

# Distance and Displacement

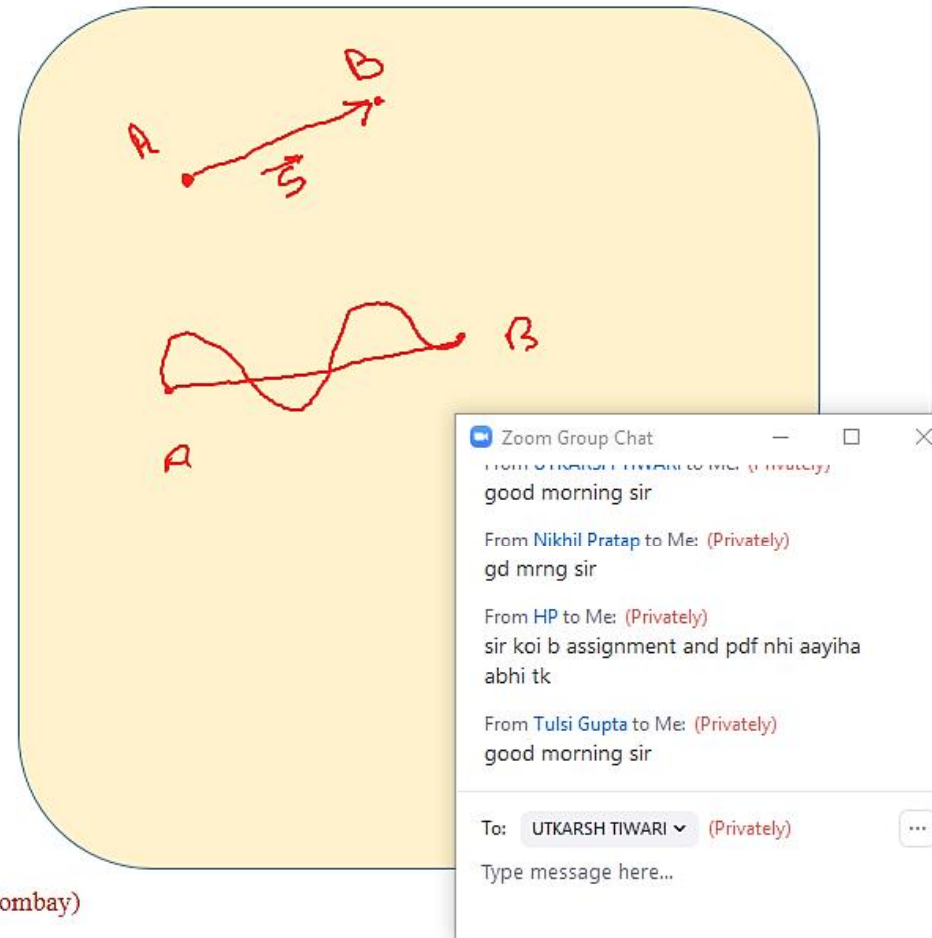
## Displacement

- Vector joining the initial and final position of the particle.
- Can be negative, positive or zero.

## Distance

- It is the length of the actual path travelled by a particle.
- Scalar quantity

$$\text{Distance travelled} \geq |\text{Displacement}|$$



# Average velocity and speed

## Average Velocity

$$\begin{aligned}\text{Average Velocity} &= \frac{\text{Displacement}}{\text{Time Interval}} = \frac{\text{Change in position}}{\text{Time Interval}} \\ &= \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i}\end{aligned}$$

- It is vector in the direction of displacement.

