t} = 0$

23. $x = 40 + 12t - t^3$

$\therefore$ $v = \frac{dx}{dt} = 12 - 3t^2$

When particle come to rest, $dx/dt = v = 0$

$\therefore$ $12 - 3t^2 = 0$

$\therefore$ $3t^2 = 12$

$\therefore$ $t = 2$s

The initial position of the particle at t = 0 is
$x_0 = 40 + 0 + 0$
$\therefore$ $x_0 = 40$ m
The position of the particle at the end of 2s is
$x_2 = 40 + (12 \times 2) - 8$
$\therefore$ $x_2 = 56$
The actual distance travelled by the particle,
$x_2 - x_0 = 56 - 40 = 16$ m

24. Time t_1 taken by car to move from X to Y = s/v_u.
Time t_2 taken by car to move from Y to X = s/v_d.
Average speed = $\dfrac{\text{Total distance travelled}}{\text{Total time taken}}$
$= \dfrac{s+s}{t_1+t_2} = \dfrac{2s}{\frac{s}{v_u}+\frac{s}{v_d}} = \dfrac{2v_u v_d}{v_d + v_u}$

25. $x = 9t^2 - t^3$
$v = \dfrac{dx}{dt} = \dfrac{d}{dt}(9t^2 - t^3) = 18t - 3t^2.$
For maximum speed, $\dfrac{dv}{dt} = 0$
$\therefore$ $18 - 6t = 0$
$\therefore$ $t = 3$ s.
$\therefore$ $x_{max} = 9(3)^2 - (3)^3 = 81 \text{ m} - 27 \text{ m} = 54$ m.

26. $f = f_0\left(1 - \dfrac{t}{T}\right)$ and $f = \dfrac{dv}{dt}$
At f = 0, $0 = f_0\left(1 - \dfrac{t}{T}\right)$
Since f_0 is a constant,
$\therefore$ $1 - \dfrac{t}{T} = 0$
$\therefore$ $t = T$
Now, $\int_0^{v_x} dv = \int_{t=0}^{t=T} f dt = \int_0^T f_0\left(1 - \frac{t}{T}\right) dt$
$\therefore$ $v_x = \left[f_0 t - \dfrac{f_0 t^2}{2T}\right]_0^T = f_0 t - \dfrac{f_0 t^2}{2T} = \dfrac{1}{2} f_0 T$

27. $s_n = u + \dfrac{a}{2}(2n - 1) \Rightarrow s_3 = 0 + \dfrac{4/3}{2}(2 \times 3 - 1)$
$\therefore$ $s_3 = \dfrac{10}{3}$ m

28. $v^2 - u^2 = 2as$
Given $v = 20 \text{ ms}^{-1}$, $u = 10 \text{ ms}^{-1}$, s = 135 m
$\therefore$ $a = \dfrac{400 - 100}{2 \times 135} = \dfrac{300}{270} = \dfrac{10}{9} \text{ m/s}^2$
$v = u + at \Rightarrow t = \dfrac{v - u}{a} = \dfrac{10 \text{ m/s}}{\frac{10}{9} \text{ m/s}^2} = 9$ s

29. $s = ut + \dfrac{1}{2}at^2$ ….(Given u = 0)
Distance travelled in 10 s, $S_1 = \dfrac{1}{2} a \cdot 10^2 = 50a$
Distance travelled in 20 s, $S_2 = \dfrac{1}{2} a \cdot 20^2 = 200a$
$\therefore$ $\dfrac{s_2}{s_1} = \dfrac{200a}{50a}$
$\therefore$ $S_2 = 4S_1$.

30. $x = (t + 5)^{-1}$ ....(i)
$v = \dfrac{dx}{dt} = \dfrac{d}{dt}(t + 5)^{-1} = -(t + 5)^{-2}$ ....(ii)
$a = \dfrac{dv}{dt} = \dfrac{d}{dt}[-(t + 5)^{-2}] = 2(t + 5)^{-3}$ ....(iii)
From equation (ii), we get
$v^{3/2} = -(t + 5)^{-3}$ ....(iv)
Substituting this in equation (iii) we get
$a = -2v^{3/2} \Rightarrow a \propto (\text{Velocity})^{3/2}$
From equation (i), we get $x^3 = (t + 5)^{-3}$
Substituting this in equation (iii), we get
$a = 2x^3 \Rightarrow a \propto (\text{distance})^3$
Hence option (a) is correct.

