

*(Dynamics)*



**1-4**

*(Johannes Kepler 1571-1630)*

( )

*.(kinematics)*

( )

( )

*.(dynamics)*

(mass) **2-4**

!

( )

*(operational definition)*

kg

(force) **3-4**

/  
N

**F**

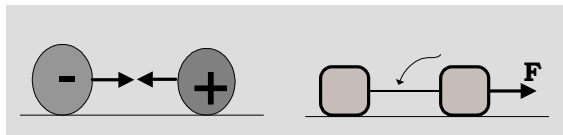
$$1 \text{ N} = 1 \text{ kg}\cdot\text{m}/\text{s}^2$$

100

(contact force)

(action at a distance)

(1-4)



(1-4)

(Newton's First Law)

**4-4**

\_\_\_\_\_ : \_\_\_\_\_ ( )

(1-4)

$$\mathbf{F}_T = 0 \Rightarrow \mathbf{v} = \text{constant} \Rightarrow \mathbf{a} = 0$$

$\mathbf{a} \quad \mathbf{v}$

$\mathbf{F}_T$

*(equilibrium)*

*(static equilibrium)*

*(static equilibrium)*

( )

$$(\mathbf{F}_T=0)$$

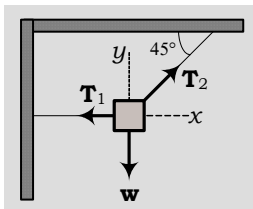
(1-4)

$(\mathbf{a}=0)$

**1-4**

$w=50 \text{ N}$

*(2-4)*



*(2-4)*

$$\mathbf{w} + \mathbf{T}_1 + \mathbf{T}_2 = 0$$

$oy \quad ox$

: *(2-4)*

$$T_1 \cos 45^\circ = T_2$$

$$T_1 \sin 45^\circ = w$$

$$T_1 = 71 \text{ N}$$

$$T_2 = 50 \text{ N}$$

(Newton's second Law)

5-4

( )

$\mathbf{a}_T \neq 0$

$\mathbf{F}_T \neq 0$

(2-4)

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

(3-4)

$\mathbf{F}_T = m\mathbf{a}$

(2-4)

(3-4) (2-4)

(dynamic definition)

(inertia)

((2-4))

8 m

2 kg

20 m

:

:

$$x = \frac{1}{2}at^2 + v_0t + x_0 \Rightarrow 8 = \frac{1}{2}a(2)^2$$

$$a = 4 \text{ m/s}^2$$

:

$$F = ma$$

:

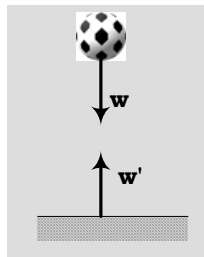
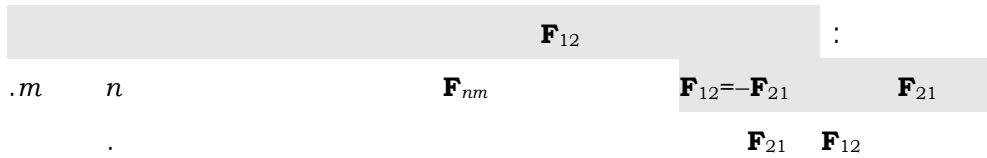
$$F = 8 \text{ N}$$

نجد:

(Action & Reaction)

:

6-4



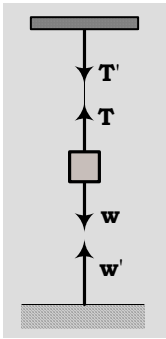
(3-4)

(3-4)

( )

( )

( )



(4-4)

$m$

(4-4)

$w$

$T$

$w'$

$T'$

$$T = -T'$$

$$w = -w'$$

$$T = -w$$

( )



7-4

(3-4)

$F_T$

(weight)  $w$  -1

$mg$

(4-4)

$$F = w = mg$$

( )

$w$

7-4

( )

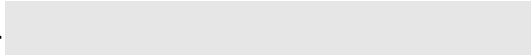
(surface reaction or normal force)  $\mathbf{N}$

-2

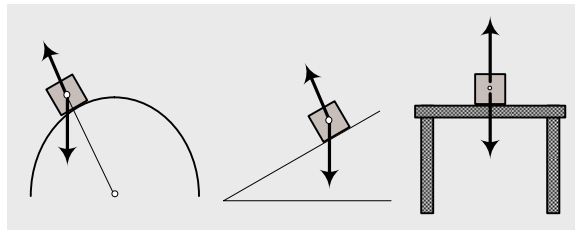
(5-4)

$\mathbf{N}$

( 5-4)