## Average Speed

$$\text{Average Speed} = \frac{\text{Distance travelled}}{\text{Time Interval}}$$

- Scalar quantity

$$\text{Average Speed} \geq |\text{Average Velocity}|$$

# Example

A 150 m long train is moving with a uniform velocity of 45 km / h. The time taken by the train to cross a bridge of length 850 metres is : **[2001]**

- (1) 56 sec (2) 68 sec (3) 80 sec (4) 92 sec

Diagram illustrating the problem:

- Train length: 150 m
- Bridge length: 850 m
- Total distance to cross: 1000 m

Calculations:

$$V = 45 \times \frac{5}{18} = 12.5 \text{ m/s}$$

$$t = \frac{S}{V} = \frac{1000}{12.5} = 80 \text{ s}$$

Zoom Group Chat

- From Nikhil Pratap to Me: (Privately) 80 s
- From Devesh Verma to Me: (Privately) 80 seconds
- From \_kunal\_43 to Me: (Privately) 80 sec
- From Varnika Singhal to Me: (Privately) 80sec

To: UTKARSH TIWARI (Privately)

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## Example

A particle travels half of total distance with speed  $v_1$  and next half with speed  $v_2$  along a straight line. Find out the average speed of the particle?

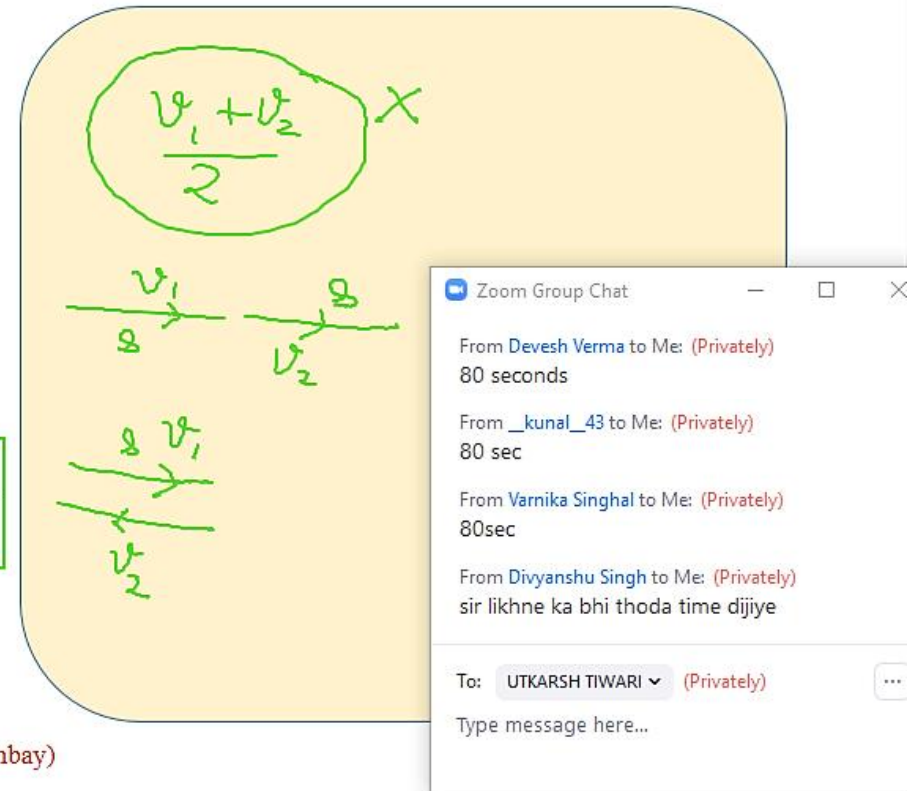
Sol.

Let total distance travelled by the particle be  $2s$ .

$$\text{Time taken to travel first half} = \frac{s}{v_1}$$

$$\text{Time taken to travel next half} = \frac{s}{v_2}$$

$$\text{Average speed} = \frac{\text{Total distance covered}}{\text{Total time taken}} = \frac{2s}{\frac{s}{v_1} + \frac{s}{v_2}} = \boxed{\frac{2v_1v_2}{v_1 + v_2}}$$



The diagram shows a particle moving along a straight line. The total distance is divided into two equal halves, each of length  $s$ . The first half is traveled with speed  $v_1$  and the second half with speed  $v_2$ . The average speed is calculated as  $\frac{v_1 + v_2}{2}$ , which is marked with a green 'X' to indicate it is incorrect. The correct formula,  $\frac{2v_1v_2}{v_1 + v_2}$ , is shown in a green box.

