INDEX					
S.No.	Торіс	PAGE NO.			
1.	Theory	1			
2.	Exercise#1	36			
3.	Exercise#2	47			
4.	Exercise#3	57			
5.	Exercise#4	68			

E:/DATA-13/NOTES/ENGLISH/PHYSICS/-XI/KINEMATICS

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KINEMATICS

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PABLES

1. KINEMATICS

1.1 INTRODUCTION

MAIN CONTRIBUTORS TO MECHANICS

- (A) <u>ARISTOTLE</u>: Born in 384 B.C., he was the first man to work in the field of mechanics. He held the view that if a body is moving, something external must be required to keep it in that state and prevent it from coming to a stop.
- (B) <u>GALILEO</u>: He was born in Pisa, Italy in 1564 A.D. He invented the concept of acceleration. From experiments on motion of bodies on inclined planes or falling freely, he contradicted the Aristotelian notion that a force was required to keep a body in motion and that heavier bodies fall down faster under gravity.
- (C) <u>NEWTON</u>: He was born in 1642 (the same year that Galileo died). He formulated the well-known laws of motion. He worked on theories of light and colour. He designed an astronomical telescope to carry out astronomical observations.

1.2 REST AND MOTION

PARTICLE

(A) <u>DEFINITION OF PARTICLE</u>

- (i) A body of finite size of splitted parts may be considered as a particle only if all parts of the body undergo same displacement and have same velocity and acceleration.
- (ii) When every part of an object undergoes same displacement and has same velocity and acceleration, we can describe its motion by the motion of any point of it.

(B) DEFINITION OF FRAME OF REFERENCE

To locate the position of a particle we need a frame of reference. A convenient way to do it, is to take three mutually perpendicular lines intersecting at a point called origin. The three lines are x-axis, y-axis, z-axis i.e. (x,y,z) are taken as the position co-ordinates of the particle.



(C) DEFINITION OF REST

If the position of an object does not change in space with respect to time (relative to an observer), it is said to be at rest.

(D) DEFINITION OF MOTION

If the position of an object in space changes with time (relative to an observer), it is said to be in motion. i.e. If all the three coordinates x,y and z of the particle remain unchanged as time passes, the particle is said to be at rest w.r.t. the frame, otherwise it will be in motion. Motion, therefore is a relative term i.e. it depends on *frame of reference* of observer.

2. BASIC MOTION DEFINING PARAMETERS

1.1 POSITION OF AN OBJECT



POSITION VECTOR

It is a vector from origin to the object which represents the position of object with respect to origin.

 $\vec{r} = x \hat{i} + y \hat{j} + z \hat{k}$, $|\vec{r}| = \sqrt{x^2 + y^2 + z^2}$

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2.2 DISTANCE AND DISPLACEMENT

ARABLES

DEFINITIONS

(A) <u>DISTANCE</u> (Denoted by x or s)

It is the scalar quantity giving actual length of the path (irrespective of direction) of motion for moving object.

Dimension [$M^{\circ}L^{1}T^{\circ}$], units : SI/MKS \Rightarrow meter(m), cgs \rightarrow centimeter (cm)

(B) <u>DISPLACEMENT</u>

It is the vector quantity whose magnitude is the *shortest distance between initial and final position of the object* (whatever be the path) and direction is specified by the ray from initial position to final position.

1. It is the change in position vector (Δr) or vector joining initial and final position (r_{AB})

i.e.
$$\Delta \vec{r} = \vec{r}_{f} - \vec{r}_{i} = \vec{r}_{B} - \vec{r}_{A} = \vec{r}_{BA}$$

$$= (x_{2} - x_{1}) \hat{i} + (y_{2} - y_{1}) \hat{j} + (z_{2} - z_{1}) \hat{k}$$

2. There can be two types of vector notations :

(i) $\Delta \vec{r} = \vec{r}_{AB}$ (where AB means vector from A \rightarrow B)

(ii) \vec{r}_{BA} (here also direction of vector is from A to B but writing B before A means we are giving position of B wrt A, as only r_B will mean position of A wrt origin, we will stick to this)

- 3. Dimension [M^o L¹ T^o], unit : MKS meter (m), cgs centimeter (cm).
- 4. Displacement of an object remains unchanged by shifting the origin of the position vector. (not every time)

DIFFERENCE BETWEEN DISTANCE AND DISPLACEMENT

Dist	Distance		Displacement			
(1)	It is scalar quantity.	(1) It i	(1) It is vector quantity			
(2)	It can never be negative.	(2) It c	(2) It can be positive or negative.			
(3)	For a moving object, it always	(3) The	e magnitude of displacement can			
	increases with time.	dec	rease with time if object is moving towards initial position.			
(4)	It is path dependent.	(4) It is path independent.				
(5)	For two points A and B, it can	(5) For two fixed points A and B, it is single valued.				
	have many values depending on					
	the path chosen.					
Ex.	Bus route between two stations	Ex.	Direct Aeroplane route gives distance between			
	twostations gives displacement		between them.			
	vector betweenthem					



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KINEMATICS

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ILLUSTRATIONS

(INITIAL POSITION A, FINAL POSITION B, PATH SHOWN BY ARROW)

(i)	A straight path		Distance = displacement = x
(ii)	Half circle (radius r)	A	Distance =, displacement =
(iii)	Full circle (radius r)	AB	Distance =, displacement =
(iv)	Stone thrown up to height h, back to ground.		Distance =, displacement =
(v)	Inclined up and down.	A B	Distance = displacement =
(vi)	Regular polygon of n sides, out of which m sides travelled. eg. Hexagon	B a a β A a A a	Distance = displacement = (Use formula $\theta = \beta = \frac{2\pi}{n}$, $\alpha = \pi - \beta = \frac{(n-2)\pi}{n}$)
(vii)	Circular Arc	A B	distance = arc = displacement =
(viii)	Curve $y = f(x)$		
	$(ds)^2 = (dx)^2 + (dy)^2$		Distance, S = $\int_{x_1}^{x_2} \left\ 1 + \left\ \frac{dy}{dx} \right\ ^2 \right\ ^{\frac{1}{2}} dx$
	$ds = \left[\frac{dy}{dx} \right]^2 \int_{0}^{1/2} dx$	y B (x_2,y_2) ds dy dy dy dy dy dx	Displacement = $\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$.

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 $\underline{CONCEPT} \qquad |Displacement| \leq Distance$

MISCONCEPT Modulus of displacement vector gives distance.

CLARIFICATION Displacement equals minimum possible distance and not any distance of any path.

GRAPHICAL INTERPRETATION

- (a) Displacement time graph does not give trajectory(trajectory = actual path followed by particle which is given by x y graph)
- (b) Whenever we talk of displacement-time graph, it means |displacement |-time graph because vector portion cannot be so easily represented in simple graph. Though, positive and negative signs are used with this magnitude to represent two opposite directions.

2.3 SPEED

DEFINITION

- 1. It is the distance covered by particle in one sec.
- 2. It's a scalar quantity.
- 3. It can never be negative

4. Dimension = $[M^0 L^1 T^{-1}]$, Unit : (MKS) \Rightarrow m/s, (CGS) \Rightarrow cm/sec.

Unit conversion formula
$$\Rightarrow$$
 x km/hr = $\left| \frac{5}{18} \right|$ x m/sec

IMPORTANT NOTE:

To show change in any physical quantity (say distance) we use the symbol Δx . To show changes in time we use the symbol Δt .

First let's define few technical terms :

- (a) Independent Variable : Ex. time; doesn't depend on anything
- (b) Dependent variable : example displacement (depends on time).

Then we can define Average speed = $\frac{x_2 - x_1}{t_2 - t_1} = \frac{Dx}{Dt}$

Instantaneous speed, $V = \lim_{Dt \otimes 0} \frac{Dx}{Dt} = \frac{dx}{dt}$

TYPES OF SPEED

<u>INSTANTANEOUS SPEED (V_{INS})</u>

It's the speed of a particle \overline{at} a particular instant of time or position.



 $V_{ins} = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$

:. Slope of the tangent at any point in distance time graph gives speed at that point $\therefore v_t = \frac{dx}{dt} = \tan \theta$.

From the above formula, it can also be predicted that

Total distance covered,
$$x = \int dx = \int v dt$$

As vdt represents area

: Area under speed time graph over time axis gives distance covered.



(A)

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(B) <u>AVERAGE SPEED</u> (v_{av}) or (< v >)

If a body covers total distance ΔS over a certain time period Δt , then



 $V_{av} = \frac{\text{total distance travelled}}{\text{total time taken}} = \frac{\Delta s}{\Delta t}$

Slope of chord between two different times t_1 (point A) and t_2 (point B) in distance time graph gives average speed.

METHOD OF FINDING AVG. SPEED WHEN MOTION IS BROKEN INTO SEVERAL PARTS

If a particle travels $\mathbf{x}_{1}, \mathbf{x}_{2}, \dots, \mathbf{x}_{N}$	at speeds	ν ₁ , ν ₂ , .		. V	takin	g tin	net ₁ ,	t ₂		t _n resp	ective	ely tl	nen
$\Delta S = X_1 + X_2 \dots + X_n$	or	$\Delta S =$	V 1	t ₁	+	V ₂	t,	+	$v_3 t_3$		+	V _n	t _n .
(any one will be known)						-	_						
$\Delta t = t_1 + t_2 + \dots$ (any one will be known)	t _n	or	Δt	=	$\frac{x_1}{v_1}$	+	$\frac{x_2}{v_2}$	+				. ,	$\frac{x_n}{v_n}$.

then, substituting above Δ_s and Δ_t in equation, $v_{av} = \frac{\Delta s}{\Delta t}$. It will give average speed.

LET'S TAKE THE FOLLOWING POSSIBLE CASES

CASE -I

values of distance and time interval for different parts of motion given individually. WHAT TO DO : Simply add all x,

all t between two specified positions and find $V_{_{AV}}=\frac{\Delta s}{\Delta t}$.

<u> CASE - II</u>

Velocity is given alongwith either x or t. Find $\Delta s = \sum vt$ and $\Delta t = \sum \frac{x}{v}$

<u>CASE - 111</u>

Instantaneous speed and time are given. Find $\Delta s = \int v dt$ and then $V_{av} = \frac{\Delta s}{\Delta t}$.

CASE - IV

If $x_1 = x_2 = \dots = x_n$ in above case then prove that Average speed is harmonic mean (HM) of individual speed and for n = 2, $v_{av} = \frac{2v_1v_2}{v_1 + v_2}$.

<u>CASE - V</u>

If $t_1 = t_2 \dots = t_n$ in above case, then prove that $v_{av} = \frac{\Sigma v_i}{n}$ i.e. Average speed is arithmetic mean (AM) of individual speeds and for n = 2, $v_{av} = \frac{v_1 + v_2}{2}$.

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DIFFERENTIATION

General formula : $\frac{dt^n}{dt} = nt^{n-1}$

SOME FORMULAS

- 1. $\frac{d}{dt}(t^n)=nt^{n-1}$ 2. $\frac{d}{dt}(t)=1$ 3. $\frac{d}{dx}(c)=0$ 4. $\frac{d}{dt}(sint) = cost$ 5. $\frac{d}{dt}(\cos t) = -\sin t$ 6. $\frac{d}{dt}(e^t)=e^t$
- 7. $\frac{d}{dt}$ Int = $\frac{1}{t}$ (t¹ 0)

8. $\frac{d}{dt}(at+b)^n = na(at+b)^{n-1}$

Rules for differentiation

1.
$$\frac{d}{dt}(cu) = c\frac{du}{dt}$$

- 2. $\frac{d}{dt}(u\pm v) = \frac{du}{dt} \pm \frac{dv}{dt}$
- 3. $\frac{d}{dt}(uv) = u\frac{dv}{dt} + v\frac{du}{dt}$

Q. Fii	nd dx/dt, if x =	YOUR ANSWER	CORRECT ANSWER
1.	t²		
2.	t		
3.	1/t		
4.	t		
5.	1/ t		
6.	t ^{3/2}		
7.	t ^{5/2}		
8.	t ⁴		
9.	t ⁵		
10	0. 2t ²		
11	. $\sqrt{2} t^2$		
12	2. 5000		
13	5. t ² + t + 5		
14	$3t^2 + 2t + 1$		
15	5. $4t^3 + 4$		
16	o. t + 1/t		
17	′. 3t + 2/t		
18	8. t sint		
19	2. t ² sint		
20). t sint		

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Application in physics:

Average acceleration = slope of secant in v-t graph Instantaneous acceleration = dv/dt.

$$v = \frac{dx}{dt}$$
, $a = \frac{dv}{dt}$; $F = \frac{dp}{dt}$; $i = \frac{dq}{dt}$; $? = \frac{d?}{dt}$; $a = \frac{d?}{dt}$

Q. If a body is rotating such that its angle from a fixed location is given by . Find its angular velocity, angular acceleration, and the time at which its angular velocity is zero.

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Q. The charge flowing through a conductor beginning with time t = 0 is given by the formula $q = 2t^2 + 3t + 1$ (coulombs). Find the current i = dq/dt at the end of the 5th second.

UNIFORM SPEED

- 1. Speed, which is not changing with time is called uniform speed.
- 2. Uniform speed is possible even in 1-D, 2-D or 3-D motion.
- 3. Slope at every point in x-t graph is same so it's a straight line in x-t graph.



NON-UNIFORM SPEED

- 1. When speed of particle changes with time, then motion is called non-uniform motion.
- 2. Curve 1, 2, 3 all represent non-uniform speed.





INTEGRATION OR ANTI DERIVATIVE

So far we studied as how to find the velocity of particle when its position is given. Now how to do back calculation, i.e. velocity is given, and we have to find the position of the particle. This reverse process is integration.

There are two kinds of integration :

(a) Indefinite integration

(b) Definite integration

General Formula :

$$\int t^n dt = \frac{t^{n+1}}{n+1} + c$$

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7

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By putting the integration constant we avoid mistake :

	YOUR ANSWER	CORRECT ANSWER
1. ∫dt		
2. ∫tdt		
3. $\int \frac{1}{t^2} dt$		
4. $\int \sqrt[3]{t^2} dt$		
5. $\int (t^2) dt$		
6. ∫(t ⁻⁴)dt		
7. ∫(2t)dt		
8. ∫(2t⁻³)dt		
9. $\int \left(\frac{5}{t^2}\right) dt$		
10. $\int \left(-\frac{2}{t^3}\right) dt$		
11. $\int \left(\frac{1}{2t^3}\right) dt$		

2.4 VELOCITY

DEFINITION

- 1. Displacement in unit time is called velocity.
- 2. It is vector quantity.
- 3. Dimension $[M^0 L^1 T^{-1}]$, Unit : (MKS) \Rightarrow m/s, (CGS) \Rightarrow cm/s.

TYPES OF VELOCITY

(A) INSTANTANEOUS VELOCITY

1. It is velocity of a particle at a particular instant.

2. $V_{ins} = \lim_{\Delta t \to 0} \left| \frac{d\vec{r}}{\Delta t} \right|_{t=0} = \frac{d\vec{r}}{dt}$

:. Slope of the tangent at any point gives value of instantaneous velocity at that point. i.e. $v = tan \theta$.

EXAMPLE :

The displacement of a particle is given by $\vec{r} = (t^2 + 2t + 1)m$ (where t is the time period). Calculate the velocity of the particle as a function of time.

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- 3. It can also be defined as rate of change of position vector.
- 4. For the curved path, instantaneous velocity is always tangential to the path followed.
- 5. Total displacement of particle in time t is $\Delta \vec{r} = \int_{0}^{t} \vec{v} dt$

: Area under velocity vs time graph and time axis with proper algebraic sign gives displacement, while without sign gives distance.

In graph, distance = $A_1 + A_2 + A_3$

$$|displacement| = A_1 - A_2 + A_3$$



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- (B) <u>AVERAGE VELOCITY</u> (\vec{v}_{av} or $\langle \vec{v} \rangle$)
- 1. It is the ratio of displacement with time.
- 2. $\vec{v}_{av} = \frac{\Delta \vec{r}}{\Delta t}$
- 3. Direction of any velocity is same as that of displacement vector.
- 4. Method of finding avg. velocity when velocity is given as a function of time

$$\overline{\mathbf{v}}_{av} = \frac{\int_{0}^{t} \vec{\mathbf{v}} dt}{\int_{0}^{t} dt}$$

EXAMPLE :

The velocity of a moving car varies as a function of time and the relation is given by v = 2at + b, where a & b are constants. Calculate the average velocity of the car during time t = 0 to t = t.

