Chapter 5: Force I

Newton's Laws of Motion:

1) Newton's First law: (القصور الذاتي)

الاجسام الساكنة تبقى ساكنة، والاجسام المتحركة تبقى متحركة مالم تؤثر عليها قوة خارجية.

$$\sum \vec{F} = 0 \quad , \quad \text{net Force} = 0$$

$$\Rightarrow \vec{V} = 0 \quad (\text{at rest})$$

$$\vec{V} = \text{Const} \quad (\text{moves at constant velocity})$$

$$\Rightarrow \vec{a} = 0$$

mass: Inertial mass مقياس لتغير حالة الجسم الحركية (القصور)

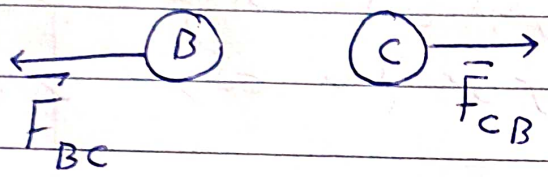
2) Newton's second law:

$$\vec{F}_{net} = m\,\vec{a}$$

or: $F_{net\,x} = m\,a_x$, $F_{net\,y} = m\,a_y$

$$[F] = kg \cdot \frac{m}{s^2} = \text{Newton } (N)$$

3) Newton's Third law: when two bodies interact the forces on the bodies from each other are always equal in magnitude & opposite in direction.

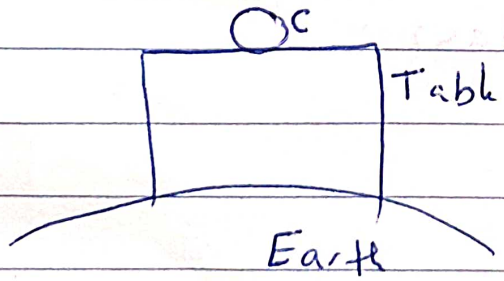


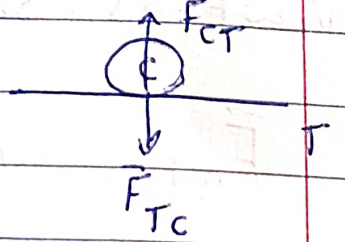
$F_{CB} = F_{BC}$ (same magnitude)

$\vec{F}_{CB} = -\vec{F}_{BC}$ (opposite direction)

$\vec{F}_{net} \neq 0$, The forces act on two bodies not one body

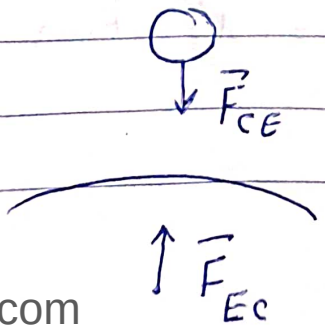
ex:

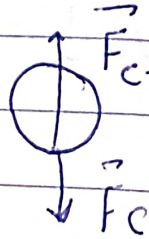




action & reaction

action & reaction



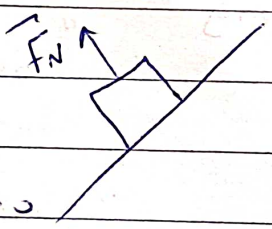


not action & reaction

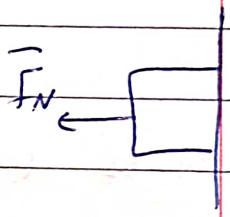
although $\vec{F}_{CT} = -\vec{F}_{CE}$ (not action & reaction, on one body).

→ Some particular Forces:

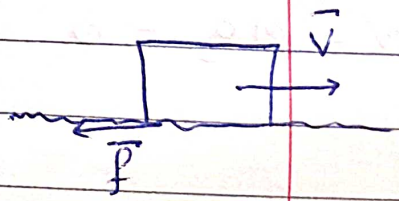
* The gravitational force : $\vec{F}_g = -mg\hat{j}$
  ≡ weight = mg .
* The normal force : $\vec{N}$ or $\vec{F}_N$



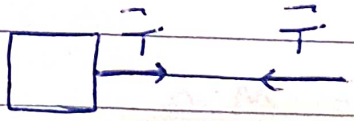
perpendicular to the surface.