.( 5-4)



( )

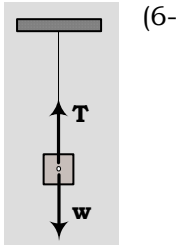
( )

( )

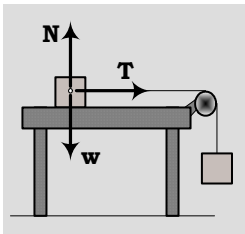
(5-4)



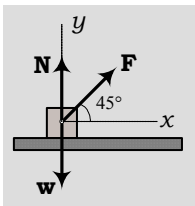




(6-4)



(7-4)



(7-4)

45°

2 m/s<sup>2</sup>

10 kg

$$\mathbf{F} + \mathbf{N} + \mathbf{w} = m\mathbf{a}$$

$$(7-4) \quad \text{oy} \quad \text{ox}$$

$$0 + 0 + F \cos 45^\circ = ma$$

$$N - w + F \sin 45^\circ = 0$$

oy

(Tension) **T** -3

4)

**T**

**N**

**T**

(7-4)

**4-4**

*F* (7-4)

*F*

7-4

:  $N$   $F$

$$N = 78 \text{ N} \quad F = 28.3 \text{ N}$$

.m

$$F \cos 45^\circ$$

:

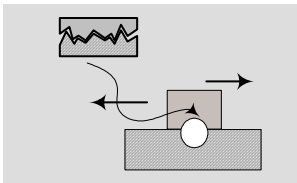
$$a = \frac{F \cos 45^\circ}{m} \Rightarrow F = \frac{ma}{\cos 45^\circ} = 28.3 \text{ N}$$

(Friction)

-4



.(8-4)



(8-4)

:

:(static friction)

-

(5-4)

$$0 \leq F_s \leq \mu_s N$$

(6-4)

$$(F_s)_{\max} = \mu_s N$$

$\mu_s$

$N$  ( )

.(coefficient of static friction)

:(kinetic friction) -

(7-4)

$$F_k = \mu_k N$$

.(coefficient of kinetic friction)

$\mu_k$

$N$

$\mu_k \mu_s$

(7-4) (6-4)

**5-4**

0.2  $F$  2 kg

6 N, 4 N, 1 N :  $F$

0.1

1 N

4 N 1 N

4 N 4 N

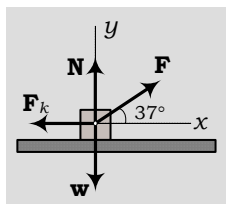
1 N

4 N

2 N 6 N

$(F_s)_{\max} = \mu_s N = \mu_s mg = 4 \text{ N}$

$F_k = \mu_k N = \mu_k mg = 2 \text{ N}$



$F=40\text{ N}$

5 kg

.(9-4)

$37^\circ$

0.4

(9-4)

**F**

**N**

**w**

: **F<sub>k</sub>**

$$\mathbf{w} + \mathbf{N} + \mathbf{F} + \mathbf{F}_k = m\mathbf{a}$$

(9-4)

oy

ox

:

$$F \cos 37^\circ - F_k = ma$$

:

$$N - w + F \sin 37^\circ = 0$$

$\mu_k N$

$g=10\text{ m/s}^2$

)

N

:(

$$N = w - F \sin 37^\circ = 50 - 40 \sin 37^\circ = 26\text{ N}$$

:

$$F_k = \mu_k N = 10.4\text{ N}$$

:

$$(40) \cos 37^\circ - 10.4 = 5a \Rightarrow a = 4.32\text{ m/s}^2$$

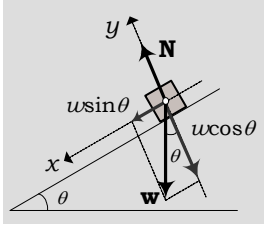
)

$\theta$

m

.(10-4)

(



(10-4)

$$\mathbf{w} + \mathbf{N} = m\mathbf{a}$$

(10-4)

$$w \sin \theta = ma$$

$$a = \frac{w \sin \theta}{m}$$

$.m$

$w \sin \theta$

$$w = mg$$

(8-4)

$$a = g \sin \theta$$

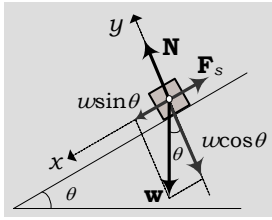
$$N = mg \cos \theta$$

$$a = -g \sin \theta$$

(8-4)

-2

$m$



(11-4)

.(11-4)