31. $\vec{v}_1 = 30\hat{i}$ m/s, $\vec{v}_2 = 40\hat{j}$ m/s
Change in velocity,
$\Delta\vec{v} = \vec{v}_2 - \vec{v}_1 = \left(40\hat{j} - 30\hat{i}\right)$
$\therefore$ $|\Delta\vec{v}| = |40\hat{j} - 30\hat{i}| = 50$ m/s
Average acceleration,
$|\vec{a}_{av}| = \dfrac{|\Delta\vec{v}|}{\Delta t} = \dfrac{50 \text{ m/s}}{10 \text{ s}} = 5 \text{m/s}^2$

32. Let s be the total distance travelled by the particle.
Let t_1 be the time taken by the particle to cover first half of the distance.
$\therefore$ $t_1 = \dfrac{s/2}{v_1} = \dfrac{s}{2v_1}$
Let t_2 be the time taken by the particle to cover remaining half of the distance.
$\therefore$ $t_2 = \dfrac{s/2}{v_2} = \dfrac{s}{2v_2}$
Average speed, $v_{av} = \dfrac{\text{Total distance travelled}}{\text{Total time taken}}$
$= \dfrac{s}{t_1 + t_2} = \dfrac{s}{\frac{s}{2v_1} + \frac{s}{2v_2}} = \dfrac{2v_1 v_2}{v_1 + v_2}$

33. $x = 8 + 12t - t^3$
$v = \dfrac{dx}{dt} = 12 - 3t^2$
The final velocity of the particle is zero, because of retardation.
When v = 0, $12 - 3t^2 = 0$ $\therefore$ t = 2 s
Now, $a = \dfrac{dv}{dt} = 0 - 6t$
$\therefore$ $a|_{t = 2s} = -12 \text{ m s}^{-2}$

34. $\vec{v}_{av} = \dfrac{(x_2 - x_1)\hat{i} + (y_2 - y_1)\hat{j}}{t_2 - t_1}$
$= \dfrac{(13 - 2)\hat{i} + (14 - 3)\hat{j}}{5 - 0}$
$= \dfrac{11\hat{i} + 11\hat{j}}{5} = \dfrac{11}{5}(\hat{i} + \hat{j})$

35. $v(x) = \beta x^{-2n}$

$a = \frac{dv}{dt} = \frac{dv}{dx}\frac{dx}{dt}$

$\therefore$ $a = v\frac{dv}{dx}$

$a = \beta x^{-2n}\frac{d}{dx}\left(\beta x^{-2n}\right)$

$a = \beta^2 x^{-2n}\left(\frac{d}{dx}x^{-2n}\right)$

$= \beta^2 x^{-2n}(-2n)x^{-2n-1}$

$= -2n\beta^2 x^{-2n-1-2n}$

$\therefore$ $a = -2n\beta^2\, x^{-4n-1}$

36. Given,

$v = At + Bt^2$

$\therefore$ $\frac{dx}{dt} = At + Bt^2$

$\therefore$ $x = \int_1^2 [At + Bt^2]dt$

$\therefore$ $x = \left[\frac{At^2}{2} + \frac{Bt^3}{3}\right]_1^2$

$\therefore$ $x = \frac{A}{2}(4 - 1) + \frac{B}{3}(8 - 1)$

$\therefore$ $x = \frac{3}{2}A + \frac{7}{3}B$

37. Velocity $v = \frac{dx}{dt}$

$\therefore$ $v_P = \frac{dx_P}{dt} = a + 2bt$

$v_Q = \frac{dx_Q}{dt} = f - 2t$

as $v_P = v_Q$ ....(given)

$a + 2bt = f - 2t$

$\therefore$ $(2 + 2b)t = f - a$

$\therefore$ $t = \frac{f - a}{2(1 + b)}$

38. Let velocity of Preeti be v_1, velocity of escalator be v_2 and distance travelled be l.

$\therefore$ Speed $= \frac{\text{distance}}{\text{time}}$

time $= \frac{\text{distance}}{\text{speed}}$

$t = \frac{l}{v_1 + v_2}$

$t = \frac{l}{\frac{l}{t_1} + \frac{l}{t_2}} = \frac{t_1 t_2}{t_2 + t_1}$

39.