* Friction : الاحتكاك



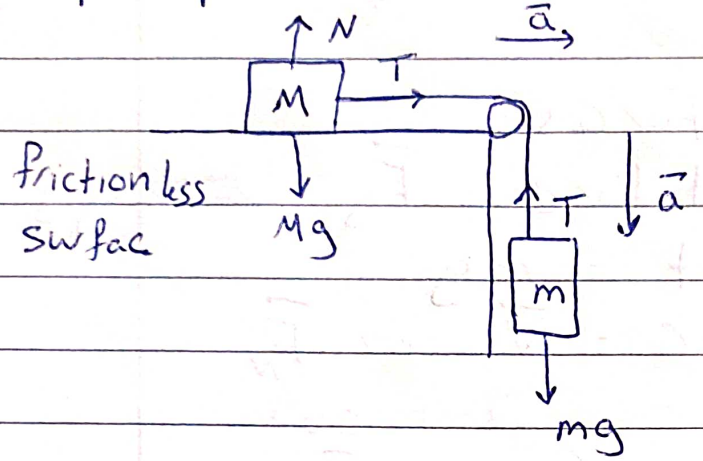
* Tension : الشد



The force on the rope = $\vec{T}$

* Applying Newton's laws :

sample problem 5.03.



M = 3.3 kg

m = 2.1 kg

Find a ??

Find T ??

* For mass (M) :

$\Sigma F_y = 0$

$N - Mg = 0 \Rightarrow N = Mg$

$N = 3.3 \times 10 = 33\ N$

$\Sigma F_x = Ma$

$T = Ma \quad \ldots (1)$

* For mass (m)

$\Sigma F_y = m(-a)$ (a is downward)

" Since the same rope T is Const. & a is Const. "

$$T - mg = -ma \quad \ldots (2)$$

To solve the eq. (1) & (2)

$$T = Ma \quad \ldots (1)$$

$$T - mg = -ma \quad \ldots (2) \quad / \ominus$$

$$mg = Ma + ma$$

$$a(M + m) = mg$$

$$a = \frac{m}{m + M} g$$

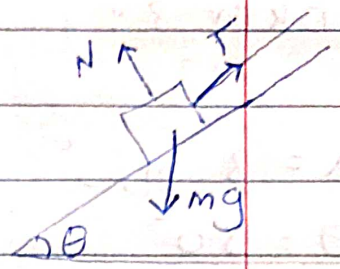
$$= \frac{2.1}{2.1 + 3.3} \times 9.8$$

$$\boxed{a = 3.8 \text{ m/s}^2}$$

$$\Rightarrow T = Ma$$

$$\boxed{T = 3.3 \times 3.8 = 13 \text{ N}}$$

Sample problem 5.04:

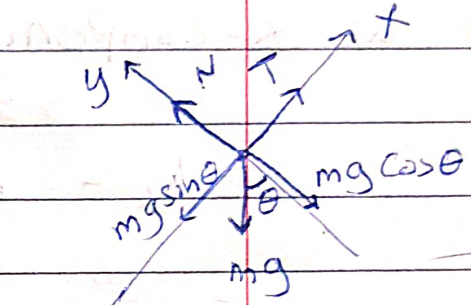


$\theta = 30^\circ$

$m = 5\ kg$

$T = 25\ N$

Find a ??



y - axis :

$\Sigma F_y = m a_y$

$N - mg\cos\theta = 0$ (No motion on the y-axis)

$a_y = 0$

X - axis :