:

$$\mathbf{w} + \mathbf{N} + \mathbf{F}_s = 0$$

:

oy ox

$$w \sin \theta - F_s = 0$$

$$F_s = w \sin \theta_s$$

:

$$N - w \cos \theta_s = 0 \Rightarrow N = w \cos \theta_s$$

:

$$F_s = (F_s)_{\max} = \mu_s N = \mu_s w \cos \theta_s$$

:

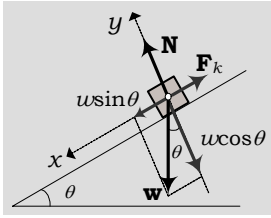
(9-4)

$$\tan \theta_s = \mu_s$$

 $\theta_s$  $\theta_s$ 

:(12-4)

.F<sub>k</sub>



(11-4)

$$\mathbf{w} + \mathbf{N} + \mathbf{F}_k = m\mathbf{a}$$

:  $ox$

$$w \sin \theta - F_k = ma \Rightarrow a = \frac{w \sin \theta - F_k}{m}$$

$m$

$$F_k = \mu_k N = \mu_k w \cos \theta$$

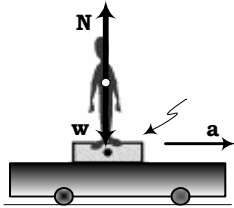
(10-4)

$$a = g(\sin \theta - \mu_k \cos \theta)$$

-3

.(*apparent weight*)

( )

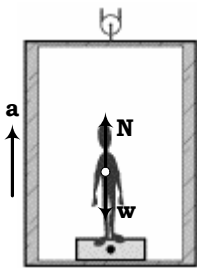


(13-4)

$$m \cdot \dots \quad (13-4)$$

$$w + N = ma$$

$$:(13-4) \quad ( )$$



(13-4)

$$:a \quad ( )$$

$$N - mg = ma$$

(11-4)

$$w' = N = w + ma = m(g + a)$$

$$w' > mg \quad (a > 0)$$

( )

$$w' = mg \quad a = 0$$

$$w' < mg \quad a < 0$$

$$w - N = ma$$

(12-4)

$$w' = N = w - ma = m(g - a)$$

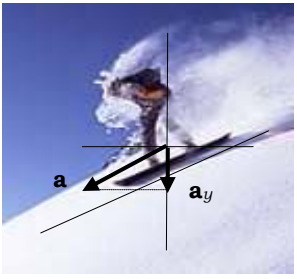


:

$$w' < mg \quad a > 0$$

$$w' > mg \quad a < 0$$

: ( )



$$(12-4) \quad (11-4)$$

( )

**7-4**

.850 N

70 kg

:

:

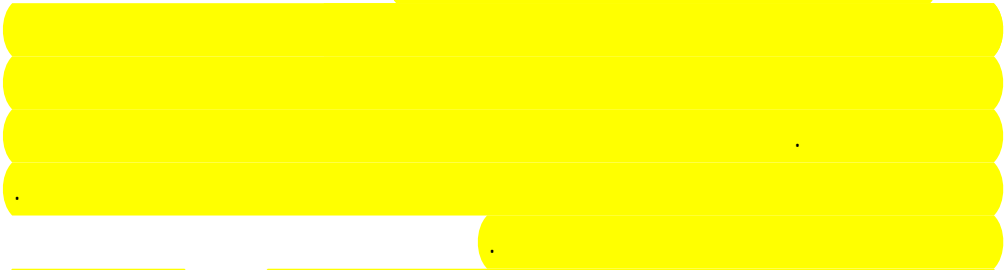
$$N - w = ma$$

$$w' = N = 850 \text{ N} \quad w = mg = 686 \text{ N} \quad m = 70 \text{ kg}$$

$$a = 2.3 \text{ m/s}^2$$

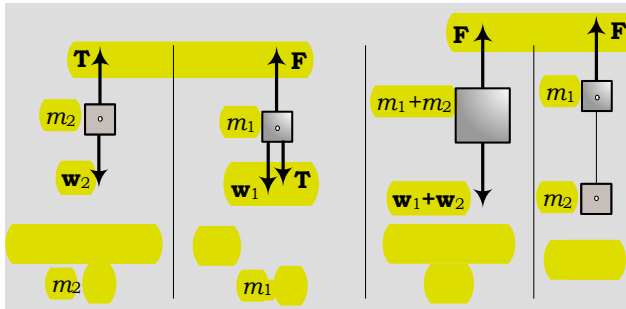
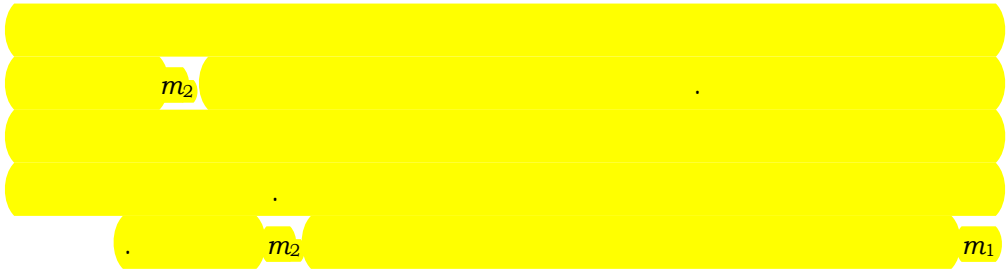
(Free Body Diagram)

