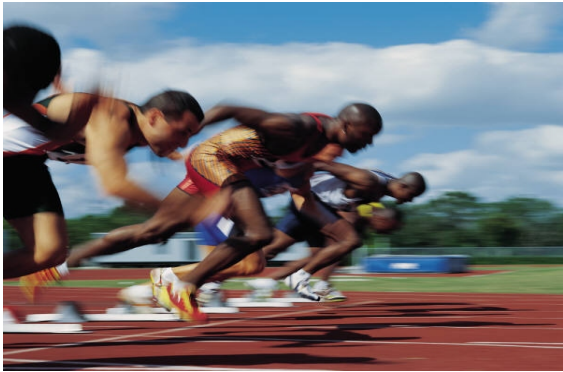


(Kinematics)



: **1-2**

() ()
(path) *(position)*
(velocity)
(acceleration)

(kinematics)

(dynamics)

(inertial frame of reference)

(initial conditions)

()

(position vector)

(Average Velocity)

2-2

50

200 km

.km/h

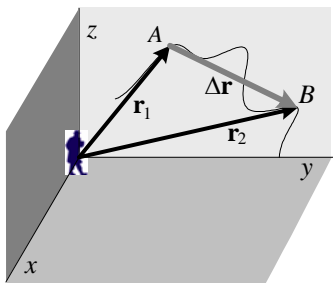
200 km

(average velocity)

(average speed)

() p

(1-2)



A

((origin)

t₁

r₁

. t₂

r₂

B

B A (displacement)

:

(1-2)

$$\Delta \mathbf{r} = \mathbf{r}_2 - \mathbf{r}_1$$

.B A

:

:

(2-2) $\Delta t = t_2 - t_1$

: B A

(3-2)

$$\mathbf{v}_{av} = \frac{\Delta \mathbf{r}}{\Delta t} = \frac{\mathbf{r}_2 - \mathbf{r}_1}{t_2 - t_1}$$

.m/s

80

km/h

(1-2)

(m/s)

:1-2



1500

/ 24.4

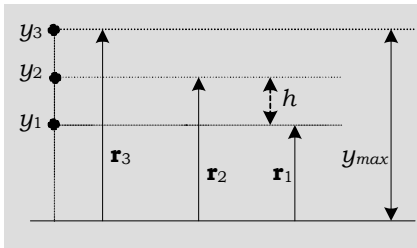
- | |
|--------------------|
| 3×10^8 |
| 3.4×10^2 |
| 4.0×10^4 |
| 1.1×10^4 |
| 9.6×10^2 |
| 6.3×10^5 |
| 7.5×10^5 |
| 2.0×10^2 |
| 1.02×10^1 |

$\Delta \mathbf{r}$

B A

2-2

(2-2)



(2-2)

: $t_2 - t_1$

$$|\Delta \mathbf{r}| = |\mathbf{r}_2 - \mathbf{r}_1| = y_2 - y_1 = h$$

$$|\Delta \mathbf{r}| = |\mathbf{r}_3 - \mathbf{r}_0| = y_{\max}$$

$$|\Delta \mathbf{r}| = 0$$

Δt

$2y_{\max}$

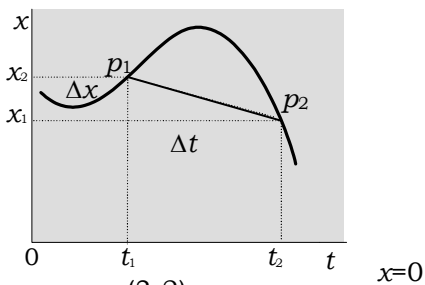
()

)

$y_{\max} / \Delta t$

(

)



(3-2)

(

(3-2)

()

$p_2 - p_1$

$p_1 p_2$

$\Delta t = t_2 - t_1$

$\Delta x = x_2 - x_1$

$\Delta x / \Delta t$ (3-2)

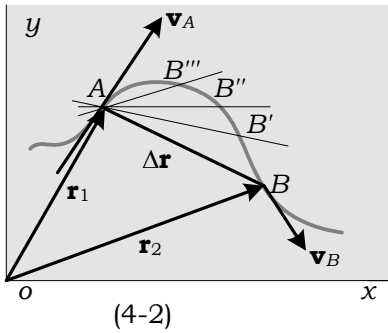
()