- (C) UNIFORM VELOCITY
- 1. When velocity of a particle does not change w.r.t. time, then it's velocity is known as uniform velocity.
- 2. It is possible only when particle moves along a straight line without reversing it's path.

(D) <u>NON-UNIFORM VELOCITY.</u>

- 1. When velocity of particle changes w.r.t. time, then it is called non uniform velocity.
- 2. There can be three reasons for this non-uniformity.
 - (a) When only magnitude changes eg. motion of a particle in straight line with constant acceleration.
 - (b) When only direction changes eg. uniform circular motion.
 - (c) When both change eg. projectile motion, vertical circular motion.

CONCEPTS REGARDING SPEED AND VELOCITY

1. For uniform speed (velocity) motion, average speed (velocity) is equal to instantaneous speed (velocity) but converse may not be true.

i.e. accidentally at one place if $v_{in} = v_{av'}$ then it does not necessarily mean that it's a uniform motion.

- 2. If velocity is constant, then speed is also constant but converse may not be true.
- **Ex.** Circular motion, where speed is constant but velocity keeps on changing due to change in direction.
- 3. All the differences between distance and displacement are applicable between average speed and average velocity.

i.e. $v_{av} \ge |\vec{v}_{av}|$, $v_{av} > 0$ but $\vec{v}_{av} > = < 0$, single valued, path independent.

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9

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4. Magnitude of instantaneous velocity is called instantaneous speed i.e. $v = |\vec{v}| = \left|\frac{d\vec{r}}{dt}\right|$ but speed $\neq \frac{d|\vec{r}|}{dt}$.

because d $|\vec{r}|$ is change in magnitude of position vector (and not the magnitude of change in position vector which is $|d\vec{r}|$).

- **Ex.** In uniform circular motion $d/\vec{r} = 0$ but speed $\neq 0$.
- 5. If direction of velocity changes, then value of | displacement | will be different from value of distance covered.

2.5 ACCELERATION DEFINITION

- 1. Rate of change of velocity is called acceleration.
- 2. It is a vector quantity, dimension $[M^0 L^1 T^{-2}]$, unit $\Rightarrow m/s^2$.

3.
$$\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$$

- 4. If constant force F is acting on mass m, then $\vec{a} = \frac{\vec{F}}{m}$.
- 5. There is no definite relation between direction of velocity vector and direction of acceleration vector.
- 6. If only direction of velocity changes, then \overline{a} is perpendicular to \overline{v} .
- 7. 3 ways of change in velocity are

TYPES OF ACCELERATION

(A) INSTANTANEOUS ACCELERATION

- 1. Acceleration of a particle at a particular instant is known as instantaneous acceleration.
- 2. $\vec{a} = \lim_{\Delta t \to 0} \left| \frac{d\vec{v}}{dt} \right| = \frac{d\vec{v}}{dt} = \frac{d^2s}{dt^2}$
- 3. $\vec{a} = \frac{d\vec{v}}{dt} = \frac{d\vec{v}}{ds} \cdot \frac{d\vec{s}}{dt} = \frac{\vec{v}d\vec{v}}{ds}$

(B) AVERAGE ACCELERATION

- 1. If change in velocity is $\Delta \vec{v}$ in time Δt , then $\vec{a}_{av} = \frac{\Delta \vec{v}}{\Delta t} = \frac{\vec{v}_2 \vec{v}_1}{t_2 t_1}$.
- 2. The direction of angular acceleration vector is the direction of the change in velocity vector.

(C) UNIFORM ACCELERATION

- If the magnitude and direction of acceleration is not changing with time then acceleration is uniform.
 eg. projectile motion.
- 2. Uniform acceleration does not mean uniform motion because velocity is still changing.
- 3. Uniform acceleration does not necessarily imply that particle is moving in one direction only. eg. projectile motion.
- 4. Displacement time graph for positively accelerated motion is upward opening parabola



while for negatively accelerated motion, it is downward opening parabola.



 $x_{_0} \neq 0$, $v_{_0} = 0$, a < 0 $x_{_0} \neq 0$, $v_{_0} < 0$, a < 0 $x_{_0} \neq 0$, $v_{_0} > 0$, a < 0

(D) NON-UNIFORM ACCELERATION

 When acceleration (either magnitude or direction or both) changes with time then it's called non-uniform acceleration.
 SUMMARY

	speed	velocity	acceleration
(1) Instant.	$\mathbf{v} = \frac{dx}{dt} = \mid \vec{v} \mid$	$\vec{v} = \left\ \frac{d\vec{r}}{dt} \right\ _{\text{at time t}}$	$\vec{a} = \left(\frac{d\vec{v}}{dt} \right)_{\text{at time t}}$
(2) average	$V_{av} = \frac{\text{total distance}}{\text{total time}}$	$\vec{v}_{av} = \frac{totaldisplacement}{totaltime}$	$\vec{a} = \frac{Net \ change \ in \ velocity}{total \ time}$
	$V_{av} \neq \vec{v}_{av} $	$= \frac{\vec{r}_2 - \vec{r}_1}{t_2 - t_1} = \frac{\Delta \vec{r}}{\Delta t}$	$=\frac{\vec{v}_2-\vec{v}_1}{t_2-t_1}=\frac{\Delta\vec{v}}{\Delta t}$
(3) uniform changing	v is not changing	neither direction	acceleration is not
	but $ec{v}$ may change	nor magnitude of	but velocity (direction
	with time.	velocity is changing	and/or magnitude) is
		so necessarily	changing. (v is
		one - D motion.	function of first power of t).
(4) non-uniform	speed is increasing	If any or both of	Rate of change of velocity
function	or decreasing with	direction and	is changing i.e. (v is
	time so acceleration	magnitude of velocity	of t^n . where $n > 1$)
	is there.	is changing then it is	
		non-uniform. So acc.	
		is there.	

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3. GRAPHICAL INTERPRETATION OF MOTION

3.1 POSITION TIME GRAPH

During motion of the particle its parameters of kinematical analysis (u, v, a, r) changes with time. This can be represented on the graph.

Position time graph is plotted by taking time t along x-axis and position of the particle on y-axis.

Let AB is a position-time graph for any moving particle

As Velocity =
$$\frac{\text{Change in position}}{\text{Time taken}} = \frac{y_2 - y_1}{t_2 - t_1}$$
 ...(i)

From triangle ABC $\tan q = \frac{BC}{AC} = \frac{AD}{AC} = \frac{y_2 - y_1}{t_2 - t_1}$ (ii)

By comparing (i) and (ii) Velocity = $\tan \theta$



It is clear that slope of position-time graph represents the velocity of the particle.

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Various position - time graphs and their interpretation

$\begin{array}{c} P \\ 0 \\ \end{array} \\ T \end{array}$	$q = 0^{\circ}$ so $v = 0$ <i>i.e.</i> , line parallel to time axis represents that the particle is at rest.
P = 0 $P = 0$ T $P = 0$ T	$q = 90^{\circ}$ so $v = \infty$ <i>i.e.</i> , line perpendicular to time axis represents that particle is changing its position but time does not changes it means the particle possesses infinite velocity. Practically this is not possible. q = constant so v = constant, a = 0 <i>i.e.</i> , line with constant slope represents uniform velocity of the particle.
$p \rightarrow p$ $p \rightarrow T$	q is increasing so v is increasing, a is positive. <i>i.e.</i> , line bending towards position axis represents increasing velocity of particle. It means the particle possesses acceleration.
	q is decreasing so v is decreasing, a is negative <i>i.e.</i> , line bending towards time axis represents decreasing velocity of the particle. It means the particle possesses retardation.
P O q T	q constant but > 90° so v will be constant but negative <i>i.e.</i> , line with negative slope represent that particle returns towards the point of reference. (negative displacement).
$ \begin{array}{c} P \\ A \\ B \\ C \\ S \\ T \end{array} $	Straight line segments of different slopes represent that velocity of the body changes after certain interval of time.
P T T	This graph shows that at one instant the particle has two positions. Which is not possible.
P O T	The graph shows that particle coming towards origin initially and after that it is moving away from origin

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3.2 IMPORTANT POINTS :-

If the graph is plotted between distance and time then it is always an increasing curve and it never comes back towards origin because distance never decrease with time. Hence such type of distance time graph is valid up to point A only, after point A it is not valid as shown in the figure.



Distance

0

3.3 VELOCITY TIME GRAPH

The graph is plotted by taking time t along x-axis and velocity of the particle on y-axis.

Distance and displacement : The area covered between the velocity time graph and time axis gives the displacement and distance travelled by the body for a given time interval.

For two particles having displacement time graph with slopes θ_1 and θ_2 possesses velocities v_1 and v_2 respectively

Then Total distance = $|A_1| + |A_2| + |A_3|$

= Addition of modulus of different area. i.e. $s = \int |u| dt$

Total displacement = $A_1 + A_2 + A_3$

= Addition of different area considering their sign. i.e. $r = \int u dt$

Here A_1 and A_2 are area of triangle 1 and 2 respectively and A_3 is the area of trapezium.

Acceleration : Let AB is a velocity-time graph for any moving particle

From triangle ABC, $\tan q = \frac{BC}{AC} = \frac{AD}{AC} = \frac{v_2 - v_1}{t_2 - t_1}$ (ii) By comparing (i) and (ii) Acceleration (a) = $\tan q$

As Acceleration = $\frac{\text{Change in velocity}}{\text{Time taken}} = \frac{\text{v}_2 - \text{v}_1}{\text{t}_2 - \text{t}_1}$

It is clear that slope of velocity-time graph represents the acceleration of the particle.



...(i)



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Various velocity - time graphs and their interpretation

	q = 0, $a = 0$, $v = constanti.e., line parallel to time axis represents that the particle is moving with constant velocity.$
C C C C C C C C C C C C C C C C C C C	$q = 90^{\circ}$, $a = \infty$, $v =$ increasing <i>i.e.</i> , line perpendicular to time axis represents that the particle is increasing its velocity, but time does not change. It means the particle possesses infinite acceleration. Practically it is not possible.
Arita of the second sec	q =constant, so a = constant and v is increasing uniformly with time <i>i.e.</i> , line with constant slope represents uniform acceleration of the particle.
Alpone of Time	q increasing so acceleration increasing <i>i.e.</i> , line bending towards velocity axis represent the increasing acceleration in the body.
Allocity O Time	<i>q</i> decreasing so acceleration decreasing <i>i.e.</i> line bending towards time axis represents the decreasing acceleration in the body
A A A A A A A A A A A A A A A A A A A	Positive constant acceleration because q is constant and < 90° but initial velocity of the particle is negative.
o Time	Positive constant acceleration because q is constant and < 90° but initial velocity of particle is positive.
O Time	Negative constant acceleration because q is constant and > 90° but initial velocity of the particle is positive.
	Negative constant acceleration because q is constant and > 90° but initial velocity of the particle is zero.
Alisonal Ali	Negative constant acceleration because q is constant and > 90° but initial velocity of the particle is negative.

2

4.3 Important points for uniformly accelerated motion

(i) If a body starts from rest and moves with uniform acceleration then distance covered by the body in t sec is proportional to t^2 (i.e. $s_{\mu} t^2$).

So we can say that the ratio of distance covered in 1 sec, 2 sec and 3 sec is $1^2 : 2^2 : 3^2$ or 1 : 4 : 9.

(ii) If a body starts from rest and moves with uniform acceleration then distance covered by the body in nth sec is proportional to (2n - 1) (i.e. $s_n \propto (2n - 1)$

So we can say that the ratio of distance covered in I sec, II sec and III sec is 1:3:5.

(iii) A body moving with a velocity u is stopped by application of brakes after covering a distance s. If the same body moves with velocity nu and same braking force is applied on it then it will come to rest after covering a distance of n²s.

As
$$v^2 = u^2 - 2as \Rightarrow 0 = u^2 - 2as \Rightarrow s = \frac{u^2}{2a}$$
, $s \propto u^2$ [since a is constant]

So we can say that if u becomes n times then s becomes n2 times that of previous value.

(iv) A particle moving with uniform acceleration from A to B along a straight line has velocities v_1 and v_2 at A and B respectively. If C is the mid-point between A and B then velocity of the particle at C is equal to

$$\boldsymbol{u} = \sqrt{\frac{\boldsymbol{u}_1^2 + \boldsymbol{u}_2^2}{2}}$$

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These are the various relations between u, v, a, t and s for the moving particle where the notations are used as :

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- u = Initial velocity of the particle at time t = 0 sec
- v = Final velocity at time t sec
- a = Acceleration of the particle
- s = Distance travelled in time t sec
- $s_n = Distance travelled by the body in nth sec$

4.1 When particle moves with zero acceleration (Uniform motion)

- (i) It is a unidirectional motion with constant speed.
- (ii) Magnitude of displacement is always equal to the distance travelled.
- (iii) v = u, s = u t [As a = 0]

4.2 When particle moves with constant acceleration

- (i) Acceleration is said to be constant when both the magnitude and direction of acceleration remain constant.
 - (ii) There will be one dimensional motion if initial velocity and acceleration are parallel or anti-parallel to each other.
 - (iii) Equations of motion in scalar from Equation of motion in vector from

$$u = u + at$$

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

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

$$\vec{s} = \vec{u}t + \frac{1}{2}\vec{a}t^{2}$$

$$\vec{v} \cdot \vec{v} - \vec{u}\vec{u} = 2\vec{a}\cdot\vec{s}$$

$$s = \left(\frac{u+v}{2}\right)t$$

$$\vec{s} = \frac{1}{2}(\vec{u} + \vec{v})t$$

$$s_n = u + \frac{a}{2}(2n-1)$$
 $\vec{s}_n = \vec{u} + \frac{\vec{a}}{2}(2n-1)$

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4.4 MOTION UNDER GRAVITY

MOTION UNDER GRAVITY

Here we will consider motion of a particle thrown vertically upward ($\theta = 90^{\circ}$ from horizontal) or falling vertically from any height.

<< methods of solving problems on motion under gravity >>

METHOD I

* For stone thrown upward, motion can be divided into two parts :

PART 1 - stone going upward : speed decreasing with time due to gravity, which is pulling it downward.

Therefore, this is the case of deceleration, so equations of motion in scalar form will be as v = u - gt, $s = ut - 1/2gt^2$, $v^2 = u^2 - 2gh$

<u>PART 2</u> - **stone falling downward :** speed increasing with time due to gravity, which is pulling it downward. Therefore, this is the case of accelerated motion, so equations of motion in scalar form will be as v = u + gt, $s = ut + 1/2 gt^2$, $v^2 = u^2 + 2gh$

<u>CAUTION</u> : You have to consider upward and downward motion separately.

METHOD II

Here, you can consider complete up and down motion as one motion and applying equations of motion in vector form with proper sign convention will give result with +/- sign, which can be interpreted according to sign convention.

SIGN CONVENTION

- (1) Upward positive , downward negative.
- (2) Point of projection to be taken as origin. (But not necessary we take any point as origin for simplicity)
- (3) All the distances to be measured from point of projection.

: distance above point of projection is positive & vice-versa

For motion under gravity, acceleration vector due to gravitational force will always be downward, whatever be the direction of velocity, so $\vec{a}_g = -9.8 \text{ m/s}^2$ always.

BASIC FIND OUTS OF MUG :

(a) If a particle is projected up with velocity u, then

(i) Maximum height reached by the particle, H = $\frac{u^2}{2g}$

(b) A ball thrown vertically up takes the same time to go up and come down and it is true for any part of its motion.



(c) A particle has the same speed at a point on the path while going vertically up and down.

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(i) Velocity of the particle when it reaches the ground i.e. v = $\sqrt{2gH}$

(ii) Time taken to reach the ground i.e. $t = \sqrt{\frac{2H}{g}}$

- (e) Whenever a ball is dropped, its initial velocity is equal to the velocity of the body, from where it is being dropped. Just after dropping, acceleration for the ball will be equal to free fall acceleration i.e. gravitational acceleration g.
- (f) If we consider constant retarding force due to air resistance, then the ball takes less time to reach the highest position and larger time to reach the ground as compared to that in the absence of air resistance.
- (g) If the body is dropped from a height H, as in time t, it has fallen a distance h from it's initial position, the

height of the body from the ground will be h' = H – h, with h = $\frac{1}{2}$ gt².