**9-4**



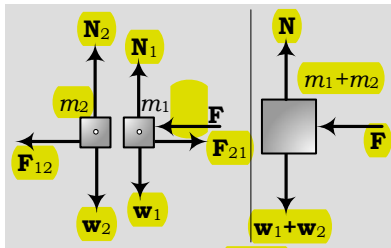
(14-4)





(14-4)

8-4



(15-4)

$m_2 = 3 \text{ kg}$       $m_1 = 2 \text{ kg}$   
 (15-4)  
 $F = 10 \text{ N}$

:  $F$

$F + mg + N = ma$

:

$F = ma = (m_1 + m_2)a$

:

$a = \frac{F}{(m_1 + m_2)} = 2 \text{ m/s}^2$

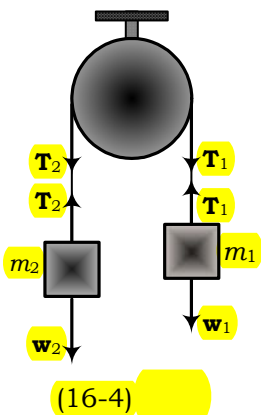
$\mathbf{N}_2$   $\mathbf{w}_2$   $m_2$   $\mathbf{F}_{21}$   $m_1$   $m_2$   $\mathbf{F}_{12}$   $m_2$   $\mathbf{F}_{12} = -\mathbf{F}_{21}$   $\mathbf{F}_{21}$

$$F_{12} = m_2 a \Rightarrow a = \frac{F_{12}}{m_2}$$

$m_2$   $F_{12}$   $m_2$

$$F_{12} = 6 \text{ N}$$

(Atwood Machine) 9-4



$m_2$   $m_1$   $r$  (16-4)

$$T_1 = T_2$$

$$\mathbf{F}_T = \mathbf{w}_1 + \mathbf{w}_2 \quad m_1 + m_2$$

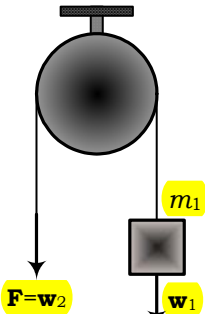
$$\mathbf{w}_1 + \mathbf{w}_2 = (m_1 + m_2)\mathbf{a}$$

$m_2$

$$w_2 - w_1 = (m_1 + m_2)a \Rightarrow a = \frac{w_2 - w_1}{m_1 + m_2}$$

$$w = mg$$

$$a = \frac{m_2 - m_1}{m_1 + m_2} g$$



$$(17-4)$$

( )

$$(17-4)$$

$$F = m_2 g$$

$$F - m_1 g = (m_2 - m_1) g$$

$$a = \frac{F - m_1 g}{m_1} = \frac{m_2 - m_1}{m_1} g$$

(Central Forces) 10-4

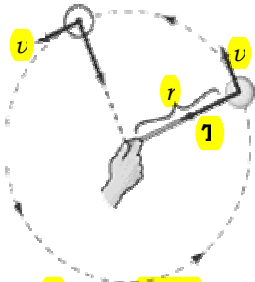
$v$   $r$

$$a_c = \frac{v^2}{r}$$

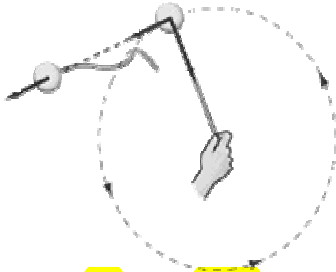
\_\_\_\_\_ :

(13-4)

$$F_c = ma_c = m \frac{v^2}{r}$$



(18-4)



(18-4)

(13-4)

(central)

(18-4)

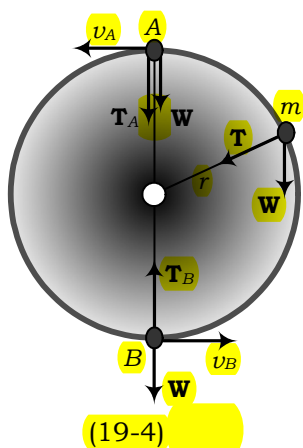
(18-4)