-5 m/s

+10 m/s

(Instantaneous Velocity)

3-2



(4-2) A

(3-2)

A B
 Δt $\Delta \mathbf{r}$
 AB

(4-2)

$$\mathbf{v} = \lim_{\substack{\Delta \mathbf{r} \rightarrow 0 \\ \Delta t \rightarrow 0}} \frac{\Delta \mathbf{r}}{\Delta t} = \frac{d\mathbf{r}}{dt}$$

: A

()
 ()



(5-2)

(4-2)

: $o_x \ o_y \ o_z$

(5-2)

$$\mathbf{v} = v_x \mathbf{i} + v_y \mathbf{j} + v_z \mathbf{k}$$

(6-2)

$$v_z = \frac{dz}{dt} \quad v_y = \frac{dy}{dt} \quad v_x = \frac{dx}{dt}$$

1-2

$$x(t) = 6t^2 - t + 1$$

$t=0$

() . t x

() $t=3$ s

()

() $t=3$ s $t=0$ s

$x(0)=1$ $t=0$ s

() :

: (4-2)

.m

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

$$v(t) = 12t - 1$$

:

$$v(0) = -1 \text{ m/s}$$

: $t=0$

1 m/s

1 m

$t=3$ s

()

:

$$v(3) = 12(3) - 1 = +35 \text{ m/s}$$

.()

35 m/s

: $t=3$ s $t=0$ s

()

$$s = \Delta x = x(3) - x(0) = 51 \text{ m}$$

(

)

$$: \quad t=3 \text{ s} \quad t=0 \text{ s} \quad ()$$

$$v_{av} = \frac{\Delta x}{\Delta t} = \frac{51}{3} = 17 \text{ m/s}$$

(7-2) $\mathbf{r} = \int \mathbf{v} dt$: (4-2)

2-2

$\mathbf{v}(t) = 2t\mathbf{i} + t^2\mathbf{j} - 3\mathbf{k}$
 () $t=0$ () t m/s
 $t=0$ 5 m

3 m/s $t=0$ $\mathbf{v}(0) = -3\mathbf{k}$
 .(oz)

: (7-2) ()

$$\mathbf{r} = \int \mathbf{v} dt = \int [2t\mathbf{i} + t^2\mathbf{j} - 3\mathbf{k}] dt = t^2\mathbf{i} + \frac{1}{3}t^3\mathbf{j} - 3t\mathbf{k} + \mathbf{c}$$

$\mathbf{r} = 5\mathbf{i}$ m \mathbf{c}
 $t=0$
 : $\mathbf{r} \quad \mathbf{c} = 5\mathbf{i}$

$$\mathbf{r} = (t^2 + 5)\mathbf{i} + \frac{1}{3}t^3\mathbf{j} - 3t\mathbf{k} \text{ m}$$

(Acceleration) **4-2**

()

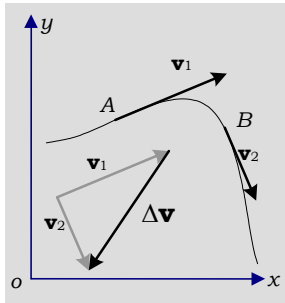
(

\mathbf{v}_1 A t_1 (7-2)

: \mathbf{v}_2 B t_2

(8-2)

$$\mathbf{a}_{av} = \frac{\Delta \mathbf{v}}{\Delta t} = \frac{\mathbf{v}_2 - \mathbf{v}_1}{t_2 - t_1}$$



(7-2)

$\Delta \mathbf{v}$ \mathbf{a}_{av}

.m/s²

(9-2)

$$\mathbf{a} = \lim_{\Delta t \rightarrow 0} \frac{\Delta \mathbf{v}}{\Delta t} = \frac{d\mathbf{v}}{dt} = \frac{d^2 \mathbf{r}}{dt^2}$$

: oz oy ox

(10-2)

$$\mathbf{a} = a_x \mathbf{i} + a_y \mathbf{j} + a_z \mathbf{k}$$

(11-2)

$$a_z = \frac{dv_z}{dt} = \frac{d^2 z}{dt^2} \quad a_y = \frac{dv_y}{dt} = \frac{d^2 y}{dt^2} \quad a_x = \frac{dv_x}{dt} = \frac{d^2 x}{dt^2}$$

(12-2)

$$\mathbf{v} = \int \mathbf{a} dt$$

()