$x = 5t - 2t^2$	$y = 10t$
$\frac{dx}{dt} = 5 - 4t$	$\frac{dy}{dt} = 10$
$v_x = 5 - 4t$	$v_y = 10$
$\frac{dv_x}{dt} = -4$	$\frac{dv_y}{dt} = 0$
$a_x = -4\ m/s^2$	$a_y = 0\ m/s^2$

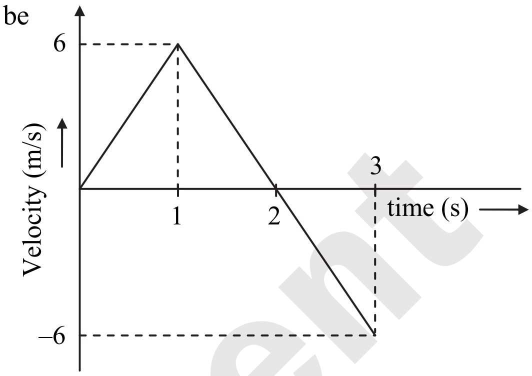
Acceleration of particle is given by

$a = a_x + a_y$

$= -4 + 0$

$a = -4\ m/s^2$ in x direction

40. Car at rest attains velocity of 6 m/s in $t_1 = 1$ s. Now as direction of field is reversed, velocity of car will reduce to 0 m/s in next 1 s. i.e., at $t_2 = 2$ s. But, it continues to move for next one second. This will give velocity of –6 m/s to car at $t_3 = 3$ s. Using this data, plot of velocity versus time will be



Average velocity

$= \frac{\text{Area under the graph considering sign}}{\text{time}}$

$= \frac{3 + 3 - 3}{3} = 1$ m/s

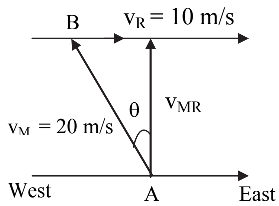
Average speed

$= \frac{\text{Area under the graph without considering sign}}{\text{time}}$

$= \frac{3 + 3 + 3}{3}$

= 3 m/s

41.



$V_m \sin\theta = V_R$

$\therefore$ $\sin\theta = \frac{V_R}{V_m}$

$\therefore$ $\sin\theta = \frac{10}{20} = \frac{1}{2}$

$\therefore$ $\theta = 30°$ with normal (i.e., west)

42. Let, 't_1' be the time taken to travel distance 'x' with constant velocity 'v_1'

$\therefore$ $t_1 = \frac{x}{v_1}$

Let 't_2' be the time taken to travel equal distance 'x' with constant velocity 'v_2'

$\therefore$ $t_2 = \frac{x}{v_2}$

Average velocity, $v = \frac{x + x}{t_1 + t_2} = \frac{2x}{\frac{x}{v_1} + \frac{x}{v_2}} = \frac{2v_1 v_2}{v_1 + v_2}$

$\therefore$ $\frac{2}{v} = \frac{1}{v_1} + \frac{1}{v_2}$

43. S_n = Distance in n^{th} sec.

i.e., $t = n - 1$ to $t = n$

S_{n+1} = Distance in $(n + 1)^{th}$ sec.

i.e., $t = (n + 1) - 1 = n$ to $t = n + 1$

As, $S_n = \frac{a}{2}(2n-1)$

$\therefore \quad \frac{S_n}{S_{n+1}} = \frac{\frac{a}{2}(2n-1)}{\frac{a}{2}\left[2(n+1)-1\right]} = \frac{2n-1}{2n+1}$

44. Velocity of car at t = 4 sec,
$v = u + at = 0 + 5(4) = 20$ m/s
At t = 6 sec,
Acceleration is due to gravity, $a = g = 10\ m/s^2$
$v_x = 20$ m/s (due to car)
$v_y = u + at$
$= 0 + g(2)$ (downward)
$= 0 + 10(2)$
$= 20$ m/s (downward)
$\therefore \quad v = \sqrt{v_x^2 + v_y^2} = \sqrt{20^2 + 20^2} = 20\sqrt{2}$ m/s

2.3 Position - time, velocity - time graphs

1. A body cannot have two values of velocities in one dimensional motion.
$\therefore$ graph (B) does not represent motion in one dimension.

2. Slope of displacement time graph is negative only at point E.

3. A particle has maximum instantaneous velocity at a point where its slope is maximum.
Because the slope is highest at C,
$v = \frac{ds}{dt}$ is maximum.