Zoom Group Chat

- From Devesh Verma to Me: (Privately) 80 seconds
- From \_kunal\_43 to Me: (Privately) 80 sec
- From Varnika Singhal to Me: (Privately) 80sec
- From Divyanshu Singh to Me: (Privately) sir likhne ka bhi thoda time dijiye

To: UTKARSH TIWARI (Privately)

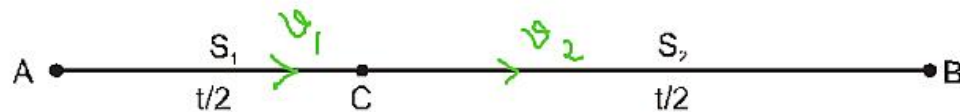
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## Example

A person travelling on a straight line moves with a uniform velocity  $v_1$  for some time and with uniform velocity  $v_2$  for the next equal time. The average velocity  $v$  is given by

Sol.



As shown, the person travels from A to B through a distance  $S$ , where first part  $S_1$  is travelled in time  $t/2$  and next  $S_2$  also in time  $t/2$ .

So, according to the condition :  $v_1 = \frac{S_1}{t/2}$  and  $v_2 = \frac{S_2}{t/2}$

$$\text{Average velocity} = \frac{\text{Total displacement}}{\text{Total time taken}} = \frac{S_1 + S_2}{t} = \frac{\frac{v_1 t}{2} + \frac{v_2 t}{2}}{t} = \frac{v_1 + v_2}{2}$$

# Instantaneous Velocity and Speed

## Instantaneous Velocity

- The velocity at a particular instant of time is known as instantaneous velocity.