- (h) As $h = \left| \frac{1}{2} \right| gt^2$, i.e. $h_{\infty} t^2$, distance fallen in time t, 2t, 3t etc. will be in the ratio of 1^2 : 2^2 : 3^2 i.e. square of integers.
- (i) The distance fallen in nth second i.e. $h_n h_{n-1} = \frac{1}{2}g(n)^2 \frac{1}{2}g(n-1)^2 = \frac{1}{2}g(2n-1)$. So, distance fallen in Ist, IInd, IIIrd sec. will be in the ratio 1 : 3 : 5 i.e. odd integers only.
- (j) Graphs for a body thrown vertically upward : Displacement - time graph :



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	acceleration - time graph :	a + O - <u>t</u> g	— t —	
	Distance travelled in vertical mot	ion = $\left \frac{u^2}{2a}\right + \frac{1}{2}\left a(t-t_o)^2\right $	for t > t_o	

4.5 EFFECTS OF MEDIUM ON MOTION UNDER GRAVITY

On a vertically falling body, three forces may act on it at a time

(1) Weight = mg (downward)

(if mass is same for different bodies, then w does not depend on volume V or density ρ).

(2) Thrust force (Th) = mass of medium displaced (upward) by the falling body x g Th = volume of body x density of medium x g = $V\sigma g$

(: Th $\alpha \sigma$ i.e. more is the density of medium, more is the thrust force : less is the net acceleration downward).

If $\rho < \sigma$, then thrust force will be greater than the weight of the body and the body will move up eg. Hydrogen balloon. So, net downward acceleration

$$= \frac{\text{Netdownwardforce}}{\text{totalmass}} = \frac{W - T_n}{m} = g - \frac{V\sigma g}{V\rho}; \ g' = g \left[\frac{1 - \sigma}{\rho} \right]$$

(Where, $m = V\rho \& w = V\rho g$), But here $\sigma > \rho$, so g' is -ve.

(3) Viscous force = $F_v = 6 phrv$ (upward)

(F_v acts in the direction opposite to motion, so it can act in both upward or downward directions, but in the usual case, in which body is falling downward, F_v is upward)

6 *ph* are constant, r=radius of body, v is instantaneous velocity of body.

 F_v depends on velocity, ie. more v, more F_v which opposes v, so v goes an decreasing

... Fv goes on decreasing

: at an instant, when $F_v = w$, no net force acts on body, so it falls thereafter with uniform velocity called terminal velocity.

i.e. mg =
$$6 \pi \eta r v_t$$
 or $\frac{4}{3} p r^3 r g = 6 \pi \eta r v_t$ so $v_t a r^2$.

: net downward acc. = $\frac{\text{Net downward force}}{\text{mass}} = \frac{W - F_v}{\text{mass}} = \frac{\text{mg} - 6\pi\eta rv}{\text{m}}$;

$$g'' = g - \frac{6\pi\eta rv}{m}$$

(m can be replaced by \Rightarrow m = V $\mathbf{r} = \frac{4}{3} \pi r^{3} \rho$)

So, here downward acceleration comes out to be a function of v. So it's a case of non uniform acceleration.

If thrust force is also acting along with viscous force then g in above eqn. will be replaced by g'

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i.e.
$$g'' = \left[g' - \frac{6\pi\eta rv}{m}\right] = \left[g' - \frac{\sigma}{\rho}\right] - \frac{\sigma}{\rho} - \frac{6\pi\eta rv}{m}\right]$$

CONCEPT If air resistance opposes motion under gravity, then



MOTION OF PARTICLE PROJECTED UPWARD UNDER TWO CONDITIONS

S.N.	motion describing parameters	without air resistance	with air resistance
(1)	acceleration during upward motion	$a_1 = g$ (downward)	$a_1' = (g+a)$ downward
(2)	acceleration during downward motion	$a_2 = g$ (downward)	a ₂ ' = (g-a) downward
(3)	maximum height attained	$H = \frac{u_1^2}{2g}$	$H' = \frac{u_1^2}{2(g+a)}$
			∴ H' _{max} < H _{max}
(4)	time to reach H _{max} from ground	$t_1 = \frac{u_1}{g} = \sqrt{\frac{2H}{g}}$	$t_{1}' = \frac{u_{1}}{g+a} = \sqrt{\frac{2H'}{g+a}}$
			∴ t ₁ ' < t ₁
(5)	time to fall to ground from ${\rm H}_{\rm max}$	$t_2 = t_1 \left \frac{1}{g} \right = \frac{u_1}{g} \left \frac{2H}{g} \right $	$t_{2}' = \sqrt{\frac{2H'}{(g-a)}}$
			$\therefore t_2' > t_1' \& t_2' > t_2$ time to fall > time to rise
(6)	speed with which body falls	$v_2 = \sqrt{2gH} = u_1$	$v_{2}' = \sqrt{2(g-a)H'}$
	on ground.	same as speed with	$u_1 = \sqrt{2(g+a)H'}$
		which particle was thrown up	$\therefore V_2' < U_1 \& V_2' < V_2$

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MOTION WITH VARIABLE ACCELERATION (REVISITED). 3.6

(i) If acceleration is a function of time

a = f(t) then $v = u + \int_{0}^{t} f(t) dt$ and $s = ut + \int (\int f(t) dt) dt$

If acceleration is a function of distance (ii)

$$a = f(x)$$
 then $v^2 = u^2 + 2 \int_{x_0}^{x} f(x) dx$

(iii) If acceleration is a function of velocity

$$a = f(v)$$
 then $t = \int_u^v \frac{dv}{f(v)}$ and $x = x_0 + \int_u^v \frac{vdv}{f(v)}$

5. RELATIVE MOTION

5.1 Introduction :

Motion is always a relative term. The motion, so far discussed was relative to a stationary origin. If the reference is now changed to a body, which may / may not be moving, then the motion is termed as Relative motion. We can interpret 4 types of equations for relative motion.

5.2 **ORIGIN SHIFTING**

Until now, the reference point was a stationary point i.e. origin O. So, for any moving body B, motion defining parameters were

r, v, a
$$\equiv$$
 r_{B'} v_{B'} a_B \equiv r_{BO'} v_{BO'} a_{BO}

Now, if we change that stationary reference point O with a body A, which is having it's own position, velocity and acceleration wrt origin O, then the new parameters describing motion of B wrt A will be r_{BA} , v_{RA} , a_{BA} .

In vector form

from triangle law of vector addition

 $\frac{\mathrm{d}}{\mathrm{d}t} \vec{\mathbf{r}}_{\mathrm{BA}} = \frac{\mathrm{d}}{\mathrm{d}t} \left[\mathbf{\vec{r}}_{\mathrm{B}} \right] - \frac{\mathrm{d}}{\mathrm{d}t} \left[\mathbf{\vec{r}}_{\mathrm{A}} \right]$

$$\vec{r}_{AO} + \vec{r}_{BA} = \vec{r}_{BO}$$

$$\therefore \qquad \vec{r}_{BA} = \vec{r}_{BO} - \vec{r}_{AO} = \vec{r}_{B} - \vec{r}_{A}$$

and

Similarly, $\vec{a}_{BA} = \vec{a}_B - \vec{a}_A$

The above treatment can be seen as shifting origin to A and attributing/transferring the velocity and acceleration of A to B in such a manner that A seems to be stationary for B.

5.3 **RELATION BETWEEN TWO RELATIVE PARAMETERS.**

If v_{AB} is relative velocity of A wrt B and v_{BC} is relative velocity of B wrt C, then $V_{AB} + V_{BC} = V_{AC}$



or V_{AC} - V_{BC} = V_{AB} where $\boldsymbol{v}_{_{\!A\!C}}$ is relative velocity of A wrt C.

(3)**NO-NEW FORMULA INTERPRETATION**

Equations of motion are equally applicable as

$$\begin{split} v_{rel} &= u_{rel} + a_{rel} t & \text{or } \vec{v}_{BA} &= \vec{u}_{BA} + \vec{a}_{BA} t \\ s_{rel} &= u_{rel} t + \frac{1}{2} a_{rel} t^2 & \text{or } \vec{s}_{BA} &= \vec{s}_{oBA} + \vec{u}_{BA} t + \frac{1}{2} \vec{a}_{BA} t^2 \end{split}$$

or v

 $v_{rel}^2 = u_{rel}^2 + 2a_{rel}s_{rel}$ or $\vec{v}_{BA}^2 = u_{BA}^2 + 2 \vec{a}_{BA} \vec{s}_{BA}$

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 $\vec{\mathbf{v}}_{\mathrm{BA}} = \vec{\mathbf{v}}_{\mathrm{B}} - \vec{\mathbf{v}}_{\mathrm{A}}$

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LAW OF INDEPENDENCE OF DIRECTION (RELATIVE MOTION IN TWO DIMENSIONS) Here also, we can convert one 2-D motion into two 1-D motions. i.e. first divide the motion in two perpendicular directions and then apply relative equations i.e. Similarly, for v direction = U+ a t = U + a . †

$$s_{x rel} = u_{xrel}t + \frac{1}{2}a_{x rel}t^{2}$$
Similarly, for y direction
$$s_{y rel} = u_{yrel}t + \frac{1}{2}a_{y rel}t^{2}$$

$$(v_{yrel})^{2} = (u_{yrel})^{2} + 2a_{y rel}s_{y rel}$$
Similarly, for y direction
$$(v_{yrel})^{2} = (u_{yrel})^{2} + 2a_{y rel}s_{y rel}$$
Similarly, for y direction
$$(v_{yrel})^{2} = (u_{yrel})^{2} + 2a_{y rel}s_{y rel}$$

RELATIVE MOTION IN ONE DIMENSION 5.4

Method of solving problems on relative motion

- (i) We should adopt a sign convention in the beginning, usually -
- Condition of collision or condition of meeting together (ii)
 - (a) At the time of collision, coordinates of both particles should be same.
 - $\begin{array}{l} x_{_1}=x_{_2\,'} \ \text{ and } y_{_1}=y_{_2} \\ x_{_1}=x_{_2\,'}\,y_{_1}=y_{_2} \ \text{and } z_{_1}=z_{_2} \end{array}$ i.e. (for a 2-D motion)
 - Similarly, (for a 3-D motion) Two particles collide at the same moment. Of course, their time of journeys may be different i.e. they may (b)
 - start at different times (t_1 and t_2 may be different). If they start together, then $t_1 = t_2$.

TYPES OF RELATIVE MOTION IN 1-D

- 1. When both bodies are moving in opposite direction
- 2. When both bodies are moving in same direction, both \vec{v} and \vec{a} are in + x direction

1. WHEN BOTH BODIES ARE MOVING IN OPPOSITE DIRECTION

- CASE 1 : Two bodies coming towards each other.
 - (Direction of velocity and acceleration of both bodies are opposite to each other)



 $\vec{u}_{BA} = \vec{u}_{B} \cdot \vec{u}_{A} = u_{B} \cdot (-u_{A}) = u_{B} + u_{A}$ (sum of individual speeds) (in + x direction) $\vec{u}_{AB} = \vec{u}_A \cdot \vec{u}_B = -(u_A + u_B)$ (same magnitude but opp. direction) (in - x direction) Here collision is sure.

Time of collision can be obtained by solving following equation for t

Position of B at the time of collision = position of A at the time of collision

$$x_{B} + u_{B}t + \frac{1}{2}a_{B}t^{2} = x_{A} - u_{A}t - \frac{1}{2}a_{A}t^{2}$$
. (in scalar form)

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PHYSICS(FDN)

CASE 2 : Two bodies moving away from each other.



- $\vec{u}_{BA} = \vec{u}_{B} \vec{u}_{A} = -u_{B} u_{A} = -(u_{B} + u_{A})$ [sum of individual speeds, in x direction]
- $\vec{u}_{AB} = \vec{u}_A \vec{u}_B = u_A (-u_B) = u_A + u_B$ [same magnitude, opp. direction, in + x direction] collision is not possible.

Summary : When two bodies move in opp. direction to each other then magnitude of relative velocity is the sum of individual speeds.

2. WHEN BOTH BODIES ARE MOVING IN SAME DIRECTION, BOTH \vec{v} AND \vec{a} ARE IN + X DIRECTION



CASE I : $\underline{u}_{\underline{A}} > \underline{u}_{\underline{B}}$ and $\underline{a}_{\underline{A}} > \underline{a}_{\underline{B}}$ then B will never meet A displacement between them goes on increasing.



$$s_{AB} = s_{oAB} + u_{AB}t + \frac{1}{2}a_{AB}t^2 = s_o + (u_A - u_B)t + \frac{1}{2}(a_A - a_B)t^2$$

surely no collision/meeting possible.

CASE II : $\underline{u}_{A} < \underline{u}_{B}$ and $\underline{a}_{A} < \underline{a}_{B}$ then collision is sure if $\underline{s}_{initial} > \underline{0}$



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collision here means $S_{final,rel} = 0$

(Note : If $S_{initial} = 0$ at t = 0, it is the only time when both are together, thereafter B will always be ahead of A.) Time, at which collision will occur will be obtained by roots of the eqn. From t, we can calculate v_1 and v_2 at that instant t.

CASE III : $\underline{u}_{A} > \underline{u}_{B}$, $\underline{a}_{A} < \underline{a}_{B}$

In this case also, collision is sure because B is gaining velocity.

x_{0A} u_{A} u_{B} t_{0} t

CASE IV : $\underline{u}_{\underline{A}} < \underline{u}_{\underline{B}}$, $\underline{a}_{\underline{A}} > \underline{a}_{\underline{B}}$

This is again an indefinite case. Here collision depends on the value of S_{initial} because though the initial velocity of A is less than that of B but A is gaining velocity.



Minimum initial distance ${\rm d}_{\rm min}$ to avoid collision.

Distance between them initially decreases with time until $v_A < v_B$ but as v_A is increasing at a faster rate, so as soon as v_A becomes greater than v_B then further on distance between them goes on increasing. So, if initially, they are at a separation of d_{min} then at the single instant of meeting together, their speeds will be same & thereafter distance between then will go on increasing.

IMPORTANT POINTS:

Some try to solve the above problem by finding and summing the distances flown by the bird each time it moves from one train to the other. This makes a relatively easy problem quite difficult. It is important to develop a thoughtful, systematic approach to solving problems. Begin by writing an equation for the unknown quantity in terms of other quantities. Then, process by determining the values for each of the other quantities in the equation.

24

KINEMATICS

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1. PROJECTILE MOTION ON HORIZONTAL PLANE

HORIZONTAL PROJECTILE MOTION



INITIALLY GIVEN PARAMETERS

POINT OF PROJECTION : The point O from where projectile is thrown.

ANGLE OF PROJECTION (θ) : The angle from horizontal, towards which projectile is thrown.

INITIAL SPEED OF PROJECTION (u) : The speed with which projectile is thrown.

The projectile motion near the surface of earth consists of superposition of two simultaneous independent motions:

- 1. Horizontal motion at *constant* horizontal *speed* $u \cos q$ and horizontal acceleration = 0 as no horizontal force is present.
- 2. Vertical motion with varying vertical speed and *constant acceleration* due to gravity=-g due to downward gravity force.
- 3. Thus, here also we can apply law of independence of direction and solve the problems by dividing one 2-D motion into two 1-D motions.

(1)	component of ini. speed	$u_x = u \cos \theta$	$u_y = u \sin \theta$
(2)	acceleration	a _x = 0	a _y = - g
(3)	velocity at any instant	$v_x = u_x = u \cos\theta$	at any time t, $v_y = u \sin\theta - gt$ at any height y $V_y^2 = u^2 \sin^2 \theta - 2gy$
(4)	position at any instant	$x = u \cos\theta t$	$y = u \sin \theta t - \frac{1}{2} gt^2$

GENERAL EQUATIONS HORIZONTAL MOTION VERTICAL MOTION

(2) POSITION OF PARTICLE AT ANY MOMENT =
$$(x,y) = (u \cos \theta t, u \sin \theta t - \frac{1}{2}gt^2)$$



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NORMAL AND TANGENTIAL ACCELERATION AT ANY MOMENT

'g' can be split into two parts, "g cos α " normally inward to the curve and "g sin α " tangentially opp. to the direction of motion, where α is the angle tangent makes with horizontal at any instant (note that α is not the angle of projection θ which is a constant entity, α decreases with ascent of projectile).