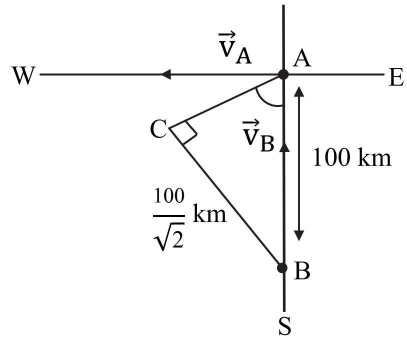
4. The slope of the displacement-time graph gives the instantaneous velocity of motion.
$\therefore \quad \frac{v_1}{v_2} = \frac{\tan\theta_1}{\tan\theta_2} = \frac{\tan(30°)}{\tan(45°)} = \frac{1}{\sqrt{3}}$

2.4 Relative velocity

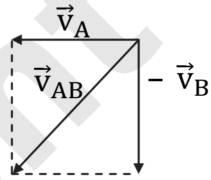
1. $v_T = +10$ m/s,
$v_P = -5$ m/s
($\because$ parrot is flying in opposite direction.)
Relative speed $= v_P - v_T = -5 - (+10)$
$= -15$ m/s
$\therefore \quad t = \frac{150}{15} = 10$ s

2. The distance between the scooter and the bus
= 1 km = 1000 m,
Time taken to overtake (t) = 100 s
Relative velocity (v_s) of the scooter with respect to the bus (v_b) $= v_s - v_b = (v_s - 10)$
$\therefore \quad \frac{1000}{(v_s - 10)} = 100$ s
$\therefore \quad v_s = 20\ ms^{-1}$.

3.



Velocity of ship A and ship B are:
$\vec{v}_A = 10$ km/h
$\vec{v}_B = 10$km/h
Velocity of A w.r.t B is
$\vec{v}_{AB} = \vec{v}_A = \vec{v}_B$



$|\vec{v}_{AB}| = \sqrt{(10)^2 + (10)^2} = \sqrt{200}$
$\therefore \quad |\vec{v}_{AB}| = 10\sqrt{2}$ km/h directed along AC
displacement AC $= \frac{100}{\sqrt{2}}$ km
$\therefore \quad$ time $t = \frac{AC}{|\vec{v}_{AB}|} = \frac{\frac{100}{\sqrt{2}}}{10\sqrt{2}}$
$\therefore \quad t = 5$ h

4. For collision, the relative position of one particle should be directed towards the relative velocity of other particle.
$\hat{v}_R$ be direction of relative velocity of B w.r.t. A.
$\hat{r}_R$ be direction of relative position of A w.r.t. B.
$\therefore \quad \hat{v}_R = \frac{\vec{v}_2 - \vec{v}_1}{|\vec{v}_2 - \vec{v}_1|}$ and $\hat{r}_R = \frac{\vec{r}_1 - \vec{r}_2}{|\vec{r}_1 - \vec{r}_2|}$
$\therefore \quad \hat{v}_R = \hat{r}_R \Rightarrow \frac{\vec{r}_1 - \vec{r}_2}{|\vec{r}_1 - \vec{r}_2|} = \frac{\vec{v}_2 - \vec{v}_1}{|\vec{v}_2 - \vec{v}_1|}$

2.5 Motion under gravity

1. $s_n = u + \frac{a}{2}(2n - 1)$
$u = 0, a = g$
$\therefore \quad s_4 = \frac{g}{2}(2 \times 4 - 1) = \frac{7g}{2}$
and, $s_5 = \frac{g}{2}(2 \times 5 - 1) = \frac{9g}{2}$
$\therefore \quad \frac{s_4}{s_5} = \frac{7}{9}$

2. Distance S_t covered in t^{th} second is given by,
$s_t = u + \frac{1}{2}g(2t - 1)$
Total distance covered in last 2s of fall is,
$s = s_t + s_{(t-1)}$
$= \left[0 + \frac{g}{2}(2t\ =1)\right] + \left[0 + \frac{g}{2}\{2\ (t\ =1) - 1\}\right]$
$\therefore \quad 40 = \frac{g}{2}(2t - 1) + \frac{g}{2}(2t - 3) = \frac{g}{2}(4t - 4)$
$\therefore \quad 40 = \frac{10}{2} \times 4(t - 1) = 20(t - 1)$
$\therefore \quad 40 = 20\ (t - 1)$

∴ $t = 3s$

Distance travelled in 3s

= height of the tower (h)