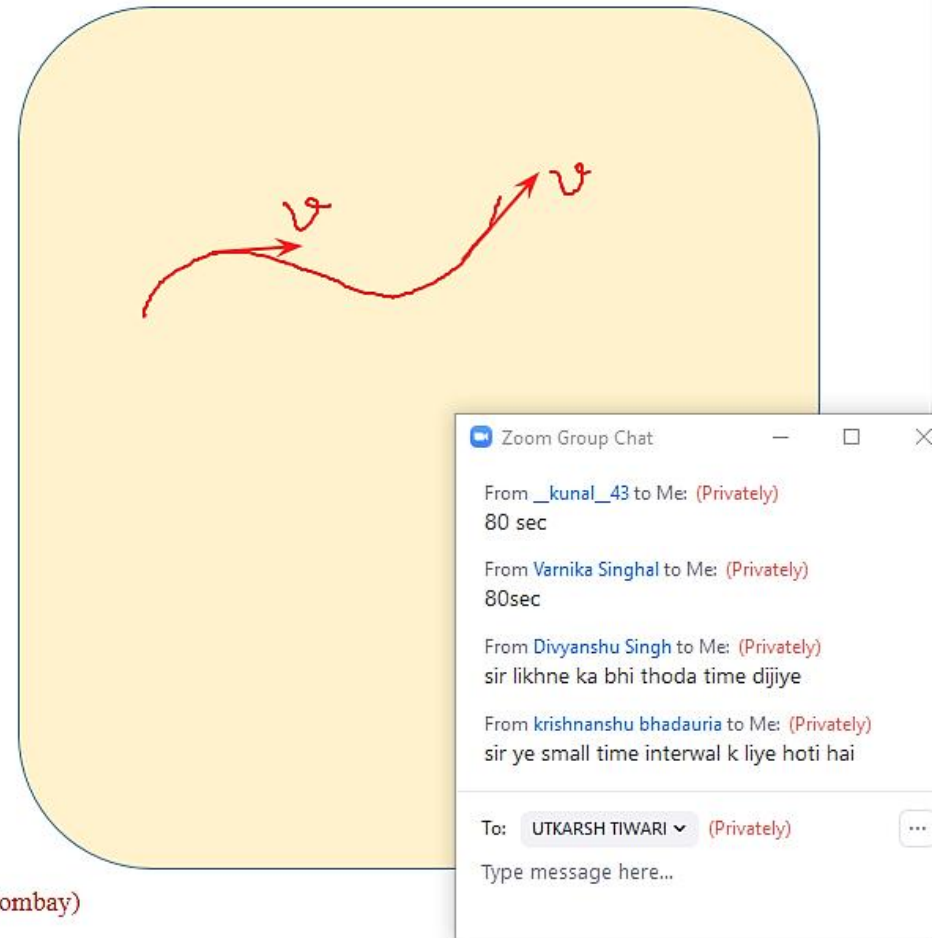
$$v = \frac{dx}{dt}$$

- It is always tangential to the path.

## Instantaneous Speed

- The magnitude of instantaneous velocity is called instantaneous speed.

$$\text{Instantaneous Speed} = |\text{Instantaneous Velocity}|$$



# Average and Instantaneous Acceleration

## Average Acceleration

$$\text{Average acceleration} = \frac{\text{change in velocity}}{\text{time interval}}$$

$$\vec{a}_{avg} = \frac{\Delta \vec{v}}{\Delta t} = \frac{\vec{v}_f - \vec{v}_i}{t_f - t_i}$$

➤ Vector in the direction of change in velocity.

## Instantaneous Acceleration

➤ It is acceleration at a particular instant of time.

$$a = \frac{dv}{dt} = v \frac{dv}{ds} = \frac{d^2x}{dt^2}$$

$$\begin{aligned}
 a &= \frac{dv}{dt} \\
 &= \frac{dv}{ds} \cdot \frac{ds}{dt} \\
 &= v \frac{dv}{ds}
 \end{aligned}$$

Zoom Group Chat

From HP to Me: (Privately)  
sir pls aap pdf bhi provide krdena aaj hi jo ab pdharheho uski

From Varnika Singhal to Me: (Privately)  
sir can we write instantaneous acc. as =  $d^2s/dt^2$ ?

From krishnanshu bhadauria to Me: (Privately)  
velocity

To: UTKARSH TIWARI (Privately)

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## Example

Position of a particle as a function of time is given as  $x = 5t^2 + 4t + 3$ . Find the velocity and acceleration of the particle at  $t = 2$  s?

Sol.

Velocity;  $v = \frac{dx}{dt} = 10t + 4$

At  $t = 2$  s  
 $v = 10(2) + 4$   
 $v = 24$  m/s

Acceleration;  $a = \frac{d^2x}{dt^2} = 10$

Acceleration is constant, so at  $t = 2$  s,  $a = 10$  m/s<sup>2</sup>

$$\frac{d}{dt}(t^n) = n t^{n-1}$$

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From [Vishnu Singh](#) to Me: (Privately)  
sir can we write instantaneous acc.  
as  $a = d^2s/dt^2$ ?

From [krishnanshu bhaduria](#) to Me: (Privately)  
velocity

From [Divyanshu Singh](#) to Me: (Privately)  
sir itne aasaan sawaal aate hai jee me

From [Murari Prajapati](#) to Me: (Privately)  
sir pahle solution mt digiye.

To: [UTKARSH TIWARI](#) (Privately)

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# Example

Equation of displacement for any particle is  $s = 3t^3 + 7t^2 + 14t + 8\text{m}$ . Its acceleration at time  $t = 1$  sec is : **[2000]**

(1)  $10 \text{ m/s}^2$

(2)  $16 \text{ m/s}^2$

(3)  $25 \text{ m/s}^2$

☒ (4)  $32 \text{ m/s}^2$

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

$$a = \frac{dv}{dt} = 18t + 14$$

$$\text{at } t = 1\text{s}$$

$$a = 18(1) + 14 \\ = 32 \text{ m/s}^2$$

## Example

The motion of a particle along a straight line is described by equation :  $x = 8 + 12t - t^3$ , where  $x$  is in metre and  $t$  in second. The retardation of the particle when its velocity becomes zero, is : **[2012]**