(13-4)

11-4

(19-4)

r



(19-4)

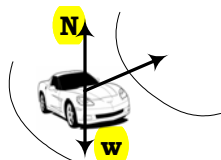
$$T_A + mg = m \frac{v_A^2}{r} \Rightarrow T_A = m \frac{v_A^2}{r} - mg$$

B

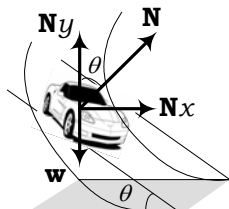
$$T_B - mg = m \frac{v_B^2}{r} \Rightarrow T_B = m \frac{v_B^2}{r} + mg$$

$T_B > T_A$

$v_B > v_A$



(20-4)



(20-4)

12-4

v

(20-4)

$N_y$

(20-4)

$\theta$

:

$N_x$

:( 20-4)

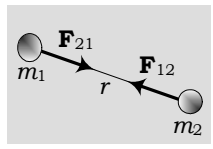
$$N_y = N \cos \theta = mg \quad N_x = N \sin \theta = m \frac{v^2}{r}$$

:

$$\tan \theta = \frac{v^2}{rg}$$

(Gravity) 11-4

$$g \quad \mathbf{w} = m\mathbf{g}$$



(21-4)

$m_2 \quad m_1$

:

(14-4)

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

$$G = 6.67 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2 \quad G$$

(21-4)  $m_1 \quad m_2 \quad m_1$

:

(15-4)

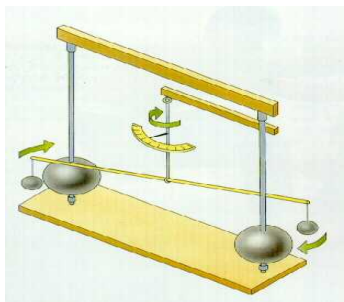
$$\mathbf{F} = -\frac{Gm_1m_2}{r^2} \mathbf{r}_1$$

.( )  $m_2$  ( )  $m_1$   $\mathbf{r}_1$

1798 (Henri Cavendish 1731-1810)

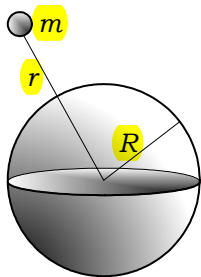
$m$  (22-4)

$m$   $M$  (fiber)



(15-4)

(22-4)



(23-4)

$m$

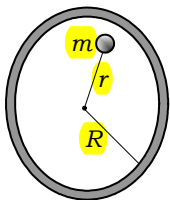
$r < R$

$M$

$r$

(23-4)

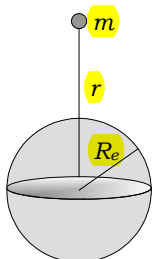
$$F = \frac{GMm}{r^2}$$



(24-4)

$m$

(24-4)



(25-4)

(16-4)

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

12-4

(25-4)

$mg$

(14-4)

$r$



$r = R_e$

(17-4)

$$g_R = \frac{GM_e}{R_e^2}$$

$R_e$   $M_e$

$$g = \frac{GM_e}{R_e^2} = 9.801 \text{ m/s}^2$$

13-4

(16-4)

$$g = \frac{GM_e}{r^2} = \frac{g_R}{2} = \frac{GM_e}{2R_e^2}$$

$$r^2 = 2R_e^2 \Rightarrow r = \sqrt{2}R_e = R_e + h \Rightarrow h \approx 0.4R_e$$

$h = 2640 \text{ km}$

$R_e = 6370 \text{ km}$

$h$

(Kepler's Laws)

13-4



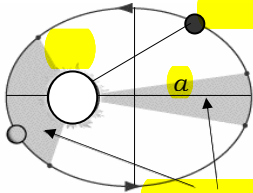
(Nicolaus Copernicus 473-1543)

(Tycho Brahe 1546-1601)

777

13-4

(Johannes Kepler 1571-1630)



(25-4)

$a$

$T$

( )

-1

(25-4)

( )

-2

( )

( )