:

3-2

$$v(t) = 3t + 5 \text{ m/s}$$

:

:

$$a = \frac{dv}{dt} = 3 \text{ m/s}^2$$

:

$$x(t) = \int v dt = \int (3t + 5) dt = \frac{3}{2} t^2 + 5t + c$$

:

$$s = x(3) - x(0) = [\frac{3}{2}(3)^2 + 5(3) + c] - [\frac{3}{2}(0)^2 + 5(0) + c] = 28.5 \text{ m}$$

c

5-2

$$9.80 \text{ m/s}^2$$

: (12-2)

(13-2)

$$\mathbf{v} = \mathbf{a}t + \mathbf{v}_0$$

.t=0

$$(\quad)$$

\mathbf{v}_0

: (7-2)

(14-2)

$$\mathbf{r} = \frac{1}{2} \mathbf{a}t^2 + \mathbf{v}_0 t + \mathbf{r}_0$$

.t=0

\mathbf{r}_0

.oz oy ox

1

:

2

(15-2)
$$\bar{v}_{AB} = \frac{v_1 + v_2}{2} = \frac{s}{t}$$

.()

t

s

()

$\mathbf{v}_0 \quad \mathbf{r}_0$

$\mathbf{v}_0 = 3 \mathbf{j} \text{ m/s} \quad \mathbf{r}_0 = 5 \mathbf{i} \text{ m}$

.t=0

()

()

6-2

ox

oy

ox

:

x_2

x_1

(16-2)

$$v_{av} = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1}$$

$$x_1 > x_2$$

$$x_2 > x_1$$

$$-8 \text{ m/s}$$

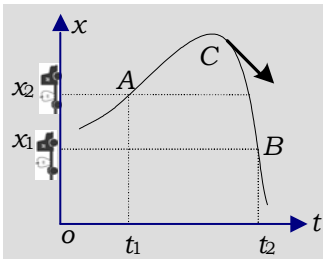
$$-5 \text{ m/s}$$

$$-4 \text{ m/s}$$

$$+6 \text{ m/s}$$

(17-2)

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



(8-3)

(8-2)

AB

B A

C

4-2

() . t x

$$x(t) = 3t - 4t^2 + t^3$$

() $t=4 \text{ s}$ $t=0 \text{ s}$

() $t=1,2,3,4 \text{ s}$

$t=4 \text{ s}$ $t=2 \text{ s}$

4	3	2	1	0	$t(\text{s})$
12	0	-2	0	0	$x(\text{m})$

: $t=4 \text{ s}$ $t=0 \text{ s}$

7-2

$$s = x(4) - x(0) = 12 - 0 = 12 \text{ m}$$

$$: \quad t=4 \text{ s} \quad t=2 \text{ s} \quad ()$$

$$v_{av} = \frac{\Delta x}{\Delta t} = \frac{x(4) - x(2)}{4 - 2} = \frac{12 - (-2)}{2} = 7 \text{ m}$$

$$: \quad (17-2) \quad t=3 \text{ s} \quad ()$$

$$v(t) = \frac{dx}{dt} = 3 - 8t + 3t^2 \Rightarrow v(3) = 6 \text{ m/s}$$

7-2

$$: \quad (14-2) \quad (13-2)$$

(18-2)

$$v = at + v_0$$

(19-2)

$$x = \frac{1}{2}at^2 + v_0t + x_0$$

:

(20-2)

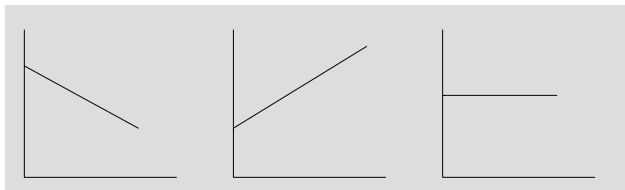
$$v^2 - v_0^2 = 2a(x - x_0) = 2as$$

.x x_0 s

$$a \quad (18-2)$$

$a \neq 0$

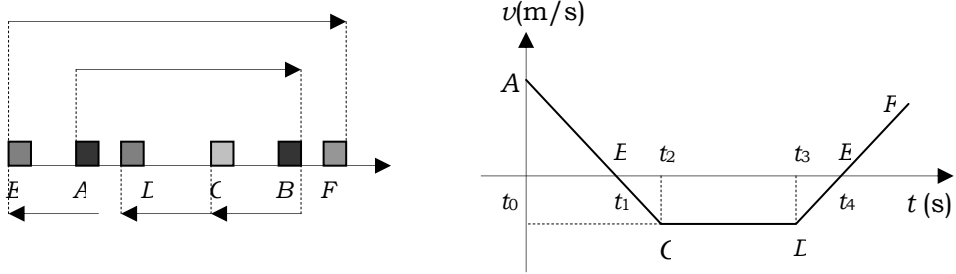
$$.(9-2) \quad a$$



(9-2)