- (1)  $24 \text{ ms}^{-2}$  (2) zero (3)  $6 \text{ ms}^{-2}$  (4)  ~~$12 \text{ ms}^{-2}$~~

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

$$v = 0 \Rightarrow 12 - 3t^2 = 0 \Rightarrow t^2 = 4 \Rightarrow t = 2$$

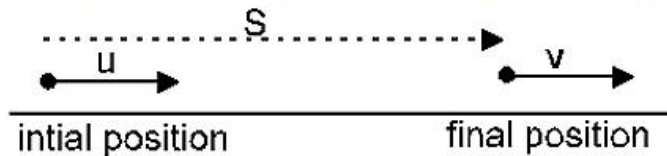
$$a = \frac{dv}{dt} = -6t$$

At  $t = 2 \text{ s}$

$$a = -12 \text{ m/s}^2$$

# Uniformly Accelerated Motion

Motion with constant acceleration



- (a)  $v = u + at$
- (b)  $\rightarrow s = ut + \frac{1}{2} at^2$
- $\rightarrow s = vt - \frac{1}{2} at^2$
- $x_f = x_i + ut + \frac{1}{2} at^2$
- (c)  $S = \left( \frac{v+u}{2} \right) t$
- (d)  $V_{av} = \frac{v+u}{2}$
- (e)  $v^2 = u^2 + 2as$
- (f)  $s_n = u + a/2 (2n - 1)$

$u$  = initial velocity  
 $a$  = acceleration  
 $v$  = final velocity  
 $s$  = displacement ( $x_f - x_i$ )  
 $x_f$  = final coordinate (position)  
 $x_i$  = initial coordinate (position)  
 $s_n$  = displacement during the  $n^{\text{th}}$  sec

**Note:** In case of motion under gravity, constant acceleration is  $g$  downwards.

$(n-1)$  to  $n$   
 $4^{\text{th}}$  sec  
 $3^{\text{rd}}$  to  $4^{\text{th}}$

Zoom Group Chat

From Harsh to Me: (Privately)  
4

From yuvraj to Me: (Privately)  
12

From Payal Verma to Me: (Privately)  
Sir screen show nhi ho rhi h

From krishnanshu bhadauria to Me: (Privately)  
yes sir mereko visible hai

To: UTKARSH TIWARI (Privately)

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## Example

A particle moving rectilinearly with constant acceleration is having initial velocity of 10 m/s. After some time, its velocity becomes 30 m/s. Find out velocity of the particle at the mid point of its path?

Sol.

Let the total distance be  $2x$ .

$\therefore$  distance upto midpoint =  $x$

Let the velocity at the mid point be  $v$  and acceleration be  $a$ .