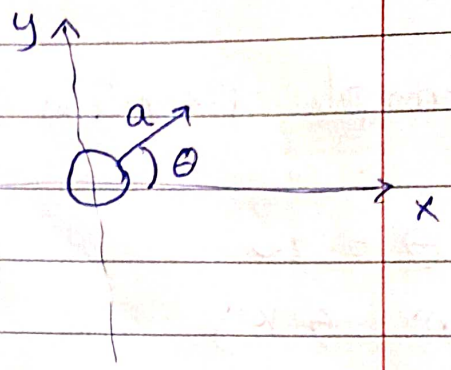
$T - mg\sin\theta = ma$

$25 - 5 \times 9.8 \sin 30 = 5a$

$0.5 = 5a$

$a = 0.1\ m/s^2$ (in +ve x-dir.)

problem 3:

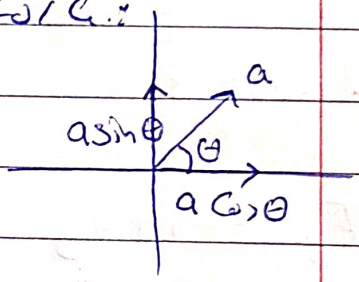


$a = 3\ m/s^2$

$\theta = 30^\circ$

$m = 2\ kg$

a) x-Component of the net force:



$$\Sigma F_x = m a_x$$

$$F_{x_{net}} = m a \cos\theta$$
$$= 2 \times 3 \times \cos 30$$
$$= 5.2\ N$$

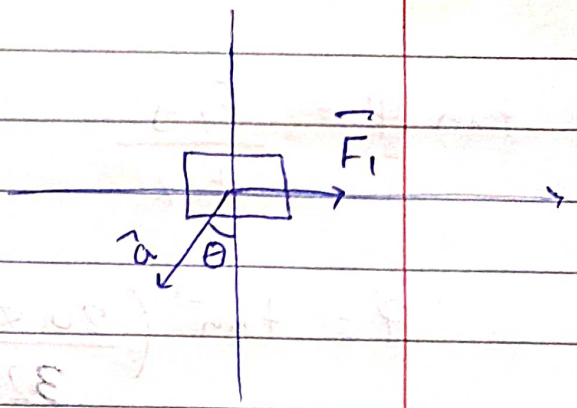
b) y. Comp. of the net force:

$$\Sigma F_y = m a_y$$

$$F_{y_{net}} = m a \sin\theta$$
$$= 2 \times 3 \sin 30$$
$$= 3\ N$$

c) $F_{net} = 5.2\ \hat{i} + 3\ \hat{j}$

problem 7:



$m = 2\ kg$

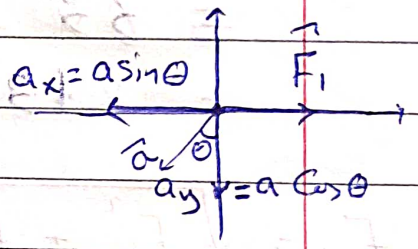
$F_1 = 20\ N$

F_2 ??

$a = 12\ m/s^2$

$\theta = 30°$

Find $\vec{F}_2$??