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

$= 0 + \frac{1}{2} \times 10 \times 3 \times 3 = 45$ m

3. Time taken by first drop to reach the ground,

$t = \sqrt{\frac{2h}{g}}$

∴ $t = \sqrt{\frac{2\times5}{10}} = 1$ s

As the water drops fall at regular intervals from a tap, hence time difference between any two drops $= \frac{1}{2}$ s

In this time, distance of second drop from the tap $= \frac{1}{2}g\left(\frac{1}{2}\right)^2 = \frac{5}{4} = 1.25$ m

Its distance from the ground = 5 – 1.25 = 3.75 m

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

For 1st object,

$u = 0$, $v = 3$m/s, $a = g = 10$ m/s^2, $s = h$

∴ $(3)^2 = (0)^2 + 2(10)h$

∴ $s = 9/20$ m

For second object,

$u = 4$ m/s, $a = g = 10$ m/s^2, $s = 9/20$ m.

∴ $v^2 = (4)^2 + 2(10) \times \frac{9}{20}$

∴ $v^2 = 25$

∴ $v = 5$ m/s

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

For half height,

$h = h/2$, $v = 10$ m/s, $a = -g$

$10^2 = u^2 - 2g\frac{h}{2}$ ….(i)

∴ $u^2 = 10^2 + gh$

For total height,

$v = 0$, $a = -g$, $s = h$

$0 = u^2 - 2gh$

∴ $u^2 = 2gh$ ….(ii)

From (i) and (ii)

$10^2 + gh = 2gh$

∴ $gh = 10^2$

∴ $h = 10$m

6. Let 'T' be the time by ball to reach highest point.

$v = u + at$

at highest point, $v = 0$, $a = -g$

∴ $0 = u - gT$

∴ $T = \frac{u}{g}$

velocity of body after (T – t) seconds,

$v = u - g(T - t)$

$= u - g(T) + gt$

$= u - g\left(\frac{u}{g}\right) + gt$

∴ $v = u - u + gt = gt$

Now, $h = ut - \frac{1}{2}gt^2$

∴ Distance covered in last t second $= (gt)t - \frac{1}{2}gt^2$

$= gt^2 - \frac{1}{2}gt^2$

$= \frac{1}{2}gt^2$

7. Interval of ball thrown = 2s

For minimum three (more than two) balls to remain in air the time of flight of first ball must be greater than 4 sec.

Because the third ball is in air after 4 s.

$T > 4s$

∴ $\frac{2u}{g} > 4s$

∴ $u > \frac{4 \times 9.8}{2}$

∴ $u > 19.6$ m/s.

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

During motion from ground to height (h/2),

$v = 10$ m/s, $s = h/2$, $a = -10$ m/s

∴ $10^2 = u^2 + 2 \times (-10) \times h/2$

∴ $u^2 = 100 + 10h$ ….(i)

During motion from ground to maximum height (h),

$v = 0$, $s = h$, $a = -10$m/s

∴ $0^2 = u^2 + 2 \times (-10) \times h$

∴ $u^2 = 20h$ ….(ii)

From (i) and (ii),

$100 + 10h = 20h$

∴ $h = 10$ m

9. $t = \sqrt{\frac{2h}{g}}$

∴ $t_A = \sqrt{\frac{2h_A}{g}}$ and $t_B = \sqrt{\frac{2h_B}{g}}$

∴ $\frac{t_A}{t_B} = \frac{\sqrt{\frac{2h_A}{g}}}{\sqrt{\frac{2h_B}{g}}} = \sqrt{\frac{h_A}{h_B}} = \sqrt{\frac{16}{25}} = \frac{4}{5}$

10. distance covered by first ball in 18 s,

$h = ut + \frac{1}{2}gt^2$

$u = 0$, $t = 18$ s, $g = 10$ m/s^2

∴ $x = \frac{1}{2} \times 10 \times 18^2$ ….(i)

Second ball has to cover the same distance to meet in (18 – 6) = 12 s.