From equations of motion

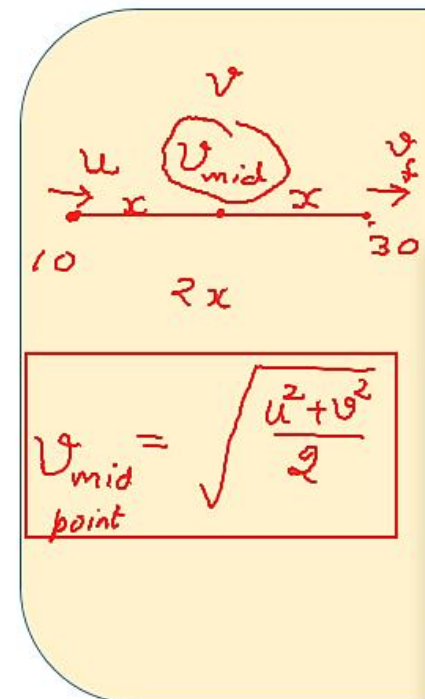
$$v^2 = 10^2 + 2ax \quad \dots (1)$$

$$30^2 = v^2 + 2ax \quad \dots (2)$$

(2) - (1) gives

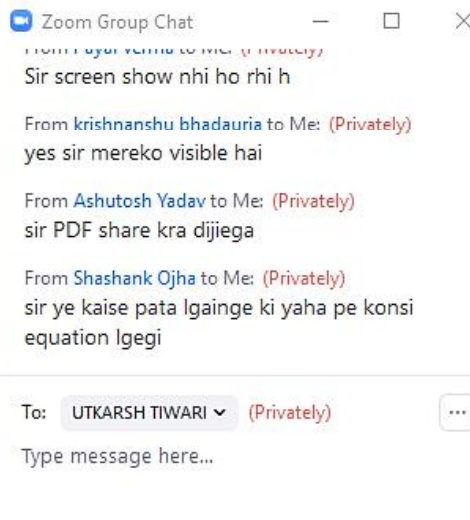
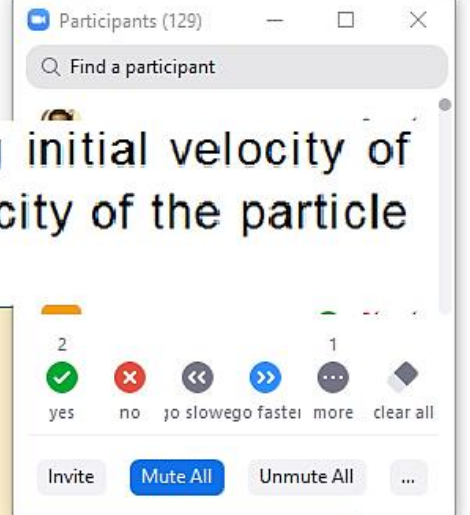
$$v^2 - 30^2 = 10^2 - v^2$$

$$\Rightarrow v^2 = 500 \quad \Rightarrow v = 10\sqrt{5} \text{ m/s}$$



Physics by Ritesh Agarwal (B. Tech. IIT Bombay)

Talking: Ritesh Agarwal





## Example

A particle is moving in a straight line with a constant acceleration. It changes its velocity from 10 m/s to 20 m/s, while passing through a distance 135 m in  $t$  seconds. The value of  $t$  is : **[2008]**

(1) 10

(2) 1.8

(3) 12

~~(4) 9~~

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

$$s = \left( \frac{u+v}{2} \right) t$$
$$135 = \left( \frac{10+20}{2} \right) t$$
$$135 = 15t$$
$$t = \frac{135}{15} = 9$$

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From Devesh Verma to Me: (Privately)  
9

From krishnanshu bhadauria to Me: (Privately)  
yes

From Archit Saini to Me: (Privately)  
option4

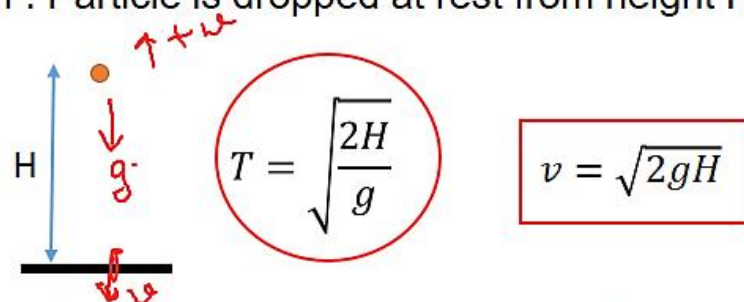
From Siddharth Gupta to Me: (Privately)  
d

To: UTKARSH TIWARI (Privately)

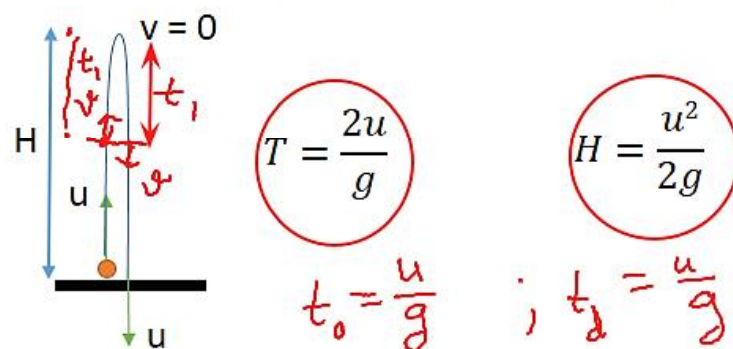
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# MOTION UNDER GRAVITY

Case I : Particle is dropped at rest from height H.