-3

(18-4)

$$T^2 \propto a^3$$

$a$

$M$

$$F = \frac{GMm}{a^2} = \frac{mv^2}{a}$$

$$T = \frac{s}{v} = \frac{2\pi a}{v} \Rightarrow v = \frac{2\pi a}{T}$$

(19-4)

$$T^2 = \left( \frac{4\pi^2}{GM} \right) a^3$$

1-4

14-4

1000 km

$$F = \frac{GMm}{r^2} = \frac{mv^2}{r} \Rightarrow v^2 = \frac{GM}{r}$$

$r$

$M$

$$r = R_e + h = 6370 + 1000 \text{ km} = 7370 \times 10^3 \text{ m}$$

$h$

$$v = \frac{6.67 \times 10^{-11} \text{ N.m}^2/\text{kg}^2 (5.98 \times 10^{24} \text{ kg})}{(7370 \times 10^3 \text{ m})} \Rightarrow v = 7.35 \times 10^3 \text{ m/s}$$

1-4

( )	( )	( )	( )	( )
0.39	0.24	0.38	0.05	(Mercury)
0.72	0.61	0.95	0.82	(Venus)
1.00	1.00	1.00	1.00	(Earth)
1.52	1.88	0.53	0.11	(Mars)
5.20	11.85	10.97	317.70	(Jupiter)
9.56	29.63	9.18	94.98	(Saturn)
19.18	83.62	3.66	14.52	(Uranus)
30.08	165.40	3.47	17.22	(Neptune)
39.50	247.78	0.47	0.02	(Pluto)
-	-	0.27	0.01	(Moon)
-	-	109.26	3.33x105	(Sun)

$$\mathbf{F}_T = 0 \Rightarrow \mathbf{v} =$$

$$\mathbf{F}_T = m\mathbf{a}$$

) ( ) :

(

$$\mathbf{w} = m\mathbf{g}$$

$$0 \leq F_s \leq \mu_s N$$

$$F_k = \mu_k N$$

$$F_c = m \frac{v^2}{r}$$

$$F = \frac{Gm_1 m_2}{r^2}$$

$$g = \frac{GM}{r^2} \quad r$$

10 N

1-4

(27-4)

(28-4)

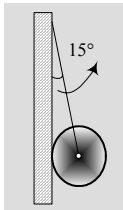
2-4

$\mathbf{F}_3$

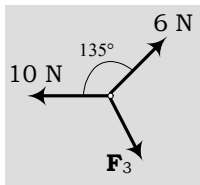
(29-4)

3-4

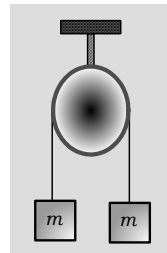
800 N



(29-4)



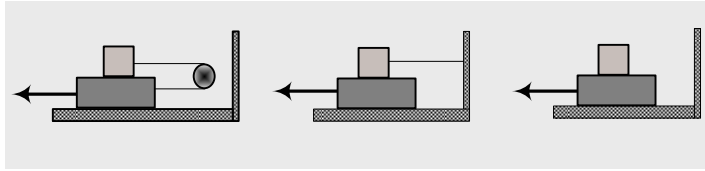
(28-4)



(27-4) الشكل

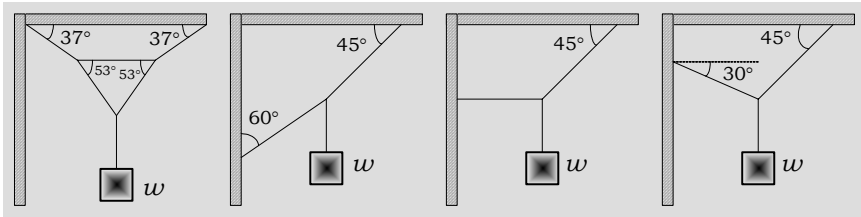
$B$  (30-4)  $B$   $A$  4-4  
 8 N  $B$  4 N  $A$

0.25

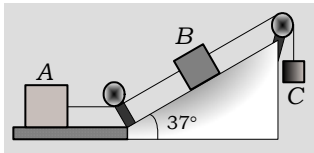


(30-4)

$w=20$  N (31-4) 5-4



(31-4)



(32-4)

(32-4)  $C$   $B$   $A$  6-4

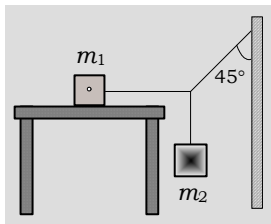
( ) .