For the second ball

$u = v$, $t = 12$ s, $g = 10$ m/s^2

Using $h = ut + \frac{1}{2}gt^2$

∴ $x = v \times 12 + \frac{1}{2} \times 10 \times 12^2$ ….(ii)

From equation (i) and (ii), we get

$\frac{1}{2} \times 10 \times 18^2 = 12v + \frac{1}{2} \times 10 \times (12)^2$

$\therefore$ $12v = \frac{1}{2} \times 10 \times [(18)^2 - (12)^2]$

$= 5 \times [(18 + 12)(18 - 12)]$

$12v = 5 \times 30 \times 6$

$\therefore$ $v = \frac{5 \times 30 \times 6}{12} = 75$ m/s

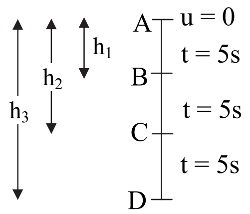
11. From 3rd equation of motion, we have,

$v^2 = u^2 + 2gh$

$u = 0$, $g = 10$ m s^{-2}, $h = 20$ m

$\therefore$ $v = \sqrt{2gh} = \sqrt{2 \times 10 \times 20} = 20$ m/s

12. At point A, u = 0



$\therefore$ $h_1 = \frac{1}{2} gt^2 = \frac{1}{2} \times 10 \times 25.$

$\therefore$ $h_1 = 125$ m

Now, $v = u + gt = 0 + 10(5)$

$\therefore$ $v = 50$ m/s

At point B, final velocity from A to B = initial velocity at B

$\therefore$ $h_2 = ut + gt^2 = 50 \times 5 + \frac{1}{2} \times 10 \times 25$

Now, $h_2 = 375$ m

$v = u + gt = 50 + 10(5)$

$\therefore$ $v = 100$ m/s

Similarly, At point C, we get,

$h_3 = 625$ m

$\therefore$ $h_1 : h_2 : h_3 = 125 : 375 : 625 = 1 : 3 : 5$

i.e., $h_1 = \frac{h_2}{3} = \frac{h_3}{5}$

13. In both the cases, the coin is in free fall and the only force acting on it is gravity.

$\therefore$ $t_1 = t_2 = \sqrt{\frac{2h}{g}}$

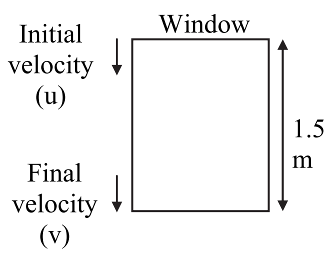
14. From 3rd equation of motion, we have,

$v^2 = u^2 + 2gh$

Given: u = 20 m/s, g = 10 m/s^2 and v = 80 m/s

$\therefore$ $h = \frac{v^2 - u^2}{2g} = \frac{(80)^2 - (20)^2}{2 \times 10} = \frac{6400 - 400}{20} = 300$ m

15.



From second kinematical equation, $s = ut + \frac{1}{2} at^2$

$1.5 = u(0.1) + \frac{1}{2} \times 10(0.1)^2$

$1.5 = (0.1)\,u + 0.05$

$u = 15 - 0.5 = 14.5$ m/s

16. For a freely falling body,

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

$\therefore$ For 1st second, $s_1 = \frac{1}{2} g$

For 2nd second, $s_2 = \frac{1}{2} g(2^2 - 1^2) = \frac{1}{2} g(3)$

For 3rd second, $s_3 = \frac{1}{2} g(3^2 - 2^2) = \frac{1}{2} g(5)$

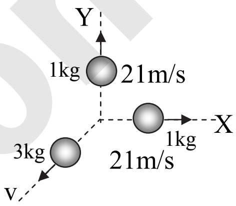
For 4th second, $s_4 = \frac{1}{2} g(4^2 - 3^2) = \frac{1}{2} g(7)$

$\therefore$ The ratio of the distances covered

= 1 : 3 : 5 : 7

2.6 Motion in a plane

1.



$P_x = m \times v_x = 1 \times 21 = 21$ kg m/s

$P_y = m \times v_y = 1 \times 21 = 21$ kg m/s

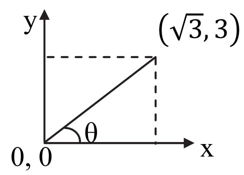
$\therefore$ Resultant $= \sqrt{P_x^2 + P_y^2} = 21\sqrt{2}$ kg m/s

The momentum of heavier fragment should be numerically equal to resultant of $\vec{P}_x$ and $\vec{P}_y$.

$3 \times v = \sqrt{P_x^2 + P_y^2} = 21\sqrt{2}$

$\therefore$ $v = 7\sqrt{2}$ m/s

2.



From figure,

$\tan\theta = \frac{3}{\sqrt{3}} = \sqrt{3}$

$\therefore$ $\theta = \tan^{-1}(\sqrt{3}) = 60°$.