5-2

(10-2)



(10-2)

$t=0$

(A)
 (B) t_1 t_0
 (C) t_2 t_1
 (D) t_3 t_2 ()
 F) (E) t_4
 . (

6-2

200 m 30 m/s

.10 m/s

1 m/s²

x

(19-2)

(11-2)

200+x



(11-2)

8-2

$$x + 200 = \frac{1}{2}at^2 + 30t$$

$$x = 10t$$

$$x = 200 \text{ (m)} \quad :$$

:

$$x = 200 + x = 400 \text{ m}$$

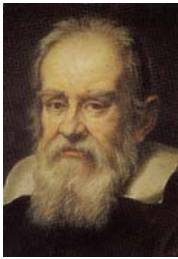
: (20-2)

$$v^2 - v_0^2 = 2as \Rightarrow v = 10 \text{ m/s}$$

(Free Fall)

8-2

(Galileo Galilee 1564-1642)



)

(

(gravitational acceleration)

.()

9.801 m/s²

g

$$a = -g$$

: (20-2) (19-2) (18-2)

(21-2)

$$v = -gt + v_0$$

(22-2)

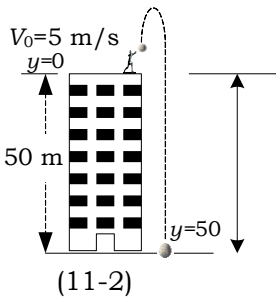
$$y = -\frac{1}{2}gt^2 + v_0t + y_0$$

(23-2)

$$v^2 - v_0^2 = 2(-g)(y - y_0) = -2gs$$

$$s = y - y_0$$

$$a = +g$$



()

$$a = -g$$

50 m

() .

7-2

5 m/s

(

.(11-2)

. $y_0=0$

$v_0=+5 \text{ m/s}$

()

: (23-2)

$$v^2 - v_0^2 = 2(-g)(y - y_0) \Rightarrow 0 - 25 = 2(-9.8)s \Rightarrow s = 1.28 \text{ m}$$

:(23-2)

$y=0$

$y_0=1.28 \text{ m}$

8-2

$$v^2 - v_0^2 = 2(-g)(y - y_0) \Rightarrow v^2 - 0 = 2(-9.8)(0 - 1.28) \Rightarrow v_0 = -5 \text{ m/s}$$

()

$$y_0 = 0$$

$$y = -50 \text{ m}$$

$$v_0 = +5 \text{ m/s}$$

: (22-2)

$$y = -\frac{1}{2}gt^2 + v_0t + y_0 \Rightarrow 0 = \frac{1}{2}(-9.8)t^2 + 5t - 50 \Rightarrow t = 3.75 \text{ s}$$

t_2

t_1

$$.t = t_1 + t_2$$

5 m/s

t_1

:

$$v = -gt + v_0 \Rightarrow 0 = -9.8t_1 + 5 \Rightarrow t_1 = 0.51 \text{ s}$$

$$y = -(50 + 1.28) = -51.28 \text{ m}$$

t_2

:

$$y = -\frac{1}{2}gt^2 + v_0t + y_0 \Rightarrow -51.28 = -\frac{1}{2}(-9.8)t_2^2 + 0 + 0 \Rightarrow t_2 = 3.24 \text{ s}$$

$$t = t_1 + t_2 = 3.75 \text{ s}$$

:

-	427	965	-	354)
					.(1038
					80



:

$$\begin{aligned}
 v_{av} &= \frac{\Delta \mathbf{r}}{\Delta t} \\
 v &= \frac{d\mathbf{r}}{dt} \\
 a_{av} &= \frac{\Delta \mathbf{v}}{\Delta t} \\
 a &= \frac{d\mathbf{v}}{dt} = \frac{d^2 \mathbf{r}}{dt^2}
 \end{aligned}$$

$$\left. \begin{aligned}
 \mathbf{v} &= \mathbf{a}t + \mathbf{v}_0 \\
 \mathbf{r} &= \frac{1}{2} \mathbf{a}t^2 + \mathbf{v}_0 t + \mathbf{r}_0 \\
 v^2 - v_0^2 &= 2as
 \end{aligned} \right\}$$

$$\left. \begin{aligned}
 a &= g \\
 v &= gt + v_0 \\
 y &= \frac{1}{2} gt^2 + v_0 t + y_0
 \end{aligned} \right\} \quad (\quad)$$

80 km/h

1-2

5 m/s

2-2

10 s

100 m

3-2

.2004

49.39

13

5000 m

5000 m

100 m/s

4-2

30 m

()

21,600 km/h

5-2

1.4×10⁹

()

- 100 km/h **6-2**
- () .88 km/h
- () 50 m
- 20 s
- () .80 s 10 s 100 m **7-2**
- ()
- 4 m/s **8-2**
- () .2 m/s
- 45° 60 km/h **9-2**
- 50 20
- 30 m/s 2.4 s 18 m/s **10-2**
- ()
- $t=0$ 20 m/s **11-2**
- () .30 m/s
- () x
- .1.8 s 1600 km/h **12-2**
- $\mathbf{r} = (t^2 + t)\mathbf{i} + (3t - 2)\mathbf{j} - (2t^3 - 4t^2)\mathbf{k}$ **13-2**
- $t=2$ s t **r**
- r** $\mathbf{r} = t^3\mathbf{i} + 6t\mathbf{j} - 2t^2\mathbf{k}$ **14-2**
- t
- 100 km/h 2.2 s **15-2**

40 cm **16-2**

50 km/h

40 m 100 km/h **17-2**

0.4 s

.()

$x(t) = 10t^2 - 0.5t^4 + 3$ **18-2**

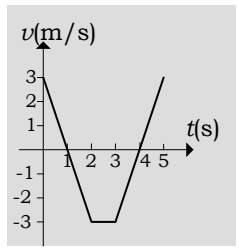
$t=3$ s $t=2$ s () . t

()

$v(t) = 2t + 3t^2 - 1$ **19-2**

. t / v

20-2



$x=1$ m $t=0$

.(12-2)

21-2

. t x $x(t) = 50t + 10t^2$

(12-

$t=3$ s

22-2

.100 m 1 m 0.1 m/s

()

3×10^6 **23-2**

.4 cm m/s

20 m 5 m/s **24-2**

.1.5 s 60 km/h **25-2**

100km/h

.15 s 600 m **26-2**

1.2 m/s² **27-2**

.1.25 m/s² 5×10⁶ m/s 1100 m **28-2**

15 m 50 m **29-2**

10 s 5 cm/s² 1 m/s² **30-2**

: .5 s **31-2**

14	12	10	8	6	4	2	0	(s)
22	20	15	10	5	2	0	0	(m/s)

() . ()

.1 cm≡2 m/s 1 cm≡1 s

1 . (t,v)

.t=13 s t=8 s cm²

10 4 s 4 m/s² **32-2**

8 m/s² . d **33-2**

2 m/s² 3 m/s²

d .75 m

.15 m/s 2 s 60 m **34-2**

5 m 10 m/s 35-2
 .1 m/s² 40 m

15 m/s 36-2
 0.7 s .5 m/s²
 2 m/s² 37-2

.10 m/s
 30 30 km/h 38-2
 .8 m/s² m

0.75 s
 v_B v_A B A 39-2
 B a A d
 $v_A - v_B \leq \sqrt{2ad}$

.36 m 40-2

.380 m 41-2

() .90 m/s 42-2

()

.3 s 43-2

23 (stunt) 44-2

() .

() 100 m

140 cm

() .4 s 1 m 45-2

()

10 m			46-2
		.4 s	
		.3 s	47-2
5 m/s		60 m	48-2
	.12 m/s		49-2
		10 s	
()		() .30 m/s	50-2
		6 s	()
	n		51-2
. a			$(n-1/2)g$
.3 m/s			52-2
	2 m		
	29.4 m/s		53-2
		20 m/s ²	54-2
.15 m/s		1 kg	55-2
		$E = \frac{1}{2}mv^2 + mgh$	
	m		h
.1 m			56-2