$B$   $A$

( )

$A$

20 N



(32-4)

$m_1$

$C$

( )  $F$

0.5

$B$

(32-4)

500 g

8-4

9.8094 m/s<sup>2</sup>

9.7996 m/s<sup>2</sup>

(ج)

1.5

9-4

( = )

50 m

	( ) $.37^\circ$	65 kg	<b>10-4</b>
		( ) .	
( ) $.2 \text{ m/s}^2$		( )	( )
		40 kg	<b>11-4</b>
	$-3 \text{ m/s}^2$	0.2	0.3
$.30 \text{ N}$		15 kg	<b>12-4</b>
		10	
	$.24000 \text{ N}$		<b>13-4</b>
		2000 kg	
		$1/6$	
		60 kg	<b>14-4</b>
1 kg	200 N		<b>15-4</b>
		( ) .	
		15	( )
$.5 \text{ m/s}$		10 kg	<b>16-4</b>
0.2			
80 km/h	1000 kg		<b>17-4</b>
	0.3		
60 kg			<b>18-4</b>
		425 N	
.	$\theta$	<b>F</b>	<b>19-4</b>
$\mu$		<b>F</b>	
	$30^\circ$		<b>20-4</b>
		0.2	

:

37° 20 kg 21-4  
( ) ( ) . 300 N

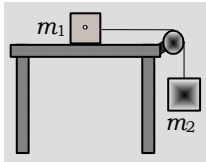
( )

600 2.5 m/s<sup>2</sup> 22-4  
( ) .300 N ( ) ( ) .N

( ) .2 m/s<sup>2</sup> 5 kg 23-4  
( ) 50 N ( )

2 m 50 N

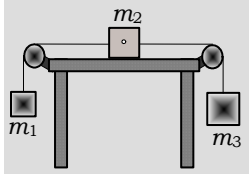
.20 m/s 37° 2 kg 24-4  
( )



(33-4)

( ) 0.3

(33-4) 25-4



(34-4)

.2 m/s<sup>2</sup>  
m<sub>2</sub>

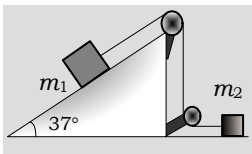
μ m<sub>1</sub>  
(34-4)

m<sub>2</sub> 26-4

m<sub>3</sub>

m<sub>2</sub>=20 kg m<sub>1</sub>=2 kg 0.1

: (35-4) 27-4



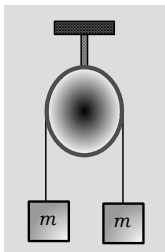
(35-4)

m<sub>1</sub>=m<sub>2</sub>=40 kg

m<sub>2</sub> ( )

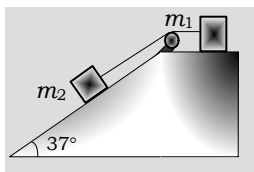
(36-4) ( ) 28-4

m<sub>2</sub>=2 kg m<sub>1</sub>=3 kg



الشكل (36-4)

2 s m<sub>2</sub> ( )  
2 kg m<sub>1</sub>



(37-4)

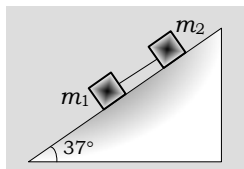
(37-4)

29-4

$m_2=1 \text{ kg}$   $m_1=10 \text{ kg}$

$m_2=8 \text{ kg}$   $m_1=4 \text{ kg}$  30-4

. (38-4)



(38-4)

$m_2$  0.25  $m_1$

0.5

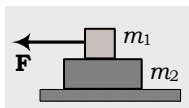
(39-4)

$m_1=10 \text{ kg}$  31-4

$m_2=40 \text{ kg}$

$m_2$   $m_1$  .100 N

$m_2$  0.4



(39-4)

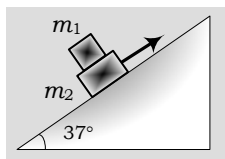
(40-4)

$m_2=10 \text{ kg}$

32-4

$m_1=5 \text{ kg}$

0.2



(40-4)

.a

(41-4)

A

33-4

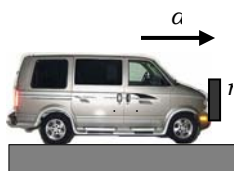
m

2.5 m/s<sup>2</sup>

$m_2$  (42-4)

**F** 34-4

0.6



(41-4)

$m_2=10 \text{ kg}$   $m_1=6 \text{ kg}$  0.4

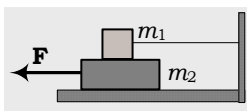
(43-4)

35-4

$m_2=0.8 \text{ kg}$   $m_1=0.2 \text{ kg}$

(43-4)

$m_3=0.2 \text{ kg}$   $m_1$

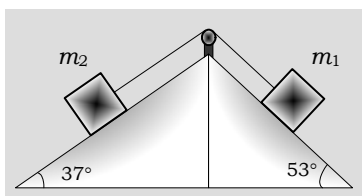


(42-4)