3. $x = a \sin \omega t$

$\therefore$ $\frac{x}{a} = \sin \omega t$ ....(i)

$y = a \cos \omega t$

$\therefore$ $\frac{y}{a} = \cos \omega t$ ....(ii)

Squaring and adding, we get

$\frac{x^2}{a^2} + \frac{y^2}{a^2} = 1$ ($\because \cos^2 \omega t + \sin^2 \omega t = 1$)

$\therefore$ $x^2 + y^2 = a^2$

Hence particle follows a circular path.

2.7 Projectile motion

1. $R = \dfrac{v^2 \sin 2\theta}{g}$

For maximum horizontal range, $\theta = 45°$

$\therefore \quad R_{max} = \dfrac{v^2}{g}$

$\therefore \quad 16000 \text{ m} = \dfrac{v^2}{10}$

$\therefore \quad v = \sqrt{16000 \times 10} = \sqrt{160000} = 400 \text{ ms}^{-1}$

2. Horizontal range $R = \dfrac{u^2 \sin 2\theta}{g}$

For body A, $R_A = \dfrac{u^2 \sin(2 \times 30°)}{g} = \dfrac{u^2}{g}\dfrac{\sqrt{3}}{2}$

For body B, $R_B = \dfrac{u^2 \sin(2 \times 60°)}{g} = \dfrac{u^2}{g}\dfrac{\sqrt{3}}{2}$

$\therefore \quad \dfrac{R_A}{R_B} = 1:1$

3. $\theta_1 = 60°, \ \theta_2 = 30°$

So range of projectile,

$R_1 = \dfrac{v_0^2 \sin 2\theta}{g} = \dfrac{v^2 \sin 2(60°)}{g} = \dfrac{v^2 \sin 120}{g}$

$= \dfrac{v^2 \sin(90° + 30°)}{g} = \dfrac{v^2(\cos 30°)}{g} = \dfrac{\sqrt{3}u^2}{2g}$

Now,

$R_2 = \dfrac{v^2 \sin 2(30°)}{g} = \dfrac{v^2 \sin(60°)}{g} = \dfrac{u^2\sqrt{3}}{2g}$

$\therefore \quad R_1 = R_2$

4. Gravity is the only force pulling both objects downwards. Time required to reach the ground is dependent on the vertical motion of the particle. Vertical motion of both the particles A and B are exactly same. Hence they will reach the ground simultaneously.

5. $R = \dfrac{u^2 \sin 2\theta}{g}$

For angle of projection $(45° – \theta)$,

$R_1 = \dfrac{u^2 \sin[2(45n) – \theta)]}{g} = \dfrac{u^2 \sin(90n) – 2n)}{g}$

$= \dfrac{u^2 \cos 2\theta}{g}$

For angle of projection $(45° + \theta)$,

$R_2 = \dfrac{u^2 \sin[2(45n), \theta)]}{g} = \dfrac{u^2 \sin(90n), 20)}{g}$

$= \dfrac{u^2 \cos 2\theta}{g}$

$\therefore \quad \dfrac{R_1}{R_2} = \dfrac{u^2 \cos 2\theta/g}{u^2 \cos 22 \ g} = \dfrac{1}{1}$

6. Speed of projectile at maximum height,

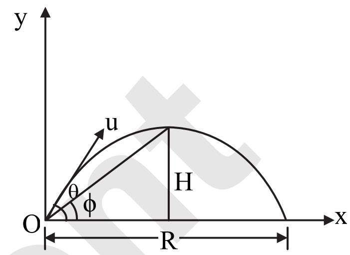
$v = u\cos\theta$

given, $v = \dfrac{u}{2}$

$\therefore \quad \dfrac{u}{2} = u\cos\theta$

$\therefore \quad \cos\theta = \dfrac{1}{2} \Rightarrow \ \theta = 60°$

7. Maximum height,



$H = \dfrac{u^2 \sin^2\theta}{2g}$

Horizontal range,

$R = \dfrac{u^2 \sin 2\theta}{g}$

$\tan\phi = \dfrac{H}{R/2}$ ....(i)

Substituting values of H and R in (i), we get

$\tan\phi = \dfrac{\frac{u^2 \sin^2\theta}{2g}}{\frac{u^2 \sin 2\theta}{2g}} = \dfrac{\sin^2\theta}{\sin 2\theta} = \dfrac{\sin^2\theta}{2\sin\theta\cos\theta} = \dfrac{1}{2}\tan\theta$