Case II : Particle is thrown with speed u from ground.



$$g = 9.8 \text{ m/s}^2$$

$$\approx 10 \text{ m/s}^2$$

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From krishnanshu bhadauria to Me: (Privately)  
sir recorded lectures bhi  
eflux

From Lokesh deshwal to Me: (Privately)  
sir ek numeraical do

From krishnanshu bhadauria to Me: (Privately)  
or sir maximum height tk pohochnai k  
time ug  
 $u/g^*$

To: UTKARSH TIWARI (Privately)

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Talking:

## Example

Two balls are dropped from heights  $h$  and  $2h$  respectively from the earth surface. The ratio of time of these balls to reach the earth is : **[2003]**

(1)  $1 : \sqrt{2}$

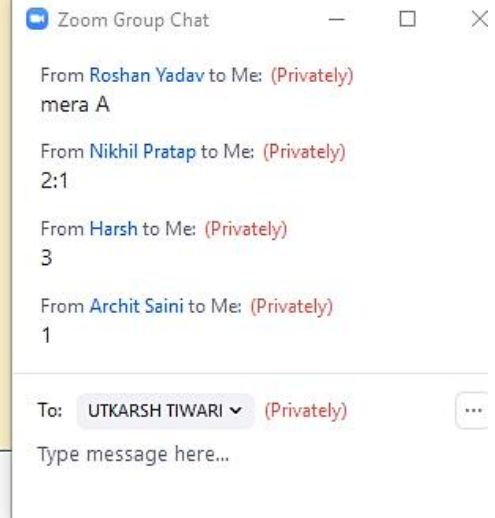
(2)  $\sqrt{2} : 1$

(3)  $2 : 1$

(4)  $1 : 4$

$$T = \sqrt{\frac{2h}{g}} \Rightarrow T \propto \sqrt{h}$$

$$\frac{T_1}{T_2} = \sqrt{\frac{h}{2h}} = \frac{1}{\sqrt{2}}$$



## Example

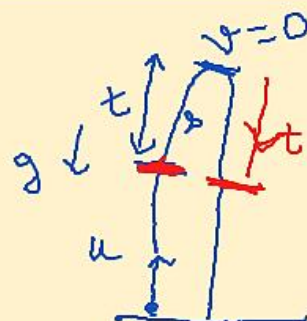
If a ball is thrown vertically upwards with speed  $u$ , the distance covered during the last  $t$  seconds of its ascent is : **[2003]**

✓(1)  $\frac{1}{2}gt^2$

(2)  $ut - \frac{1}{2}gt^2$

(3)  $(u - gt)t$

(4)  $ut$



$$s = vt - \frac{1}{2}at^2$$

$$s = 0 - \frac{1}{2}(-g)t^2 = \frac{1}{2}gt^2$$

$$\begin{aligned} u &= 0 \\ s &= ut + \frac{1}{2}at^2 \\ &= \frac{1}{2}gt^2 \end{aligned}$$

Zoom Group Chat

From Aditya Singh to Me: (Privately)  
1

From Ashutosh Yadav to Me: (Privately)  
2

From Faizy Murtaza to Me: (Privately)  
sir pls repeat kr dijie

From Aditya to Me: (Privately)  
1/2 gt^2  
sorry sir by mistake

To: UTKARSH TIWARI (Privately)

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SAFALTA DM

## Example

A particle is dropped from a tower. It is found that it travels 45 m in the last second of its journey. Find out the height of the tower? (take  $g = 10 \text{ m/s}^2$ )