RESULTANT VELOCITY OF PARTICLE V AT ANY MOMENT

$$v = \sqrt{v_x^2 + v_y^2} = \sqrt{u^2 \cos^2 \theta + (u \sin \theta - gt)^2} = \sqrt{u^2 + g^2 t^2 - 2ugt \sin \theta}$$

: Resultant velocity goes on decreasing during the first half of motion and becomes minimum at max. height. $v_{min} = u_x = u\cos\theta$ at max. height.

at an angle α from horizontal i.e. $\tan \alpha = \frac{v_y}{v_x} = (u \sin \theta - gt)/u \cos \theta$

CHANGE IN MOMENTUM (during complete flight)

Initial velocity $\vec{u}_i = u \cos \theta \hat{i} + u \sin \theta \hat{j}$

Final velocity $\vec{u}_{f} = u \cos \theta \hat{i} - u \sin \theta \hat{j}$

Change in velocity for complete motion, $\Delta \vec{u} = \vec{u}_f - \vec{u}_i = -2u \sin \theta \hat{j}$

Change in momentum for complete motion, $\Delta \vec{p} = \vec{p}_f - \vec{p}_i = m (\vec{u}_f - \vec{u}_i)$

$$\Delta \vec{p} \ = \mbox{m} \ (\mbox{-2 u} \sin \theta) \ \hat{j} \ = \mbox{-2 mu} \sin \theta \ \hat{j} \ = \mbox{mgT} \ (\mbox{-} \ \hat{j})$$

or
$$\Delta \vec{p} = - mgT \hat{j}$$

KINETIC ENERGY AND POTENTIAL ENERGY AT ANY INSTANT T

 $KE = 1/2 mv^{2} = 1/2 m [u^{2} \cos^{2} \theta + (u \sin \theta - gt)^{2}]$

Velocity is minimum at highest point, which equals to horizontal component u $\cos heta$, so

KE (min) = $1/2 \text{ m} \left| u \cos \theta \right|^2 = 1/2 \text{ m} u^2 \cos^2 \theta = \text{KE}_0 \cos^2 \theta$ Where, KE₀ is initial kinetic energy = $1/2\text{m}u^2$

Potential energy at any instant = mg y = mg (u sin θ t - $\frac{1}{2}$ gt²)

$$= mg x tan \theta \left(\frac{1}{R} - \frac{x}{R} \right)$$

Potential energy will be max at highest point and equal to

 $(PE)_{H} + (KE)_{H} = \frac{1}{2} mu^{2} (sin^{2}\theta + cos^{2}\theta) = \frac{1}{2} mu^{2}$

$$(\mathsf{PE})_{\mathsf{H}} = \mathsf{mgH} = \mathsf{mg} \frac{\mathrm{u}^2 \sin^2 \theta}{2\mathrm{g}} = \frac{1}{2} \mathsf{mu}^2 \sin^2 \theta$$

SO,

Which is the ME at the point of projection. So, in projectile motion mechanical energy is conserved. Furthermore,

So if $\theta = 45^{\circ}$

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- 26 -

KINEMATICS

i.e., if a body is projected at an angle of 45° to the horizontal then at the highest point, half of its mechanical energy is kinetic and half potential.

RADIUS OF CURVATURE AT ANY POINT ON THE PATH OF A PROJECTILE

Consider a particle moving along any curve (may be parabola or circle or any other). At any instant t, let its velocity vector v is making an angle α with the horizontal. We choose tangential axis and normal axis as shown in fig.

Centripetal acceleration of particle is directed towards normal axis. Component of g towards normal axis provides centripetal acceleration.

As $a_c = \frac{v^2}{R_c}$ (where a_c = centripetal acceleration , R_c = radius of curvature).

 $\therefore R_{c} = \frac{(\text{instantaneous velocity})^{2}}{\text{centripetal acceleration}}$

(i) Radius of curvature in terms of t :

Radius of curvature
$$R_c = \frac{v^2}{a_c} = \frac{v^2}{g \cos \alpha}$$

As
$$v^2 = V_x^2 + V_y^2 = (u\cos\theta)^2 + (u\sin\theta - gt)^2 = u^2 + g^2t^2 - 2ugt\sin\theta$$

and

$$\tan \alpha = \frac{v_y}{v_x} = \frac{(u\sin\theta - gt)}{u\cos\theta}$$

$$\therefore R_{c} = \frac{u^{2} + g^{2}t^{2} - 2ugt \sin \theta}{g \cos \alpha}$$
where, $\alpha = \tan^{-1} \left\{ \frac{u \sin \theta - gt}{u \cos \theta} \right\}$



$$v_{y}^{2} = (u \sin \theta)^{2} - 2gy$$

$$v_{x} = u \cos \theta$$

$$v^{2} = u^{2}\cos^{2}\theta + u^{2}\sin^{2}\theta - 2gy = u^{2} - 2gy$$

$$\tan \alpha = \frac{v_y}{v_x} = \frac{\sqrt{(u\sin\theta)^2 - 2gy}}{u\cos\theta}$$

$$\therefore \qquad \mathsf{R}_{\mathsf{c}} = \frac{\mathsf{u}^2 - 2\mathsf{g}\mathsf{y}}{\mathsf{g}\cos\alpha}$$

where
$$\alpha = \tan^{-1} \left\{ \frac{\sqrt{(u \sin \theta)^2 - 2gy}}{u \cos \theta} \right\}$$

Equation of Radius of curvature in general = $R_c = \frac{\frac{d^2y}{dx^2}}{\frac{d^2y}{dx^2}}$

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MEMORY POINTS PROJECTILE MOTION

(1) Range is same for two angles, θ and $(90 - \theta)$.

(2) Sum of heights at angles θ and (90 - θ) is independent of θ , it is $H_{\theta} + H_{\theta^0 - \theta} = \frac{U^2}{2g}$ and $\frac{H_{\theta}}{H_{\theta^0^0 - \theta}} = \tan^2 \theta$.

(3) $H = \frac{1}{4} R \tan \theta$ or $R = 4H \cot \theta$. If range is n times of H, then $\tan \theta = \frac{4}{n}$.

(for $\theta = 45^{\circ}$, R is 4 times H)

(4) $\tan \theta = \tan \alpha + \tan \beta$. If B is the highest point, then $\alpha = \beta$ and then $\tan \alpha_{\rm H} = \frac{1}{2} \tan \theta$.



(5) The greatest height to which man can throw a stone is H. The greatest distance upto which he can throw the stone is 2H.

: $H = \frac{1}{8} gT^2$ (H = max. height, T = time of flight)

2. PROJECTION FROM A MOVING BODY

Introduction

(If a particle is projected from some moving body then particle gains the instantaneous velocity only of the moving body and not it's acceleration).

projectile motion from a moving body

Consider a boy who throws a ball from a moving trolley. Let the velocity of ball relative to boy is u.

$$\vec{V}_{\text{ball, trolley}} = \vec{V}_{\text{ball}} - \vec{V}_{\text{trolley}}$$

 $\vec{V} - \vec{V} - \vec{V}$

 $V_{\text{ball}} = V_{\text{ball, trolley}} + V_{\text{trolley}}$

Above equation shows that absolute velocity of ball is vector sum of its velocity with respect to trolley and velocity of trolley. Apply this equation to horizontal as well as vertical motion of the ball. Now consider following cases:

CASE (I) : Ball is projected in direction of motion of trolley

Horizontal component of ball's velocity = $u \cos \theta + v$

Vertical component of ball's velocity = $u \sin \theta$





Horizontal component = $u \cos \theta + v$ Vertical component = $u \sin \theta$

Horizontal component = $u \cos \theta - v$ Vertical component = $u \sin \theta$

KINEMATICS

PHYSICS (FDN)

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CASE (II) : Ball is projected opposite to direction of motion of trolley

Horizontal component of ball's velocity = $u \cos\theta - v$

Vertical component of ball's velocity = $u \sin \theta$

<u>CASE</u> (III) : Similarly, for a ball projected upwards from an upward moving platform, horizontal component of ball's velocity = $u \cos\theta$

Vertical component of ball's velocity = $u \sin\theta + v$





Horizontal component = $u \cos \theta$ Vertical component = $u \sin \theta + v$

Horizontal component = $u \cos \theta$ Vertical component = $u \sin \theta$ - v

<u>CASE</u> (IV) : For a downward moving platform Horizontal component of ball's velocity = $u \cos\theta$ Vertical component of ball's velocity = $u \sin\theta$ - v

CONCEPT 1

Initial projection angle so that particle passes through a given point P (x,y): From the equation of trajectory,

$$y = x \tan \alpha - \frac{gx^2}{2u^2 \cos^2 \alpha} \qquad \dots (13)$$
$$y = x \tan \alpha - \frac{gx^2}{2u^2} (1 + \tan^2 \alpha)$$
$$\tan^2 \alpha - \frac{2u^2}{gx} \tan \alpha + \frac{2u^2 y}{gx^2} + 1 = 0$$

or

~

If point P is within the range of projectile then roots of above equation must be real. Complex roots imply that point P is out of range. By method of completing the square,

Putting discriminant of the above equation = 0(14) we obtain :

$$\tan \alpha = \frac{u^2}{gx}$$
 (where u² / gx is the root of the equation)(15)

which is the required angle such that the trajectory just reaches point P on the envelope of possible trajectories for a given u.

For complementary angles of projection if T_1 and T_2 are the respective times of flight, then



<u>CONCEPT - 2</u> COLLISION OF PROJECTILE WITH A WALL.

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KINEMATICS

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ASSUMPTION : collision is elastic, wall is erect and smooth.

<u>FORMULA USED</u> : speed of approach = speed of separation Speed of wall does not change after collision too.

<u>NOTATION</u> : v_{xb} = horizontal component of instantaneous speed of projectile just before collision

 v_{xa} = horizontal component of instantaneous speed of projectile just after collision in opposite direction. v_{w} = instantaneous velocity of wall at the time of collision. Let us take + v_{w} if wall is coming towards projectile before collision (to avoid complexity, we are not using vector notations here, just applying common sense of collision).

 x_1 = horizontal distance covered by projectile before collision.

 x_2 = horizontal distance covered by projectile after collision.

Range = R if wall/collision were absent.

CASE I Wall is stationary

 $v_{xa} = v_{xb}$ so $x_1 + x_2 =$ Range (if there were no wall). i.e. ball rebounds with same horizontal speed.



<u>CASE II</u> Wall is moving with uniform speed v_w towards projectile speed of approach = speed of separation

 V_{xb} + V_{w} = V_{xa} - V_{w}

 $\therefore V_{xa} = 2V_{w} + V_{xb}$

.. horizontal component of projectile velocity increases by twice the speed of wall

 \therefore $x_1 + x_2 > Range$

<u>CASE III</u> Wall is moving with uniform speed v_w (away from projectile) speed of approach = speed of separation $v_{xb} - v_w = v_{xa} + v_w$

$$\therefore$$
 V_{xa} = V_{xb} - 2V_w

CASE IV Wall is accelerating towards projectile

 \Rightarrow same treatment as case II, here we need to find out speed of wall at the time of collision to be used as v_w in formula v_{xb} + v_w = v_{xa} - v_w

Hence, on elastic collision from vertical smooth wall (whether at rest or uniform or non-uniform motion, only horizontal component of velocity changes. There is no change in vertical component, so time of flight and maximum height attained remain unchanged.

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3. PROJECTION FROM A HEIGHT

HORIZONTAL PROJECTION (PROJECTILE THROWN PARALLEL TO THE HORIZONTAL) u_ = u $u_v = 0$ $a_v = -g$ Horizontal motion x = ut(1) $-h = 0(t) - \frac{1}{2}gt^{2}$ Vertical motion (2) From Eqn. (1) and (2) $t = \sqrt{\frac{2h}{g}}$ \Rightarrow h = u_x t = u $\sqrt{\frac{2h}{g}}$ Horizontal range (R) R PROJECTION AT AN ANGLE **q**ABOVE HORIZONTAL $u_v = u \cos \theta$ $u_{u} = u \sin \theta$ $a_v = -g$ Eqn. of horizontal motion : $x = u \cos \theta t$(1) Eqn. of vertical motion : $-h = u \sin \theta t - \frac{1}{2}gt^2$ (2) From Eqn. (1) and (2), $gt^2 - 2u \sin\theta t - 2h = 0$ $t = \frac{u \sin \theta}{g} \pm \sqrt{\frac{u^2 \sin^2 \theta}{q^2} + \frac{2h}{g}}$ or

PROJECTION AT AN ANGLE $\,\theta\,$ BELOW HORIZONTAL



Similarly, for projection at an angle θ downwards with horizontal, the eqns. are Eqn. of horizontal motion :

$$x = u \cos \theta t \qquad \dots (1)$$

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KINEMATICS

Eqn. of vertical motion :

$$-h = -u \sin \theta t - \frac{1}{2}gt^2$$
(2)

from equation (2),

or
$$gt^2 + 2u \sin \theta t - 2h = 0$$

or

$$t = \frac{-2u\sin\theta \pm \sqrt{4u^2\sin^2\theta + 8gh}}{2g}$$
 Neglect -ve root of t, as

negative value of t has no meaning.

NOTE: In all the above three cases, we can calculate the velocity of projectile at the instant of striking the ground by using

$$V = \sqrt{\frac{V_x^2 + V_y^2}{V_x + V_y^2}}$$

$$\tan \theta = \frac{V_y}{V_x}$$
 [angle at which projectile strikes ground]

4. PROJECTILE ON AN INCLINED PLANE

Now, we are considering the motion of a projectile on an inclined plane which makes an angle α with the horizontal. Projectile makes angle θ with the inclined plane.

The various parameters can be represented as :

TIME OF FLIGHT

Here

and

 $v_{\perp} = v_{o} \sin \theta$ $a_{\parallel} = g \cos \alpha$



Thus,

$$T = \frac{2v_{\perp}}{a_{\perp}} = \frac{2v_{o}\sin\theta}{g\cos\alpha}$$

RANGE ALONG THE INCLINED PLANE

Т

The range of the projectile along the inclined plane is given by

~

$$R' = v_{||}T - \frac{1}{2}a_{||}T^{2}$$

$$T = \frac{2v_{\perp}}{a_{\perp}} = \frac{2v_{o}\sin\theta}{g\cos\alpha}$$

Since

On solving, we get :

$$\therefore \qquad \mathsf{R}' = \frac{2v^2}{g} \frac{\sin\theta\cos(\theta + \alpha)}{\cos^2\alpha} \text{ [Putting } \mathsf{v}_{11} = \mathsf{v}_0\cos\theta \text{ and } \mathsf{a}_{11} = \mathsf{g}\sin\alpha\text{]}$$

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- 32 -

KINEMATICS

PHYSICS (FDN)

ABLES

IMPORTANT POINTS

(a) The maximum range occurs when

$$\theta = \frac{\pi}{4} - \frac{\alpha}{2}$$

(b) The maximum range along the inclined plane when the projectile is thrown upwards is given by



(c) The maximum range along the inclined plane when the projectile is thrown downwards is given by



(d) For maximum range in inclined projectile, the direction of projection bisects the angle that the inclined plane makes with vertical direction to ground (OY')



MAXIMUM HEIGHT OF THE PROJECTILE

If a projectile is thrown up an inclined plane, as shown in the fig. maximum height attained is given by

$$H = \frac{v_{\perp}^{2}}{2a_{\perp}} \implies H = \frac{(v_{o}\sin\theta)^{2}}{2g\cos\alpha} = \frac{v_{o}^{2}\sin^{2}\theta}{2g\cos\alpha}$$

For projectile up the inclined plane, we can use these formulae which are applicable to 'same-level-horizontal-projectile', also

$$T = \frac{2V_{\perp}}{a_{\perp}}; R' = V_{11}T - \frac{1}{2}a_{11}T^{2}; H = \frac{V_{\perp}^{2}}{2a_{\perp}}$$

maximum range occurs at $\theta = \frac{\pi}{4} - \frac{\alpha}{2}$ i.e. ($\theta < 45^{\circ}$)

$$\mathsf{R'}_{\max} \text{ (up the plane)} = \frac{v_0^2}{g(1+\sin\alpha)}, \ \mathsf{R'}_{\max} \text{ (down the plane)} = \frac{v_0^2}{g(1-\sin\alpha)}; \ \mathsf{H} = \frac{v_0^2 \sin^2 \theta}{2g \cos \alpha}$$

NOTE : The angle of projectile θ is measured from inclined plane, not ground.

PROJECTILE WITH VARIABLE ACCELERATION

Suppose a projectile moves in the two dimensional plane with velocity $v = a\hat{i} + bx\hat{j}$ where a and b are constant. Initially, consider the particle to be situated at origin i.e. at x = 0 & y = 0. Now, let us first find out the equation of trajectory of the projectile. So.