$\therefore \quad \tan\phi = \dfrac{1}{2}\tan 45°$

$\therefore \quad \tan\phi = \dfrac{1}{2} \qquad (\because \ \theta = 45)$

$\therefore \quad \phi = \tan^{-1}\left(\dfrac{1}{2}\right)$

8. For maximum range, angle of projection, $\theta = 45°$

$R = \dfrac{u^2 \sin 2\theta}{g}$

$\therefore \quad R_{max} = \dfrac{u^2 \sin 90°}{g} = \dfrac{u^2}{g}$

$\therefore \quad R_{max} = \dfrac{(20 \text{ m/s})^2}{(10 \text{ m/s}^2)} = 40 \text{ m}$

9. Horizontal range = Maximum height

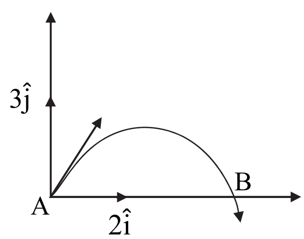
$\therefore \quad \dfrac{u^2 \sin 2\theta}{g} = \dfrac{u^2 \sin^2\theta}{2g}$

$\therefore \quad \dfrac{2u^2 \sin\theta\cos 2}{g} = \dfrac{u^2 \sin^2\theta}{2g}$

$\therefore \quad \tan\theta = 4$

$\therefore \quad \theta = \tan^{-1}(4)$

10.



Horizontal (X) component remains the same while the vertical (Y) component changes.

Therefore, velocity at B = $(2\hat{i} – 3\hat{j})$ m/s.

11. For projectiles with equal trajectory, their range and height must be same.

$\therefore$ $(H_{max})_1 = (H_{max})_2$

$\therefore$ $\dfrac{u_1^2\sin^2\theta}{2g_1} = \dfrac{u_2^2\sin^2\theta}{2g_2}$

$\therefore$ $\dfrac{u_1^2}{u_2^2} = \dfrac{g_1}{g_2}$

$\therefore$ $g_2 = \dfrac{9.8 \times 3^2}{5^2} = 3.5 \text{ m/s}^2$

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

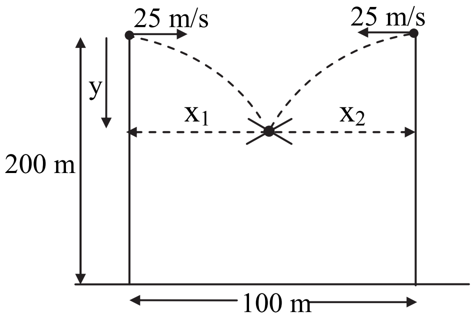
$\therefore$ $v^2 = u^2 + 2\, g \sin\theta\, x$

$\sin\theta.\, X = \text{constant}$

$\therefore$ $x \propto \dfrac{1}{\sin\theta}$

$\therefore$ $\dfrac{x_1}{x_2} = \dfrac{\sin\theta_2}{\sin\theta_1} = \dfrac{1/2}{\sqrt{3}/2} = 1 : \sqrt{3}$

13.



Let the bullets collide at time t

The horizontal displacement x_1 and x_2 is given by the equation

$x_1 = ut$ and $x_2 = ut$

$\therefore$ $x_1 + x_2 = 100$

$\therefore$ $25t + 25t = 100$

$\therefore$ $t = 2s$

Vertical displacement 'y' is given by

$y = \frac{1}{2} gt^2 = \frac{1}{2} \times 10 \times 2^2 = 20m$

$\therefore$ $h = 200 - 20 = 180m$

14. Time period,

$T = \dfrac{2\pi R}{v} \Rightarrow v = \dfrac{2\pi R}{T}$

Maximum height,

$H_{max} = \dfrac{v^2\sin^2\theta}{2g} = \dfrac{2\pi^2R^2\sin^2\theta}{gT^2}$

But $H_{max} = 4R$ ….(Given)

$\therefore$ $\dfrac{2\pi^2R^2\sin^2\theta}{gT^2} = 4R$

$\therefore$ $\sin\theta = \left(\dfrac{2gT^2}{\pi^2R}\right)^{1/2}$

$\therefore$ $\theta = \sin^{-1}\left(\dfrac{2gT^2}{\pi^2R}\right)^{1/2}$

15. At the highest point of projectile, vertical component of velocity is zero.

$\therefore$ $v = u_x = u\cos\theta = 10 \times \cos(30°) = 5\sqrt{3}\ \text{ms}^{-1}$