**Sol.**

Let the total time of journey be  $n$  seconds.

$$\text{Using; } s_n = u + \frac{a}{2}(2n-1)$$

$$\Rightarrow 45 = 0 + \frac{10}{2}(2n-1)$$

$$n = 5 \text{ sec}$$

$$\text{Height of tower; } h = \frac{1}{2}gt^2$$

$$= \frac{1}{2} \times 10 \times 5^2 = 125 \text{ m}$$

Physics by Ritesh Agarwal (B. Tech. IIT Bombay)

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From KOMAL GUPTA to Me: (Privately)  
145 m

From ak to Me: (Privately)  
125m

From Saumya Singh to Me: (Privately)  
125 m

From Tulsi Gupta to Me: (Privately)  
125m

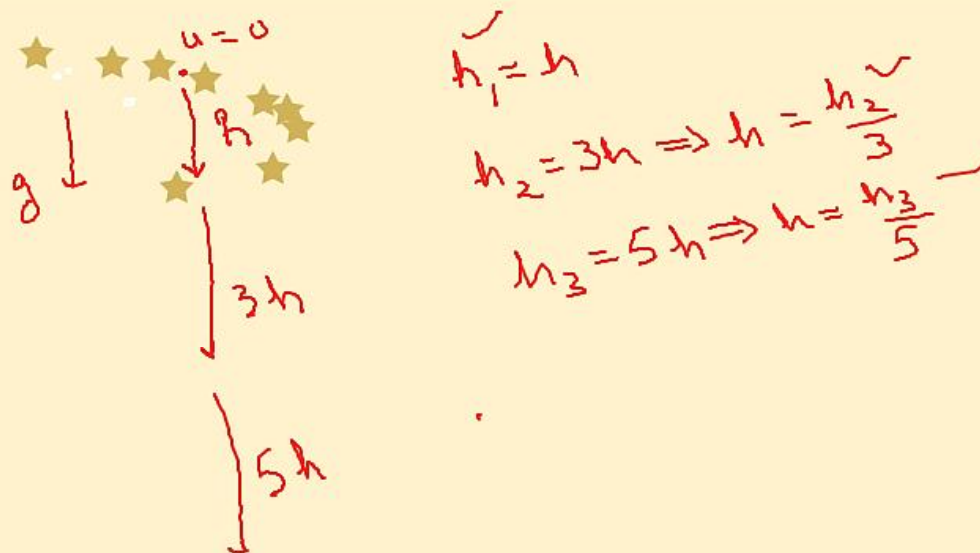
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# Example

A stone falls freely under gravity. It covers distances  $h_1$ ,  $h_2$  and  $h_3$  in the first 5 seconds, the next 5 seconds and the next 5 seconds respectively. The relation between  $h_1$ ,  $h_2$  and  $h_3$  is :- **[2013]**

- (1)  $h_1 = h_2 = h_3$  (2)  $h_1 = 2h_2 = 3h_3$  (3)  $h_1 = h_2/3 = h_3/5$  (4)  $h_2 = 3h_1$  and  $h_3 = 3h_2$



# Example

From the top of a tower, a particle is thrown vertically downwards with a velocity of 10 m/s. The ratio of the distances, covered by it in the 3rd and 2nd seconds of the motion is (Take  $g = 10 \text{ m/s}^2$ )

(1) 5 : 7

☒ (2) 7 : 5

(3) 3 : 6

(4) 6 : 3

**[2002]**

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

$$s_2 = 10 + \frac{10}{2} (2 \times 2 - 1) = 10 + 15 = 25$$

$$s_3 = 10 + \frac{10}{2} (2 \times 3 - 1) = 10 + 25 = 35$$

$$\frac{s_3}{s_2} = \frac{35}{25} = \frac{7}{5}$$

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From Archit Saini to Me: (Privately)  
21  
1 option  
2 option

From Abhinav to Me: (Privately)  
7:5

From Aditi Rai to Me: (Privately)  
Option2

To: UTKARSH TIWARI (Privately)

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