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		$v = a\hat{i} + bx$	ĵ	
		v _x = a and	$v_y = bx$	
	But	$v = \frac{dr}{dt}$		
	i.e.	$\frac{\mathrm{d}x}{\mathrm{d}t}$ = a and	$\frac{\mathrm{d}y}{\mathrm{d}t} = \mathrm{b}x$	
		x = at and	dy = bxdt	
	On substituting value of x we have			
		dy = b. at dt		
	On integrating			
		$y = \frac{abt^2}{2}$		

$$y = \frac{ab}{2} \left\| \frac{x}{a} \right\|^{2}$$
$$y = \frac{bx^{2}}{2a}$$

 $R = \frac{\left| \frac{dy}{dx} \right|^2}{\frac{d^2y}{dx^2}}$

This is the equation of trajectory of the projectile. Now, radius of curvature of trajectory is given by,

Since

$$\frac{d^2 y}{dx^2} = \frac{b}{a}$$

$$R = \frac{\left| \left| 1 + \left| \frac{bx}{a} \right|^2 \right|^{3/2}}{\frac{b}{a}} = \frac{a}{b} \left| \left| 1 + \left| \frac{bx}{a} \right|^2 \right|^{3/2} \right|^{3/2}$$

 $y = \frac{b}{2a} . x^2 ; \frac{dy}{dx} = \frac{b}{2a} . 2x = \frac{bx}{a}$

...

5. RELATIVE MOTION

Relative motion Between two projectiles :

Let us now discuss the relative motion between two projectiles or the path of one projectile observed by the other. Suppose that two particles are projected from the ground with speed u_1 and u_2 at angles α_1 and α_2 as shown in fig. Acceleration of both the particles is g downwards. So, relative acceleration between them is zero because

- 34 -
COMPETITION BOOKLET KINEMATICS PHYSICS (FDN)



i.e., the relative motion between the two particles is uniform. Now,

 $\begin{array}{c} u_{1x} = u_1 \cos \alpha_1, \quad u_{2x} = u_2 \cos \alpha_2 \\ u_{1y} = u_1 \sin \alpha_1 \text{ and } u_{2y} = u_2 \sin \alpha_2 \\ \end{array}$ Therefore, $\begin{array}{c} u_{12x} = u_{1x} - u_{2x} = u_1 \cos \alpha_1 - u_2 \cos \alpha_2 \\ \text{and} \qquad u_{12y} = u_{1y} - u_{2y} = u_1 \sin \alpha_1 - u_2 \sin \alpha_2 \\ u_{12x} \text{ and } u_{12y} \text{ are the x and y components of relative velocity of 1 with respect to 2.} \end{array}$

Hence, relative motion of 1 with respect to 2 is a straight line at an angle $\theta = \tan^{-1} \left\| \frac{u_{12y}}{u_{12x}} \right\|$ with positive x-axis.



Now, if $u_{12x} = 0$ or $u_1 \cos \alpha_1 = u_2 \cos \alpha_2$, the relative motion is along y-axis or in vertical direction (as $\theta = 90^{\circ}$). Similarly, if $u_{12y} = 0$ or $u_1 \sin \alpha_1 = u_2 \sin \alpha_2$, the relative motion is along x-axis or in horizontal direction (as $\theta = 0^{\circ}$).

CONDITION OF COLLISION OF TWO PROJECTILES

Now, let the particles are projected simultaneously from two different heights h_1 and h_2 with speeds u_1 and u_2 in the directions shown in fig. Then the particles collide in air if relative velocity of 1 with respect to $2(\vec{u}_{12})$ is along line AB or the relative velocity of 2 with respect to $1(\vec{u}_{21})$ is along the line BA. Thus,

$$\vec{u}_1 = u_1 \cos \alpha_1 \hat{i} + u_1 \sin \alpha_1 \hat{j} \qquad \vec{u}_2 = -u_2 \cos \alpha_2 \hat{i} + u_2 \sin \alpha_2 \hat{j}$$

$$\tan \theta = \frac{u_{12y}}{u_{12x}} = \left| \frac{h_2 - h_1}{s} \right|$$

Here, $u_{12y} = u_{1y} - u_{2y} = u_1 \sin \alpha_1 - u_2 \sin \alpha_2$

and $u_{12x} = u_{1x} - u_{2x} = (u_1 \cos \alpha_1) - (-u_2 \cos \alpha_2) = u_1 \cos \alpha_1 + u_2 \cos \alpha_2$ If both the particles are initially at the same level $(h_1 = h_2)$, then for collision

 $u_{12y} = 0 \text{ or } u_1 \sin \alpha_1 = u_2 \sin \alpha_2$



The time of collision of the two particles will be

$$t = \frac{AB}{|\vec{u}_{12}|} = \frac{AB}{\sqrt{(u_{12x})^2 + (u_{12y})^2}}$$

Further, the above conditions are not merely sufficient for collision to take place. For example, the time of collision discussed above should be less than the time of collision of either of the particles with the ground.

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Q.1A bod The m tivelyQ.1A bod The m tively(A) $\frac{pr}{2}$ (C) prQ.2The di groun of the(A) \sqrt{p} (C) 2π Q.3A bus given (b) BI(A) $\frac{2x}{3t}$ (C) $\frac{2x}{3t}$ Q.4If V(t) 3 sec. (A) 16 (C) 10Q.5A man distan (A) 4 k (C) 1.5Q.6A point with a veloci time. motio	by moves over hagnitude of r- r , $r\sqrt{2}$ isplacement of d, when the wheel is R) $\frac{R}{r^2 + 4}$ R goes from st in fig. $A \xrightarrow{x}{2t} \neq B$ D (c) AD. $\frac{x}{t}, \frac{3x}{2t}, \frac{x}{t}$	EXERCISE#1 er one fourth of a circ distance travelled and (B) (D) of the point of the wh wheel roles forward h (B) (D) cation A to D through B $\frac{x}{t} > c \frac{2x}{t} > D$. Find the a (B)	Eular arc in a circle of radial d displacement will be $\frac{pr}{4}$, r πr , r meel initially in contact w half a revolution will be $R\sqrt{p^2+4}$ πR B, C. The distance and the average speed between $\frac{x}{3t}$, $\frac{3x}{2t}$, $\frac{x}{t}$	adius r. respec- vith the (radius ime are (a) AC ime are (a) AC	KILLS: Ilate shortest using change on with time. KILLS: Iculate the in position of t considered on le. KILLS: Iculate the velocity in lits of time
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Q.2The digroun of the $(A) \sqrt{p}$ $(C) 2\pi$ Q.3A bus given (b) BI $(A) \frac{2x}{3t}$ $(C) \frac{2x}{3t}$ Q.4If V(t) 3 sec. (A) 16 (C) 10Q.5A mar distan (A) 4 k (C) 1.5Q.6A poir with a veloci time. motio	isplacement of d, when the e wheel is R) $\frac{R}{r^{2}+4}$ R goes from st in fig. $A \xrightarrow{x}{2t} = B$ O (c) AD. $\frac{3x}{t}, \frac{x}{t}$	of the point of the wh wheel roles forward h (B) (D) ation A to D through B $\frac{x}{t} > c \frac{2x}{t} > D$. Find the a (B)	heel initially in contact v half a revolution will be $R\sqrt{p^2 + 4}$ πR B, C. The distance and the average speed between $\frac{x}{3t}, \frac{3x}{2t}, \frac{x}{t}$	with the <i>TOPIC SI</i> (radius To ca change the point the circl ime are <i>TOPIC SK</i> (a) AC To cal average given sp	KILLS: Iculate the in position of t considered on le. (ILLS: Iculate the velocity in lits of time
(A) $\overline{\sqrt{p}}$ (C) 2π (C) 2π (C) 2π (C) 2π (D) BI (A) $\frac{2x}{3t}$ (C) $\frac{2x}{3t}$ (C) $\frac{2x}{3t}$ (C) $\frac{2x}{3t}$ (C) $\frac{2x}{3t}$ (C) $\frac{2x}{3t}$ (C) $\frac{1}{5}$ (C) 10 (C) 10 (C) 1.5 (C) 1.5 (C	$\frac{R}{R}$ goes from st in fig. $A \xrightarrow{x}{2t} = B$ D (c) AD. $\frac{x}{t}, \frac{3x}{2t}, \frac{x}{t}$	(B) (D) tation A to D through I $3 - \frac{x}{t} > c - \frac{2x}{t} > D$. Find the a (B)	$R\sqrt{p^2 + 4}$ πR B , C . The distance and the transformation of transforma	ime are (a) AC (a) AC (b) AC (c) A	(<i>ILLS</i> : lculate the velocity in lits of time
(C) 2π Q.3 A bus given (b) BE (A) $\frac{2x}{3t}$ (C) $\frac{2x}{3t}$ Q.4 If V(t) 3 sec. (A) 16 (C) 10 Q.5 A man distan (A) 4 k (C) 1.5 Q.6 A poin with a veloci time. motio	R goes from st in fig. $A \xrightarrow{x}{2t} B$ D (c) AD. $\frac{x}{2}, \frac{3x}{2t}, \frac{x}{t}$	(D) tation A to D through I $3 - \frac{x}{t} > C - \frac{2x}{t} > D$. Find the a (B)	πR B, C. The distance and the average speed between $\frac{x}{3t}, \frac{3x}{2t}, \frac{x}{t}$	ime are TOPIC Sk To cal average given sp 	(ILLS: Iculate the velocity in lits of time
Q.3A bus given (b) BI(A) $\frac{2x}{3t}$ (A) $\frac{2x}{3t}$ (C) $\frac{2x}{3t}$ Q.4If V(t) 3 sec. (A) 16 (C) 10Q.5A mar distar (A) 4 k (C) 1.5Q.6A poir with a veloci time. motio	goes from st in fig. $A \xrightarrow{x}{2t} B$ D (c) AD. $\frac{x}{2t}, \frac{3x}{2t}, \frac{x}{t}$	tation A to D through I $3 \frac{x}{t} > C \frac{2x}{t} > D$. Find the a (B)	B, C. The distance and t average speed between $\frac{x}{3t}, \frac{3x}{2t}, \frac{x}{t}$	ime are <i>TOPIC Sk</i> (a) AC To cal average given sp	KILLS: Iculate the velocity in lits of time
(A) $\frac{2x}{3t}$ (C) $\frac{2x}{3t}$ (C) $\frac{2x}{3t}$ (C) $\frac{2x}{3t}$ (C) $\frac{2x}{3t}$ (C) $\frac{2x}{3t}$ (C) $\frac{2x}{3t}$ (A) $\frac{16}{(C)}$ (C) 10 (C) 10 (C) 1.5 (C) 1.5 (C) 4 k (C) 1.5 (C) 4 c (C) 1.5 (C) 1.5 (C	$\frac{x}{2t}, \frac{3x}{2t}, \frac{x}{t}$	(B)	$\frac{x}{3t}$, $\frac{3x}{2t}$, $\frac{x}{t}$		
(C) $\frac{2x}{3t}$ Q.4 If V(t) 3 sec. (A) 16 (C) 10 Q.5 A mar distar (A) 4 k (C) 1.5 Q.6 A poin with a veloci time. motio	$\frac{x}{t}$, $\frac{3x}{t}$, $\frac{x}{t}$				
 Q.4 If V(t) 3 sec. (A) 16 (C) 10 Q.5 A mar distan (A) 4 k (C) 1.5 Q.6 A poin with a veloci time. motio 	•	(D)	$\frac{2x}{3t}, \frac{3x}{2t}, \frac{2x}{t}$		
 (A) 16 (C) 10 Q.5 A mandistan (A) 4 k (C) 1.5 Q.6 A point with a velocit time. motion) = 6t ² + 2t +	\cdot 1, then find the avg s	speed during period t =	0 to t = $\begin{array}{ } & \\ & TOPIC SK \\ & \\ & To calcu$	(ILLS: Jate average
 Q.5 A mar distan (A) 4 k (C) 1.5 Q.6 A poin with a veloci time. motio 	m/s m/s	(B) (D)	8 m/s 22 m/s	velocity calculus.	by applying
 (A) 4 k (C) 1.5 Q.6 A poin with a veloci time. motio 	n travels firs nce with spee	t half distance with s _l ed 2 km/hr. Find Aver	peed 6 km/hr and seco rage speed.	ond half <i>TOPIC SK</i> To calcu	(ILLS: Jate average
Q.6 A poir with a veloci time. motio	km/hr. 5 km/hr	(B)	3 km/hr.	velocity speed co	by distance oncept.
motio	nt travelling a a velocity v _o . ity v ₁ for half The mean ve	along a straight line tr The remaining part of the time and with velo elocity of the point av	raverses one third the d the distance was cover ocity v_2 for the other hal veraged over the whole	listance <i>TOPIC Sk</i> ed with To calcu If of the velocity time of of distar	KILLS : ulate average in given splits nce.
(A) $\frac{1}{3(2)}$	$\frac{v_{o}(v_{1} + v_{2})}{v_{1} + v_{2} + v_{o}}$	(B)	$\frac{3v_{o}(v_{1}+v_{2})}{v_{1}+v_{2}+v_{o}}$		
(C) $\frac{v}{v_1}$	$\frac{v_{0}(v_{1}+v_{2})}{+v_{2}+4v_{0}}$	(D)	$\frac{3v_{o}(v_{1}+v_{2})}{v_{1}+v_{2}+4v_{o}}$		
Q.7 The vertice		ar is given by $\ _V^{}$ = (4t vial displacement of th	: + 2) m/s, where t is the car in time t. = 0.255	he time j. j. j. he time j. j. j. j. j. j. j. j. j. j. j. j. j.	(<i>ILLS</i> : tion of ment applying
(A) 2m	elocity of a c d. Find the to		1.6m	calculus	
	elocity of a c d. Find the to	(B)	0.2 m		

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COM	PETITION BOOKLET	KINEMATICS PHYSIC	CS(FDN)
Q.8	If a car covers $2/5^{th}$ of distance with v_2 then av	the total distance with v_1 speed and 3 erage speed is	/5 th TOPIC SKILLS : Calculation of average speed using distance
	(A) $\frac{1}{2}\sqrt{V_1V_2}$	(B) $\frac{V_1 + V_2}{2}$	split concept.
	(C) $\frac{2v_1v_2}{v_1 + v_2}$	(D) $\frac{5v_1v_2}{3v_1 + 2v_2}$	
Q.9	The relation $3t = \sqrt{3x} + 6$ one direction where is	describes the displacement of a particle in metres and t in sec. The displaceme	e in TOPIC SKILLS : ent, Calculation of velocity & displacement by
	(A) 24 metres	(B) 12 metres	calculus applications.
	(C) 5 metres	(D) Zero	
Q.10	The motion of a particle where a = 15 cm and b sec will be	is described by the equation $x = a + = 3$ cm. Its instantaneous velocity at tim	bt ² <i>TOPIC SKILLS</i> : ne 3 To calculate Instantaneous velocity
	(A) 36 cm/sec	(B) 18 cm/sec	by calculus application.
	(C) 16 cm/sec	(D) 32 cm/sec	
Q.11	A person completes half with speed $\mathbf{n}_{\!_2}$. The aver	of its his journey with speed $\mathbf{n}_{_{\!\!1}}$ and rest I age speed of the person is	half TOPIC SKILLS : To calculate average speed using time split
	(A) $u = \frac{u_1 + u_2}{2}$	(B) $u = \frac{2u_1 u_2}{u_1 + u_2}$	
	(C) $u = \frac{u_1 u_2}{u_1 + u_2}$	(D) $u = \sqrt{u_1 u_2}$	
Q.12	The motion of a body is g	given by the equation	<i>TOPIC SKILLS</i> : Applying calculus &
	$\frac{dv(t)}{dt} = 0$	6.0 – 3v (t)	
	when v (t) is the speed in t = 0 ;	n m/s and t in sec. If the body was at res	tat
	Then, test the correctnes	s of the following results.	I
	(A) the terminal speed is 2.0) m/s.	
	(B) the magnitude of initial	acceleration is 6.0 m/s ² .	
	(D) the speed is 1.0 m/s wh	en the acceleration is half the initial value.	
Q.13	The displacement of a pa s = $2t^2 + 2t + 4$ where s is of the particle is	rticle, moving in a straight line, is given in metres and t in seconds. The accelerat	by <i>TOPIC SKILLS</i> : tion Applying calculus for finding 'a'
	(A) 2 m/s ²	(B) 4 m/s ²	i
	(C) 6 m/s ²	(D) 8 m/s ²	i
Q.14	The position x of a parti acceleration of the partic	cle varies with time t as $x = at^2 - bt^3$. the will be zero at time t equal to	The <i>TOPIC SKILLS</i> : Applying calculus for finding 'a' at given time
	(A) $\frac{a}{b}$	(B) $\frac{2a}{3b}$	't'
	~		
	(C) $\frac{d}{3b}$	(D) Zero	
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39