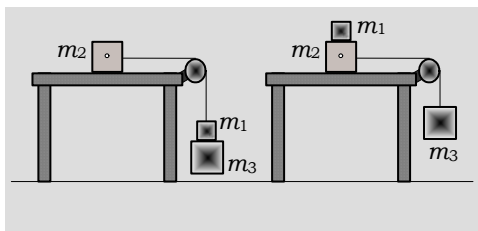
(44-4)

36-4

$m_2=100 \text{ kg}$   $m_1=50 \text{ kg}$



(43-4)



(43-4)



:

( ) 155 rev/min

**37-4**

( ) 2 m

0.1 kg

20 cm 0.2 kg

**38-4**

0.2 s

1 m

**39-4**

500 N

1 m

1 kg

**40-4**

650 km/h

90 kg

**41-4**

( )  $g) 7g$

2

1 m

0.1 kg

**42-4**

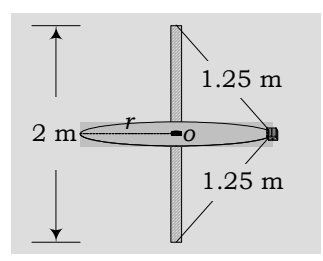
( ) . 30°

m/s

( )

( )

( )



(45-4)

(45-4)

4 kg

**43-4**

1.25 m

( ) .

200 m

60 N

**44-4**

.15 m/s

30 m/s

600 kg      0.15 m      1 kg      **45-4**

                 .0.25 m      800 kg      0.2 m

**46-4**

1.5×10<sup>8</sup> m

$h$       **47-4**

$\rho = 8\pi\rho Gmh/3$

                 .( / )

                 3.85×10<sup>5</sup> km      27.3      **48-4**

                 500 km      **49-4**

                 2.1 m/s<sup>2</sup>      100 km

160 km      **50-4**

$m_1=2$  kg      **51-4**

( ) .(4,0)       $m_3=4$  kg      (2,0)       $m_2=3$  kg

( )

                 1.52      **52-4**

( ) **53-4**

( )      ( ) 100 kg

8 km/h

0.25      3.5 kg      **54-4**

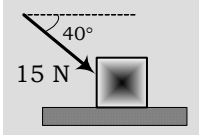
10°      ( ) .0.1

30°      ( )

( ) **55-4**

( ) 85 km/h      100 m

60 m



(46-4)

$40^\circ$

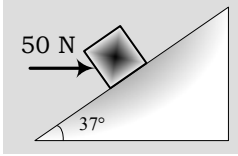
15 N

3.5 kg

**56-4**

0.25

.(46-4)



(47-4)

( )

( ) .(47-4)

( )

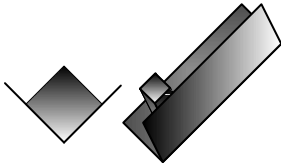
4 m/s

5 kg

**57-4**

50 N

$37^\circ$



(48-4)

$37^\circ$

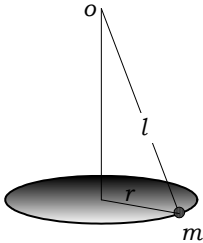
2 kg

**58-4**

0.3

0.4

.(48-4)



(49-4)

$l=1.2$  m

$m=50$  kg

**59-4**

( ) .(49-4)

$r=25$  cm

( )

5 cm

100 g

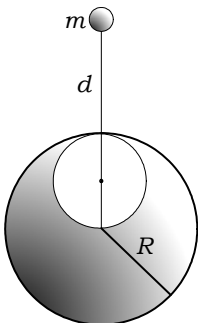
**60-4**

( ) .

3.14 s

( )

( )



(50-4)

$d$

$m$

$\rho$

$R$

(50-4)

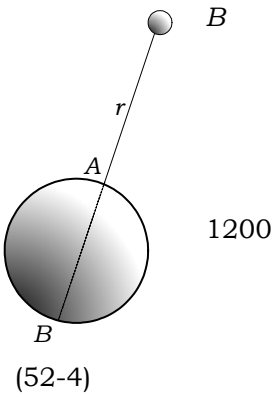
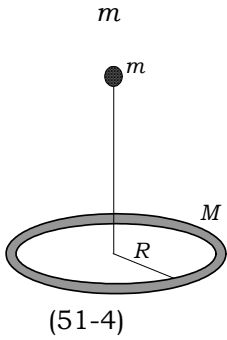
$R$

10 cm

20 km

**61-4**

**62-4**



(51-4)

(52-4)

( )

F

$$F = 2GMmR/r^3$$

( ) .(tidal force)

63-4

h

R

M

( ) 64-4

A

65-4

1200

20 kg

960 N

.N

15 m

66-4

600 N

360 N

10 m/s

( 854 250- 925 313)

.Rhazes