$/\!/$	ABLES	PHYSICS(FDN)	KINEMATICS	COMPETITION BOOKLET
Q.29	In the previous (A) 1 sec	case, the time taken	(B) 1.5 sec	<i>TOPIC SKILLS</i> : Maximum height by vertically projected
	(C) 2 Sec		(D) 2.5 Sec	body
Q.30	In the previous projection is	case, the total time	taken to come back to the point of	TOPIC SKILLS : Time taken by vertically
	(A) 1.5 sec		(B) 2 sec	projected body
	(C) 2.5 sec		(D) 3 sec	
Q.31	A particle is rele times to fall equ	eased from rest from ual heights h i.e. t ₁ : 1	a tower of height 3h. The ratio of $t_2 : t_3$ is :	 <i>TOPIC SKILLS</i> : Time of flight
	(A) $\sqrt{3}$: $\sqrt{2}$: 1		(B) 3 : 2 : 1	
	(C) 9 : 4 : 1		(D) 1 : $(\sqrt{2} - 1)$: $(\sqrt{3} - \sqrt{2})$	1
Q.32	A balloon is mor a height of h, a in 4 seconds, th	ving vertically with a body is gently releas ne height of the ballo	velocity of 4 m sec ⁻¹ . When it is at ed from it. If it reaches the ground on, when the body is released is : (B) 42.4m	TOPIC SKILLS : Time of descent
	(C) 78.4 m		(D) 82.2 m	
Q.33	If a ball is thr covered during	own vertically upw the last t seconds of	ards with speed u, the distance its ascent is	 <i>TOPIC SKILLS</i> : Vertically projected body
	(A) $\frac{1}{2}$ gt ²		(B) ut - $\frac{1}{2}gt^2$	-
	(C) (u- gt)t		(D) ut	
Q.34	A stone droppe seconds on ear (one upwards a reach the earth	ed from a building o th. From the same l nd other downwards) a surface after t ₁ and	of height h and it reaches after t building if two stones are thrown with the same velocity u and they t_2 seconds respectively, then	TOPIC SKILLS : Vertically projected body
	(A) $t = t_1 - t_2$		(B) $t = \frac{t_1 + t_2}{2}$	1
	(C) $t = \sqrt{t_1 t_2}$		(D) $t = t_1^2 t_2^2$	1
Q.35	Water drops fal ground. The thi touches the gro that instant	l at regular intervals ird drop is leaving th ound. How far above	from a tap which is 5 m above the le tap at the instant the first drop the ground is the second drop at	TOPIC SKILLS : Meeting of vertically projected & freely falling bodies.
	(A) 2.50 m		(B) 3.75 m	
	(C) 4.00 m		(D) 1.25 m	1
Q.36	A body is relea earth. Another second later. T after the releas	ased from a great he body is released fr he separation betwo se of the second body	eight and falls freely towards the om the same height exactly one een the two bodies, two seconds y is	 <i>TOPIC SKILLS</i> : Freely falling body
	(A) 4.9 m	-	(B) 9.8 m	ļ
	(C) 19.6 m		(D) 24.5 m	
- 42 -				COTA 畲 (0744) 6450883, 2405510

СОМ	PETITION BOOKLET	KINEMATICS	PHYSICS(FDN)	ABLES
Q.37	The acceleration of a pa The particle starts fron distance travelled by the	rticle is increasing linearly with t n the origin with an initial velo particle in time t will be	ime t as bt. $ $ TC city v _o . The $ $ From	OPIC SKILLS : eely falling body
	(A) $V_0 t + \frac{1}{3}bt^2$	(B) $V_0 t + \frac{1}{3} b t^3$		
	(C) $v_0 t + \frac{1}{6} b t^3$	(D) $v_0 t + \frac{1}{2}bt^2$		
Q.38	The point from where a coordinate axes. The x arby x = 6t and y = 8t – 5t	ball is projected is taken as the ond nd y components of its displaceme ² . What is the velocity of projectio	origin of the 70 nt are given ar n?	OPIC SKILLS : elocity of projectile at ny point.
	(A) 6 ms ⁻¹	(B) 8 ms ⁻¹		
	(C) 10 ms ⁻¹	(D) 14 ms ⁻¹	i	
Q.39	A bullet is fired from a c projection is 15° and g =	cannon with velocity 500 m/s. If $r = 10 \text{ m/s}^2$, then the range is :	the angle of H pr	OPIC SKILLS : orizontal range of rojectile.
	(A) 25×10^3 m	(B) 12.5×10^3 m		
	(C) 50×10^2 m	(D) 25×10^2 m		
Q.40	A ball is thrown upwards the ground at a distance initial velocity at an angle	at an angle of 60° to the horizonta of 90 m. If the ball is thrown wi a 30°, it will fall on the ground at a	al. It falls on 70 th the same H distance of: pr	OPIC SKILLS : orizontal range of rojectile.
	(A) 120 m	(B) 90 m	i	
	(C) 60 m	(D) 30 m	i	
Q.41	During a projectile motion tal range, then the angle	on if the maximum height equals of projection with the horizontal	the horizon- is : M	OPIC SKILLS : aximum height range projectile
	(A) $\tan^{-1}(1)$	(B) tan ⁻¹ (2)		projectile
	(C) tan ⁻¹ (3)	(D) tan ⁻¹ (4)		
Q.42	A particle is projected horizontal plane is tw acceleration due to gravi	with a velocity v, so that its vice the greatest height attain ity, then its range is :	range on a To ned. If g is M of	DPIC SKILLS : aximum height, range [*] projectile
	$4v^2$	Aa	i	
	(A) $\frac{40}{50}$	(B) $\frac{4g}{5y^2}$		
	59	37		
	(C) $\frac{4v^3}{5g^2}$	(D) $\frac{4v}{5g^2}$		
Q.43	The equation of the traje	ectory of an oblique projectile is		OPIC SKILLS : omparing the equation ith equation of
	У	$v = \sqrt{3} \mathbf{x} - \frac{1}{2} \mathbf{g} \mathbf{x}^2$	pi	rojectile.
	Here, x and y are in metr (A) 0°	re and g is in m/s ² . The angle of pr (B) 90°	rojection is : 	
	(C) 45°	(D) tan⁻¹ √3	i	

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- 43 -

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Q.44	Three particles A same speed. A is	A, B and C are thro thrown straight u	wn from the top of a tower with the o, B is thrown straight down and C is	TOPIC SKILLS : Motion under gravity
	thrown horizont respectively.	ally. They hit the	ground with speeds υ_A , υ_B and υ_C	
	(A) $\upsilon_A = \upsilon_B = \upsilon_C$		(B) $\upsilon_{\rm B} > \upsilon_{\rm C} > \upsilon_{\rm A}$	
	(C) $v_A = v_B > v_C$		(D) $v_A > v_B = v_C$	
Q.45	If wind exerts trajectory of the obstacle for wind	a constant force i e particle dropped d).	n west direction then what is the from top of tower (tower is not an	<i>TOPIC SKILLS</i> : Motion under gravity under the influence of air resistance.
		B	<pre>✓</pre>	
	(A) A		(B) B	1
	(C) C		(D) D	
Q.46	A cart moves w From the cart, a (A) The particle wi (B) The particle wi (C) The particle wi (D) The particle wi	ith a constant spe particle is thrown of Il land somewhere or Il land outside the cir Il follow an elliptical p Il follow a parabolic p	ed along a horizontal circular path. up vertically with respect to the cart. a the circular path. cular path. bath. bath.	 <i>TOPIC SKILLS</i> : Relative motion.
Q.47	A projectile fire R. If the initial then the range	TOPIC SKILLS : Horizontal range of		
	(A) 2R		(B) R/2	projectne.
	(C) R		(D) 4R	
Q.48	An object is th with the horizon equal to-	rown along a dirental direction. The	ection inclined at an angle of 45° horizontal range of the particle is	 <i>TOPIC SKILLS</i> : Range & maximum height of projectile
	(A) Vertical heigh	it 	(B) Twice the vertical height	
Q.49	(C) Inrice the ve	nd the distance o	(D) Four times the vertical height	 TOPIC SKILLS :
	projectile on a are given by y second. The ve	certain planet (v = (8t – 5t²) mete locity with which	with no surrounding atmosphere) or and $x = 6t$ meter, where t is in the projectile is projected is-	Comparision of probalic path of parabola.
	(A) 8 m/sec		(B) 6 m/sec	
	(C) 10 m/sec		(D) Not obtainable from the data	Ì
Q.50	The maximum I Keeping the an increase in hor	neight attained by gle of projection izontal range ?	a projectile is increased by 5%. constant, what is the percentage	TOPIC SKILLS : Projectile motion range
	(A) 5%	3-	(B) 10%	
	(C) 15%		(D) 20%	1
- 44 -				。 (OTA 曾 (0744) 6450883, 2405510 -

COM	PETITION BOOKLET	KINEMATICS	PHYSICS(FI	DN) ARABLES
Q.51	The maximum height at Keeping the angle of p crease in the time of f	tained by a projectile is incorojection constant, what is light ?	reased by 10%. percentage in-	TOPIC SKILLS : Maximum height related with time of bight
	(A) 5%	(B) 10%		night
	(C) 20%	(D) 40%		
Q.52	The velocity of projecti other factors as consta maximum height attain	on of a body is increased nt, what will be percentag ed ?	by 2%. Keeping e change in the	<i>TOPIC SKILLS</i> : Concept of velocity & Maximum height
	(A) 1%	(B) 2%		
	(C) 4%	(D) 8%		
Q.53	In the above question, time of flight ?	what will be the percentag	e change in the	<i>TOPIC SKILLS</i> : Concept of velocity &
	(A) 1%	(B) 2%		Time of Height.
	(C) 4%	(D) 8%		
Q.54	In the above question, range of projectile ?	what will be the percentag	e change in the	<i>TOPIC SKILLS</i> : Range of projectile.
	(A) 1%	(B) 2%		
	(C) 4%	(D) 8%		
Q.55	A bomb is dropped fr constant speed. When the bomb-	om an aeroplane moving air resistance is taken int	horizontally at o consideration,	<i>TOPIC SKILLS</i> : Relative motion & horizontal projectile
	(A) Falls to earth exactly(B) Falls to earth behind to(C) Falls to earth abead of	below the aeroplane the aeroplane of the aeroplane		
	(D) Flies with the aeropla	ne.		
Q.56	A stone is just released a horizontal straight tra a :	d from the window of a tra ack. The stone will hit the g	in moving along ground following	<i>TOPIC SKILLS</i> : Relative motion & horizontal projectile
	(A) Straight line path	(B) Circular path		
	(C) Parabolic path	(D) Hyperbolic pa	th	
Q.57	When a particle is throw projectile at any time t	vn horizontally, the resultan t is given by :	nt velocity of the	<i>TOPIC SKILLS</i> : Horizontal projectile.
	(A) gt	(B) $\frac{1}{2}$ gt ²		
	(C) $\sqrt{u^2 + g^2 t^2}$	(D) $\sqrt{u^2 - g^2 t^2}$		
Q.58	Two paper screens A an A and then B. The hole bullet is travelling hori velocity of the bullet a	d B are separated by 150 m. in B is 15 cm below the H zontally at the time of hit t A is : (g = 10 ms ⁻²)	A bullet pierces nole in A. If the ting A, then the	<i>TOPIC SKILLS</i> : Projectile motion velocity at any point
	(A) 100 √3 ms ⁻¹	(B) $200\sqrt{3}$ ms ⁻¹		
	(C) $300\sqrt{3}$ ms ⁻¹	(D) $500\sqrt{3}$ ms ⁻¹		

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- 45 -

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Q.59	A particle is pro horizontal from particle strikes	jected with a certain v the foot of an inclined the plane normally the	elocity at an angle α above the l plane of inclination 30°. If the n α is equal to :	TOPIC SKILLS : Projectile on inclined plane
	(A) 30° + tan ⁻¹) 45°	•
	(C) 60°	(D) 30° + tan ⁻¹ (2√ 3)	
Q.60	A particle is thro projectile mak projectile to rea AB is equal to-	own on a plane inclined ses angle of 60° with sch from A to B on inclir	at an angle of 30° such that the h ground. Time taken by the hed plane is t. Then the distance	TOPIC SKILLS : Projectile on inclined plane

(A) $\frac{ut}{\sqrt{3}}$	(B) $\frac{\sqrt{3} ut}{2}$
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(C) $\sqrt{3}$ ut (D) 2ut

ANSWERKEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	А	В	Α	D	В	D	С	D	D	В	В	All	В	С	С
Que.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Ans.	А	В	Α	С	С	D	С	А	В	А	С	D	В	А	В
Que.	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Ans.	D	Α	Α	С	В	D	С	С	В	В	D	Α	D	А	В
Que.	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Ans.	B,D	D	D	С	Α	А	С	В	С	В	С	С	D	А	А



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47 ·

	ABLES PHYSICS(FDN) KINE	EMATICS COMPETITION BOOKLET
Q.6	The displacement of a particle is given by y = a The initial velocity and acceleration are respectiv	+ bt + ct² – dt⁴. <u>Notes</u>
	(A) b, – 4d	
	(B) – b, 2c	
	(C) b, 2c	
	(D) 2c, – 4d	
Q.7	Acceleration of a particle changes when-	
	(A) Direction of velocity changes	i
	(B) Magnitude of velocity changes	Ì
	(C) Both of above	
	(D) Speed changes	
Q.8	The average velocity of a body moving with unifor travelling a distance of 3.06 m is 0.34 ms ⁻¹ . If the cl of the body is 0.18 ms ⁻¹ during this time, its unifor is-	orm acceleration hange in velocity orm acceleration
	(A) 0.01 ms ⁻²	
	(B) 0.02 ms ⁻²	
	(C) 0.03 ms ⁻²	
	(D) 0.04 ms ⁻²	
Q.9	The displacement x of a particle varies with time be ^{bt} , where a, b, a and b are positive constants. Th particle will-	t as x = ae ^{-at} + e velocity of the
	(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	
Q.10	A car, starting from rest, accelerates at the rate f th S, then continues at constant speed for time t and	rough a distance then decelerates
	at the rate $\frac{f}{2}$ to come to rest. If the total distance S, then-	e traversed is 15
	$(A) S = \frac{1}{2} ft^2$	
	$(B) S = \frac{1}{4} ft^2$	
	(C) S = $\frac{1}{72}$ ft ²	
	$(D) S = \frac{1}{6} ft^2$	
Q.11	A particle moves along x-axis as $x = 4(t - 2) + a(t - 2)$	t – 2) ² . Which of
	(A) The initial velocity of particle is 4	
	(B) The acceleration of particle is 2a	
	(C) The particle is at origin at $t = 0$	
	(D) None of these	
10		

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COM	PETITION BOOKLET	KINEMATICS	PHYSICS(FDN)	ABLES
Q.12	A body starting from ratio of distance cover covered in 5 sec is-	rest moves with constant red by the body during th	acceleration. The he 5th sec to that	<u>Notes</u>
	(A) $\frac{9}{25}$			
	(B) $\frac{3}{5}$			
	(C) $\frac{25}{9}$			
	(D) $\frac{1}{25}$			
Q.13	What determines the n (A) Speed (B) Velocity (C) Accelerati (D) None of t	nature of the path followed on hese	d by the particle ? 	
Q.14	A body is slipping from If the angle of inclinati from the top to the bo	a an inclined plane of heigon is θ , the time taken by ottom of this inclined plan	ht h and length ℓ. the body to come e is-	
	(A) $\sqrt{\frac{2h}{g}}$			
	(B) $\sqrt{\frac{2\ell}{g}}$			
	(C) $\frac{1}{\sin\theta} \sqrt{\frac{2h}{g}}$			
	(D) sin $\theta \sqrt{\frac{2h}{g}}$			
Q.15	A very large number of succession in such a way one is at the maximun number of balls thrown	balls are thrown vertically that the next ball is thrown height. If the maximum per minute is (take g = 10	y upwards in quick when the previous height is 5m, the 0 ms ⁻²).	
	(A) 120			
	(B) 80 (C) 60		1	
	(D) 40		i	
Q.16	The acceleration due acceleration due to gra 2m on the surface of person on the planet B	to gravity on the planet vity on planet B. A man ju A. What is the height of _ 3-	A is 9 times the mps to a height of jump by the same	
	(A) 18m			
	(B) 6m			
	(C) $\frac{2}{3}$ m			
	(D) $\frac{2}{9}$ m			
			I	

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- 49 —

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	ABLES PHYSICS(FDN) KINEMATI	CS COMPETITION BOOKLE
Q.17	A body falls from rest in the gravitational field of the distance travelled in the fifth second of its $(q = 10 \text{ m/s}^2)$	e earth. The <u>Notes</u> motion is
	(A) 25m	i
	(B) 45m	i
	(C) 90m	I
	(D) 125m	
Q.18	A ball is released from the top of a tower of height h takes T seconds to reach the ground. What is the pos ball in T/3 seconds ?	n meters. It ition of the
	(A) h/9 meters from the ground	I
	(B) 7h/9 meters from the ground	
	(C) 8h/9 meters from the ground	
	(D) 17h/18 meters from the ground	
Q.19	When a ball is thrown up vertically with velocity $V_{o'}$ i maximum height of 'h'. If one wishes to triple the maxi then the ball should be thrown with velocity-	it reaches a mum height
	(A) $\sqrt{3} V_{o}$	
	(B) 3V ₀	Ì
	(C) 9V ₀	
	(D) 3/2V ₀	
Q.20	A parachutist, after bailing out falls 50m without frie parachute opens, it decelerates at 2m/s ² . He reaches with a speed of 3m/sec. At what height did he bail ou	tion. When the ground it ?
	(A) 293 m	
	(B) 111 m	
	(C) 91 m	
	(D) 182 m	Ì
Q.21	A 210 meter long train is moving due North at a speed A small bird is flying due South a little above the train 5m/s. The time taken by the bird to cross the train is	of 25 m/s. with speed S-
	(A) 6s	ĺ
	(B) 7s	
	(C) 9s	
	(D) 10s	
Q.22	A police jeep moving with velocity of 45 km/h is chasir another jeep moving with velocity of 153 km/h. Police f with muzzle velocity of 180 m/s. The velocity with w strike the car of the thief is-	ng a thief in ires a bullet /hich it will
	(A) 150 m/s	
	(B) 27 m/s	
	(C) 450 m/s	ĺ
	(D) 250 m/s	
Q.23	A train of 150 meter length is going towards north di speed of 10m/sec. A parrot flies at the speed of 5m/s south direction parallel to the railway track. The time t parrot to cross the train is-	rection at a sec towards aken by the
- 50 -		B-A, TALWANDI, KOTA ☎ (0744) 6450883, 2405510



	ABLES PHYSICS(FDN)	KINEMATICS	COMPETITION BOOKLET
			Notes
	(A) $\sqrt{\frac{2}{2}}$		
	V3		
	(B) $\frac{2}{\sqrt{3}}$		
	(C) $\sqrt{\frac{3}{2}}$		
	(D) $\frac{\sqrt{3}}{2}$		
Q.29	At what point of a projectile motion, ac perpendicular to each other-	celeration and velocity are	
	(A) At the point of projection		
	(B) At the point of drop		
	(C) At the topmost point		i
	(D) Any where in between the popoint.	int of projection and topmost	
Q.30	A ball is rolled off the edge of a horizont second. It hits the ground after 0.4 seco below is true-	al table at a speed of 4 m/ nd. Which statement given	
	(A) It hits the ground at a horizon edge of the table.	tal distance of 1.6 m from the	
	(B) The speed with which it hits	the ground is 4.0 m/sec.	
	(C) Height of the table is 0.4 m.		
	(D) It hits the ground at an angle	e of 60° to the norizontal.	
Q.31	A particle (A) is dropped from a height thrown in horizontal direction with speed height. The correct statement is-	and another particle (B) is of 5 m/sec from the same	
	(A) Both particles will reach the g	ground simultaneously	
	(B) Both particles will reach the	ground with same speed	1
	(C) Particle (A) will reach the ground	I first with respect to particle (B)	1
	(D) Particle (B) will reach the ground	I first with respect to particle (A)	
Q.32	At the height 80 m, an aeroplane is mov is dropped from it so as to hit a target. target should the bomb be dropped (giv	ing with 150 m/s. A bomb At what distance from the en g = 10 m/s ²)	
	(A) 605.3 m		1
	(B) 600 m		I
	(C) 80 m		1
	(D) 230 m		
Q.33	A bomber plane moves horizontally with bomb released from it strikes the ground it strikes the ground will be (g = 10 m/	a speed of 500 m/s and a I in 10 sec. Angle at which ′s²)	
			1

COM	PETITION BOOKLET	KINEMATICS	PHYSICS(FDN)	ABLES
				Notes
	(A) tan ⁻¹			
	(B) tan ⁻¹ 10 (B) tan ⁻¹			
	(C) tan-1 (1)			
	(D) tan ⁻¹ (5)			
Q.34	A rifle shoots a bullet w small target 400 m away bullet must be aimed to	vith a muzzle velocity o . The height above the ta hit the target is : (g =	f 400 m/sec at a a arget at which the 10 ms ⁻²)	
	(A) 1m (B) 5m			
	(C) 7m			
	(D) 10m			
Q.35	A grasshopper can jump m time on the ground. How	aximum distance 1.6m. I far can it go in 10 secon	t spends negligible ds ?	
	(A) 5 √2 m			
	(B) 10√2 m			
	(C) 20√2 m			
	(D) 40√2 m			
Q.36	A boy throws a ball with a At the same instant he statthe ball before it hits the a velocity of- (A) $V_o \cos \alpha$ (B) $V_o \sin \alpha$ (C) $V_o \tan \alpha$ (D) $\sqrt{V_o^2 \tan \alpha}$	n velocity V _o at an angle (arts running with uniforr ground. To achieve this, l	to the horizontal. n velocity to catch he should run with 	
Q.37	A ball is projected with v The velocity of the ba perpendicular to its initi	velocity v_0 at an angle θ III at the instant whe al direction of motion is	with the ground. n its velocity is	
	(A) $\frac{v_0}{\cos\theta}$			
	(B) $\frac{v_0}{\sin\theta}$			
	(C) v_0 tan θ			
	(D) $v_0 \cot \theta$		İ	
Q.38	A large number of bullets speed v. What is the may bullets will spread-	s are fired in all direction kimum area on the groui	ons with the same nd on which these 	
ABLE	S, 588-A, TALWANDI, KOTA 🕿 (074	44) 6450883, 2405510		53

$/\!/$	APABLES	PHYSICS(FDN)	KINEMATICS	COMPETITION BOOKLET
		2		Notes
	(A) ⁻	g		
	(B) ²	$\frac{\tau v^4}{g^2}$		
	(C)	$\frac{\tau^2 v^4}{g^2}$		
	(D) -	$\frac{\tau^2 v^2}{g^2}$		
Q.39	If the maximum height attained	n horizontal range for by it is	a projectile is R, the greatest	
	(A) 4 (B) R	R /2		
	(C) 2 (D) E	R		
Q.40	The velocity at velocity u. Its i	the maximum height of ange on the horizonta	f a projectile is half of its initial I plane is	
	(A) ²	$\frac{2u^2}{3g}$		
	(B) -	$\frac{u^2}{g}$		
	(C) -	$\frac{\sqrt{3}u^2}{g}$		
	(D)	$\frac{1^2}{3g}$		
Q.41	A particle is pro appears to have The initial velo	jected at an angle of el an angle of elevation b city will be-	levation a and after t seconds it as seen from point of projection.	
	(A) $\frac{1}{2}$	$\frac{\text{gt}}{\sin(\alpha-\beta)}$		
	(B) <u>-</u> 2	$\frac{\operatorname{gt}\cos\beta}{\sin\left(\alpha-\beta\right)}$		
	(C) ⁵	$\frac{\sin(\alpha-\beta)}{2gt}$		
	(D) ²	$\frac{2\sin(\alpha-\beta)}{\operatorname{gt}\cos\beta}$		
Q.42	A ball rolls off t If the steps are edge of the nth	he top of a stair way w h metres high and b m step, if-	rith a horizontal velocity u m/s. netres wide, the ball will hit the	

— 54 ——

СОМ	PETITION BOOKLET	KINEMATICS PI	HYSICS(FDN)	ABLES	
	(A) $n = 2hu/gb^2$ (B) $n = 2hu^2 / gb$ (C) $n = 2hu^2 / gb$ (D) $n = hu^2 / gb^2$	2		<u>Notes</u>	
Q.43	If a particle follows the t	trajectoryy = $x - \frac{1}{2} x^2$, then the	time of		
	flight is :				
	(A) $\frac{1}{\sqrt{g}}$				
	(B) $\frac{2}{\sqrt{g}}$				
	(C) $\frac{3}{\sqrt{g}}$		i I I		
	(D) $\frac{4}{\sqrt{g}}$				
Q.44	At a certain moment of tim the acceleration a of a par ferred about its motion at t (A) It is curvilinear (B) It is rectilinear (C) It is curvilinea (D) It is rectilinear	he, the angle between velocity vector rticle, is greater than 90°. What can hat moment? r and decelerated and accelerated r and accelerated and decelerated	or v and n be in- 		
Q.45	A particle moves in the XY y = a (1 - cos w t), where a the particle is (A) a parabola (B) a straight line (C) a circle (D) an ellipse.	plane according to the law x = asin and w are constants. Then, the traje equally inclined at x and y-axes	wt and ectory of 		
Q.46	A particle is thrown with a When the particle makes changes to υ .	speed u at an angle ${f q}$ with the horal an angle ${f f}$ with the horizontal, it	rizontal. s speed 		
	(A) $\upsilon = u\cos\theta$		i		
	(B) $\upsilon = u\cos\theta$. co	Sф			
	(C) $\upsilon = u\cos\theta$. s	eco			
	(D) $v = usec \theta. c$	ΟSφ	i		
Q.47	From the top of a tower of the horizontal direction w distance x from the tower top of another tower of he falls on the ground at a d velocity of the second boo	height h, a body of mass m is project ith a velocity v. It falls on the grou if a body of mass 2m is projected f ight 2h in the horizontal direction s listance 2x from the tower, the ho dy is-	ected in und at a from the o that it prizontal		
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Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	D	Α	Α	В	С	С	С	В	D	С	В	Α	D	С	С
Que.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Ans.	Α	В	С	А	Α	В	Α	D	В	D	Α	D	С	С	А
Que.	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Ans.	А	А	Α	В	С	А	D	В	D	С	В	В	В	А	С
Que.	46	47	48												
Ans.	С	В	В												

COMPETITION BOOKLET

KINEMATICS

EXERCISE#3

ONE OR MORE CORRECT OPTION TYPE :

- Q.1 A particle is moving in XY plane. At t = 0, it is located at the origin O(0, 0)and has the velocity vector $v_0 = a(\sqrt{3}\hat{i} + \hat{j})$, where 'a' is a positive constant and $\hat{\mathbf{j}}$, $\hat{\mathbf{j}}$ are unit vectors in the positive direction of the x and y axes. Its acceleration is a constant and is given by $\vec{a} = -\frac{1}{3}\hat{i} + \hat{j}\hat{k}$. In its subsequent motion (t > 0) it will cross the x-axis at the instant of time given by : [a > 0] (A) t = a (B) t = $\sqrt{3}$ a (C) t = 2a (D) t = 4a Q.2 A stone is projected from ground. Its path is as shown in figure. At which point its speed is decreasing at fastest rate ? (A) A (B) B (C) C
 - (D) D

Q.3 A particle moves with an initial velocity v_0 and retardation **b**v, where v is its velocity at any time t.

- (a) The particle will cover a total distance of v₀ / β .
- (b) The particle will continue for a very long time.
- (c) The particle will stop shortly
- (d) The velocity of particle will become v_0 / 2 after time 1/ β .
 - (A) a, b
 - (B) a, b, d
 - (C) a, c
 - (D) None of these.
- Q.4 A particle travels along a straight path covers one-third of total distance with velocity v_0 and remaining $\frac{2}{3}$ rd with velocity v_1 for half the time and velocity v_2 for other half of the time. The mean velocity averaged over whole of the distance is :

Notes

ABLES PHYSICS(FDN)	KINEMATICS	COMPETITION BOOKLET
(A) $\frac{3v_0(v_1+v_2)}{(v_1+v_2+4v_0)}$		Notes
(B) $\frac{3v_0v_1v_2}{(v_1+v_2+v_0)}$		
(C) $\frac{v_0(v_1 - v_2)}{(v_1 + v_2 + v_0)}$		
$v_{0}(v_{1}+v_{2})$		

- (D) $\frac{v_0 v_1}{(v_1 + v_2 + v_0)}$
- Q.5 Three persons P, Q, R are at the three corners of an equilateral triangle of each side *I*. They start moving simultaneously with velocity v such that P always moves towards Q, Q always moves towards R and R always moves towards P. After what time they would meet each other at O ?



Q.6 A particle moves in a straight line with the velocity as shown in the fig. At t = 0, x = - 16 m-



- (a) The maximum value of the position coordinate of the particle is 54 m.
- (b) The maximum value of the position coordinate of the particle is 36 m.
- (c) The particle is at the position of 36 m at t = 18 sec.
- (d) The particle is at the position of 36 m at 30 sec.
 - (A) a, c, d
 - (B) a, b, c
 - (C) a, b, d
 - (D) b, c, d





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59



Q.11 A particle starts from origin accelerates for t sec then decelerates with same acceleration till $2t_0$ sec along the x-direction. The graph representing variation of displacement (x) with time (t) is-



Q.12 A particle having a velocity $v = v_0$ at t = 0 is decelerated at the rate | a | = $\alpha \sqrt{v}$, where α is a positive constant-

- (A) The particle comes to rest at t = $\frac{2\sqrt{v_0}}{c}$
- (B) The particle will come to rest at infinity.
- (C) The distance traveled by the particle is $\frac{v_0^{3/2}}{\alpha}$
- (D) The distance traveled by the particle is $\frac{2}{3} \frac{v_0^{3/2}}{\alpha}$
- Q.13 Initially car A is 10.5 m ahead of car B. Both start moving at time t = 0 in the same direction along a straight line. The velocity time graph of two cars is shown in figure. The time when the car B will catch the car A, will be-





Notes



(A) $t = 21 \sec^{-1}{100}$

(B) t = $2\sqrt{5}$ sec

- (C) 20 sec
- (D) None of these
- Q.14 A particle is at angle 60° with speed 1003, from the point 'A' as shown in the figure. At the same time the wedge is made to move with speed 1003 towards right as shown in the figure. Then the time after which particle will strike with wedge is -



- (A) 2 sec(B) 2√3 sec
- (C) $\frac{4}{\sqrt{3}}$ sec (D) None
- Q.15 A body is projected at time (t = 0) from a certain point on a planet's surface with a certain velocity at a certain angle with the planet's surface (assumed horizontal). The horizontal and vertical displacement x & y

(in meter) respectively vary with time t in second as, x = $10\sqrt{3}$ t and

 $y = 10t - t^2$. Then the maximum height attained by the body is-

- (A) 200 m
- (B) 100 m
- (C) 50m
- (D) 25 m

Q.17

Q.16 In the figure shown, the two projectiles are fired simultaneously. The minimum distance between them during their flight is-

 $20\sqrt{3} \text{ m/s}$ $20\sqrt{3} \text{ m/s}$ 20 m/s (A) 20 m $(B) 10\sqrt{3} \text{ m}$ (C) 10 m (D) NoneA projectile moves from the ground such that its horizontal displacement is x = Kt and vertical displacement is y = Kt(1 - at),

displacement is x = Kt and vertical displacement is y = Kt(1 - at), where K and a are constants and t is time. Find out total time of flight (T) and maximum height attained (Y_{max}) its

ABLES, 588-A, TALWANDI, KOTA 🖀 (0744) 6450883, 2405510

	ABLES PHYSICS(FDN)	KINEMATICS	COMPETITION BOOKLET
	K K		Notes
	(A) $I = \alpha$, $Y_{max} = \frac{1}{2\alpha}$		
	(B) T = $\frac{1}{\alpha}$, Y _{max} = $\frac{2K}{\alpha}$		
	(C) T = $\frac{1}{\alpha}$, Y _{max} = $\frac{K}{6\alpha}$		
	(D) T = $\frac{1}{\alpha}$, Y _{max} = $\frac{K}{4\alpha}$		
Q.18	A particle is projected with velocity V_0 a on the particle is proportional to the squ origin i.e. $a = ax^2$, the distance at which	long x-axis. The deceleration uare of the distance from the 1 the particle stops is	
	(A) $\sqrt{\frac{3V_0}{2\alpha}}$		
	(B) $\left(\frac{3V_0}{2\alpha}\right)^{\frac{1}{3}}$		
	(C) $\sqrt{\frac{2V_0^2}{3\alpha}}$		
	$(D) \left(\frac{3V_0^2}{2\alpha}\right)^{\frac{1}{3}}$		
0.40			
0.19	a height H at instants t_1 and t_2 seconds due height attained is (g is acceleration due	uring its flight. The maximum to gravity)	
	(A) $\frac{g(t_2 - t_1)^2}{8}$		
	(B) $\frac{g(t_1 + t_2)^2}{4}$		
	(C) $\frac{g(t_1 + t_2)^2}{8}$,
	(D) $\frac{g(t_1 - t_1)^2}{4}$		1
Q.20	Which of the following is the graph b projectile and time (t), when it is projec	etween the height (h) of a cted from the ground	
	h t		
	(A) (A) (A)		
- 62			。 XOTA 畲 (0744) 6450883, 2405510 一



ABLES, 588-A, TALWANDI, KOTA 🖀 (0744) 6450883, 2405510 -

//	AABLES	PHYSICS(FDN)	KINEMATICS	COMPETITION BOOKLET
	PASSAGE TYPE :			Notes
PAS	SAGE 1			
A pai	rticle starts from res rds ard a in m /s .	st with a time varying acce	eration a= (2t – 4). Here t is in	1
Q.22	Particle comes t	o rest after a time t =	second.	İ
	(A) I (B) 4			1
	(D) 4 (C) 3			
	(D) 2			1
Q.23	Maximum veloci	ty of particle in negative	direction is at t =seconds.	1
	(A) 3			i
	(B) 4			i
	(C) 2 (D) 1			ĺ
Q.24	The velocity tim	e graph of the particle is	·	1
	(A) Parabo	ola passing through origin		
	(B) Straig	ht line not passing through o	prigin	
	(C) Parabo	ola not passing through orig	in	l
	(D) Straig	ht line passing through origi	n.	
PAS	SAGE 2			i
Wher comp rema	n you throw a ball in ponent of velocity at ins unchanged.	air with some velocity at sa highest point is zero and l	ne angle with horizontal, vertical norizontal component of velocity	
Ques	tion : Velocity of a p	rojectile at height 15 m fror	n ground is $(20\hat{i}+10\hat{j})$ m/s. Here,	1
î is i	in horizontal directio	n and \hat{j} is vertically upward	ls. Then:	1
Q.25	Speed with whic (A) 30	h particle is projected fr	om ground ism/s.	1
	(B) 20√ <u>2</u>			
	(C) √ <u>20</u>			1
	(D) 3 √40			ĺ
Q.26	Angle of project	ile with ground is		1
	(A) 45°			
	(B) 30 ⁰			
	(C) 25° (D) 60°			1
Q.27	Maximum height	from the ground is	m	
	(A) 30			
	(B) 60			
	(C) 40			
	(D) 20			l I
Q.28	Horizontal range (A) 60	e on the groun ism		
	(B) 50			i
	(C) 80			i
	(D) 70			İ
- 64 -				XOTA 畲 (0744) 6450883, 2405510 -

COM	PETITION BOOKLET	KINEMATICS	PHYSICS(FDN)	ABLES	
	ASSERTION - REASON TYPE QUESTI	ONS		Notes	
	 The following questions consist of the another labelled Reason (R) from the codes given below : (A) Both A and R are true and R (B) Both A and R are true but R (C) A is true but R is false (D) A is false but R is true. (E) A and R both are false. 	of two statements one labelled As: . Select the correct answers to the R is the correct explanation of A. is not correct explanation of A	sertion (A) and hese questions		
Q.29	Assertion : When $t = \sqrt{x} + 3$, the	motion is constantly accelerated r	notion.		
	Reason : The second derivative of	of x in this case will be a constant	with time.		
Q.30	Assertion : In a free fall, weight	of a body becomes effectively ze	ro.		
	Reason : Acceleration due to gra	avity acting on a body having free	fall is zero.		
Q.31	Assertion : An object can have con (Instantaneous).	nstant speed (Instantaneous) but v	variable velocity		
	Reason : Speed is a scalar but v	elocity is a vector quantity.			
Q.32	Assertion : In projectile motion, a acceleration at the highest point is	the angle between the instantanec s 180º.	ous velocity and		
	Reason : At the highest point, ve only	elocity of projectile will be in horiz	zontal direction		
Q.33	Assertion : When range of a proj 45° or 135°.	ectile is maximum, its angle of pro	ojection may be		
	Reason : Whether θ is 45° 135°, changes.	value of range remains the same	e, only the sign 		

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ABLES PHYSICS(FDN)

KINEMATICS

COMPETITION BOOKLET

Notes

MATRIX MATCH TYPE :

Q.34 Column I gives some graphs for a particle moving along x-axis in positive x-direction. The variables v, x and t represent speed of particle. xcoordinate of particle and time respectively. Column I gives certain resulting interpretation. Match the graphs in column I with the statements in column II.





	Column I		Column I I
(A)	Acceleration at $t = 2$ sec.	(p)	$\beta + 5\gamma$
(B)	Average velocity during 3rd sec.	(q)	2γ
(C)	Velocity at t = 1 sec.	(r)	α
(D)	Initial displacement	(s)	$\beta + 2\gamma$

COMPETITION BOOKLET

KINEMATICS

PHYSICS(FDN)

Notes

Q.36 A particle is projected with velocity 20 $\sqrt{2}$ m/s at 45° with horizontal. After is (g = 10 m/s²) match the following table :

	Column I	Column II
(A)	Average velocity	(p) 10√5 m/s
(B)	Change in velocity	(q) 25 m/s
(C)	Instantaneous velocity	(r) 10 m/s
		(s) None

Q.37 The projectile collides perpendicularly with the inclined plane. (Refer the figure)

	$ \begin{array}{c} \beta \\ \alpha \end{array} \rightarrow $		
	Column I		Column I I
(A)	Maximum height attained by the	(p)	zero
	projectile from the ground.		
(B)	Maximum height attained by the	(q)	g
	projectile from inclined plane.		
(C)	Acceleration of the projectile before	(r)	$\frac{u^2 \sin^2 \beta}{2g \cos \alpha}$
(D)	Horizontal component of acceleration	(s)	$\frac{u^2 \sin^2(\alpha + \beta)}{2g}$

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Ans.	С	Α	Α	Α	D	Α	С	Α	D	D	С	A,C	Α	Α	D	
Que.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Ans.	С	D	D	С	С	D	В	С	Α	В	Α	D	С	Α	С	
Que.	31	32	33													
Ans.	Α	Е	А													
Que.		;	34	35			36			37						
Ans.	A-q,s	B-p	C-p	D-q,r	A-q	B-p	C-s	D-r	A-q	B-r	C-r		A-s	B-r	C-q	D-p

ANSWERKEY

//	ABLES	PHYSICS(FDN)	KINEMATICS	COMPETITION BOOKLET
		Notes		
Q.1	Speed of two ic ratio of the res from that insta (A) 1 : 1 (B) 1 : 4 (C) 1 : 8 (D) 1 : 1	Jentical cars are u and pective distance in wh nt is 6	I 4u at a specific instant. The hich the two cars are stopped [AIEEE 2002]	
Q.2	Two balls A and building. A, thro with velocity V (A) Veloc (B) Veloc (C) Both (D) None	d B of same masses an own upward with veloci , then ity of A is more than B a ity of B is more than A a A & B strike the ground of these	the thrown from the top of the ity V and B, thrown downward [AIEEE 2002] at the ground at the ground with same velocity	
Q.3	A ball is projec horizontal. At t will be (A) Zero	ted with kinetic energ he highest point durin	gy E at an angle of 45° to the g its flight, its kinetic energy [AIEEE 2002]	
	(B) E/2			
	(C) E/√2			
	(D) E			
Q.4	In a projectile	motion, velocity at ma	aximum height is	1
			[AIEEE 2002]	
	(A) $\frac{u\cos}{2}$	$\underline{\theta}$		
	(B) ucose	1		
	(C) $\frac{u\cos}{2}$	$\overline{\Theta}$		
	(D) None	of these		
	(2) 110110			
Q.5	A ball is releas takes T second ball in T/3 sec (A) h/9 n (B) 7h/9 (C) 8h/9 (D) 17h/7	ed from the top of a s to reach the ground onds neters from the ground meters from the ground meters from the ground 18 meters from the groun	tower of height h meters. It . What is the position of the [AIEEE 2004] nd	
Q.6	For a given velo of projection. If	city, a projectile has the t_1 and t_2 are the times	e same range R for two angles of flight in the two cases then [AIEEE 2004]	
	(A) $t_1 t_2 \propto$	R ²		
	(B) t ₁ t ₂ ∝	R		İ
	(C) t₁t₂ ∝	<u>1</u>		
	12	к 1		1
	(D) $t_1 t_2 \propto$	$=\frac{1}{R^2}$		
- 68				(OTA 🖀 (0744) 6450883, 2405510 -

CON	IPETITION BOOKLET	KINEMATICS	PHYSICS(FDN	ABLES
Q.7	A bullet fired into a pentrating 3 cm. How to rest assuming that	fixed target loses half of i much further it will penetra it faces constant resistance	ts velocity after te before coming to motion.	Notes
	(A) 1.5 cm			
	(B) 1.0 cm			
	(C) 3.0 cm			
	(D) 2.0 cm			
Q.8	The relation between ti b are constants. The r	me and distance is $t = Ax^2 + etardation$ is	bx, where a and	
			[AIEEE 2005]	
	(A) 2αν ³			
	(B) 2βv ³			
	(C) $2\alpha\beta v^3$			
	(D) $2\beta^2 v^3$		i i	
Q.9	A car, starting from res S, then continues at co	t, accelerates at the rate f th nstant speed for time t and	rough a distance then decelerates	
	at the rate $\frac{f}{2}$ to come	to rest. If the total distance	e traversed is 15	
	S, then		[AIEEE 2005]	
	(A) S = $\frac{1}{2}$ ft ²			
	$(B) S = \frac{1}{4} ft^2$			
	(C) S = $\frac{1}{72}$ ft ²			
	(D) S = $\frac{1}{6}$ ft ²			
Q.10	A parachutist after bal parachute opens, it de with a speed of 3 m/s	lling out falls 50 m without celerates at 2 m/s². He rea . At what height, did he ba	frinction. When ches the ground il out	
			[AIEEE 2005]	
	(A) 293 m			
	(B) 111 m			
	(C) 91 m			
	(D) 182 m		İ	
Q.11	A particle located at	x = 0, starts moving alo	ng the positive	
	x-direction with a v	$\mathbf{v} = \alpha \sqrt{X}$. the		
	displacement of the pa	rticle varies with time as	[AIEEE 2006]	
	(A) t			
	(B) t ^{1/2}			
	(C) t ³			
	(D) t ²			
			i	
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	ABLES	PHYSICS(FDN)	KINEMATICS	COMPETITION BOOKLET
Q.12	The velocity of at t = 0, then	Notes		
			[AIEEE 2007]	
	(A) v ⁰ +	2g + 3f		
	(B) v ₀ +	g/2 + f/3		
	(C) V ₀ +	g + f		
	(D) v ₀ +	g/2 + f		
Q.13	A body is a res	t at $x = 0$. At $t = 0$, it so a constant acceleration	starts moving in the positive	

x-direction with a constant acceleration. At the same instant another body passes through x = 0 moving in the positive x-direction with a constant speed. The position of the first body is given by $x_1(t)$ after time 't' and that of second body by $x_2(t)$ after the same time interval. Which of the following graphs correctly describes $(x_1 - x_2)$ as a function of time t.

[AIEEE 2008]








COM	PETITION BOOKLET KIN	IEMATICS	PHYSICS(FDN)	ABLES
Q.14	A particle has an initial velocit	by of $3\hat{i} + 4\hat{j}$ and an accele	eration of	Notes
	0.4 \hat{i} + 0.3 \hat{j} . Its speed after 10 s (A) 10 units (B) $7\sqrt{2}$ units (C) 7 units (D) 8.5 units	is [AIE	EE 2009] 	
Q.15	An object, moving with a speed	l at a rate		
	given by : $\frac{dv}{dt} = -2.5\sqrt{v}$			
	where v is the instantaneous spectrum to rest, would be : (A) 2s (B) 4s (C) 8s (D) 1s	ed. The time taken by the [AIEEE	object, to 2011] 	
Q.16	A water fountain on the ground speed of water coming out of the the fountain that gets wet is :	sprinkles water all around e fountain is v, the total are [All	it. If the ea around EEE2011]	
	(A) $\pi \frac{v^4}{g^2}$			
	(B) $\frac{\pi}{2} \frac{v^4}{g^2}$			
	(C) $\pi \frac{v^4}{g^2}$			
	(D) $\pi \frac{v^4}{g}$			
Q.17	A small block slides, without fring from rest. Let S _n be the distance	ction, down an inclined plan e travelled from t = (n – 1	ne starting) seconds	
	to t = (n) second. Then $\frac{S_n}{S_{n+1}}$ is	: [IIT 2004] 	
	(A) $\frac{2n-1}{2n}$			
	(B) $\frac{2n+1}{2n-1}$			
	(C) $\frac{2n-1}{2n+1}$			
	(D) $\frac{2n}{2n+1}$			
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	ABLES	PHYSICS(FDN)	KINEMATICS	COMPETITION BOOKLET
(C)	The object is atta massless spring o The other end of ceiling of an eleva rest. The elevator constant accelera object is observed the period it main	ched to one end of a f a given spring constant. the spring is attached to the ator. Initially everything is at starts going upwards with a attion a. The motion of the d from the elevator during attains this acceleration.	(r) The kinetic energy of the objects keeps on decreasing.	<u>Notes</u>
(D)	The object is proj surface vertically $2\sqrt{GM_e/R_e}$, when earth and Re is the Neglect forces fro the earth.	ected from the earth's upwards with a speed e M_e is the mass of the he radius of the earth, m objects other than	(s) The object can change its direction only once.	
Q.22	Column I gives	a list of possible set of par	ameters measured in some	

experiments. The variations of the parameters in the form of graphs are shown in Column II. Match the set of parameters given in Column I with the graphs given in Column II. [IIT 2008]

	Column I	Column II
(A)	Potential energy of a simple pendulum (y-axis) as a function of displacement (x-axis).	(p) y x
(B)	Displacement (y-axis) as a function of time (x-axis) for a one dimensional motion at zero or constant acceleration when the body is moving along the positive x-direction.	(q) 0 x
(C)	Range of a projectile (y-axis) as a function of its velocity (x-axis) when projected at a fixed angle.	(r) 0 x
(D)	The square of the time period (y-axis) of a simple pendulum as a function of its length (x-axis)	(s) 0 x

- 74 -

COMPETITION BOOKLET

KINEMATICS

PHYSICS(FDN)

<u>Notes</u>

Q.23 An object A is kept fixed at the point x = 3m and y = 1.25 m on a plank P raised above the ground. At time t = 0, the plank starts moving along the +x direction with an acceleration $1.5m/s^2$. At the same instant a stone is projected from the origin with a velocity \vec{u} as shown. A stationary person on the ground observes the stone hitting the object during its downward motion at an angle of 45° to the horizontal. All the motions are in the x-y plane. Find \vec{u} and the time after which the stone hits the object. Take $g = 10 m/s^2$.

[IIT 2000]



Q.24 On a frinctionless horizontal surface, assumed to be the x-y plane, a small trolley A is moving along a straight line parallel to the y-axis

(see figure) with a constant velocity of $(\sqrt{3}-1)$ m/s. At a particular

instant, when the line OA makes an angle of 45° with the x-axis, a ball is thrown along the surface from the origin O. Its velocity makes an angle **f** with the x-axis and it hits the trolley.

(a) The motion of the ball is observed from the frame of the trolley. Calculate the angle **q** made by the velocity vector of the ball with the x-axis in this frame. [IIT 2005]



(b) Find the speed of the ball with respect to the surface if $f = \frac{4t}{2}$

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	D	С	В	В	С	В	В	А	С	А	D	В	Α	В	Α
Que.	16	17	18	19	20	21			22						
Ans.	А	С	В	Α	А	A-p	B-q,r	С-р	D-q,r	A-p,s	B-q,s	C-s	D-q		

Q.23 t = 1 sec. $\vec{u} = 3.75 \,\vec{i} + 6.25 \,\vec{j}$

Q.24 (a) $\theta = 45^{\circ}$ (b) 2m/s

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