$\Sigma F_x = m a_x$

$F_1 + F_{2x} = -m a \sin\theta$, $F_{1x} = F_1$

$20 + F_{2x} = -2 \times 12 \sin 30$

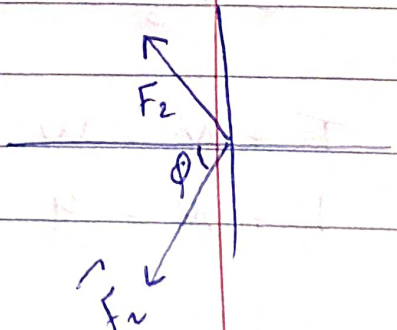
$F_{2x} = -12 - 20 = -32N$

$\Sigma F_y = m a_y$

$F_{2y} = -m a \cos\theta$, $F_{1y} = 0$

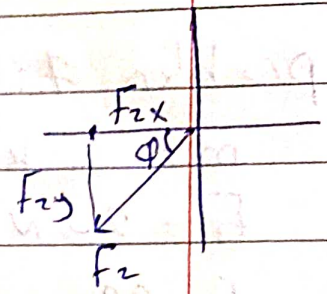
$F_{2y} = 2 \times 12 \cos 30$

$= -20.8\ N$



$\vec{F_2} = -32\hat{i} + 20.8\hat{j}\ N$

$$\tan\phi = \frac{F_{2y}}{F_{2x}}$$

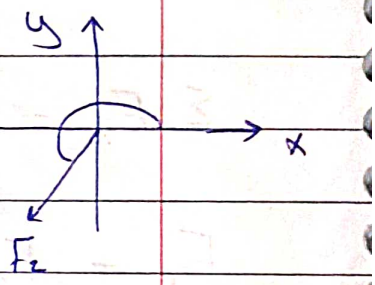


$$\phi = \tan^{-1}\left(\frac{20.8}{32}\right)$$

$$= 33^\circ$$

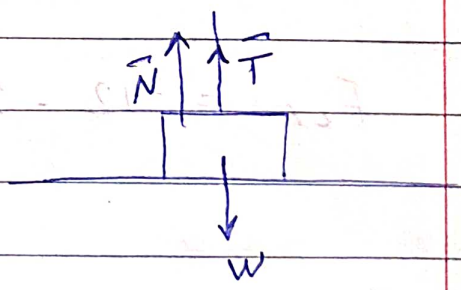
$$= 33^\circ + 180 =$$

$$= 213^\circ \quad \text{form } +x$$



$$F_2 = \sqrt{F_x^2 + F_y^2}$$

problem 14:



Weight = 4 N

F_T = 1 N = T

Find the force of the block on the horizontal surface?

$\Sigma F_y = ma_y = 0$ (the block is not moving)

$T + N - W = 0$

$1 + N - 4 = 0 \Rightarrow N = 3\ N$

N : (Normal force) قوة تأثير السطح على الجسم

By Newton's third law, the force exerted by the block on the surface has the same magnitude but opposite direction

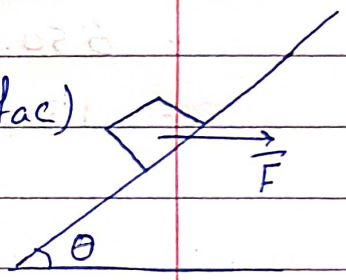
= 3 N (down ward)

problem 34 :

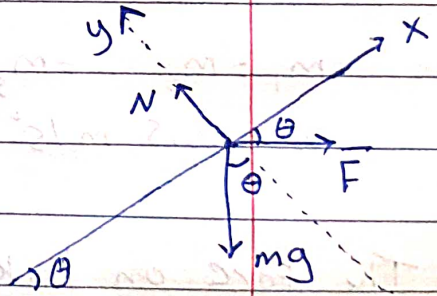
m = 115 kg (frictionless surface)

constant speed !! (a = 0)

θ = 30°



a) Find $\vec{F}$??



$\Sigma F_x = m a_x$

$F \cos\theta - mg \sin\theta = 0$

$F = \frac{mg \sin\theta}{\cos\theta}$

$= 115 \times 9.8 \tan 30$

$= 650.7$ N

$\vec{F} \begin{cases} F_x = F \cos\theta \\ F_y = -F \sin\theta \end{cases}$

$\vec{mg} \begin{cases} (mg)_x = -mg \sin\theta \\ (mg)_y = -mg \cos\theta \end{cases}$

b) The force of the cart from the ramp?
[Find N ??]

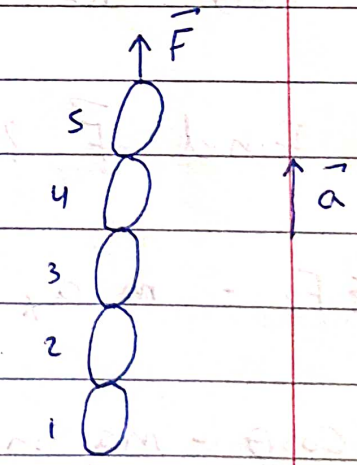
$\Sigma F_y = m a_y$ ($a_y = 0$, No motion on the y-axis)

$N - F \sin\theta - mg \cos\theta = 0$

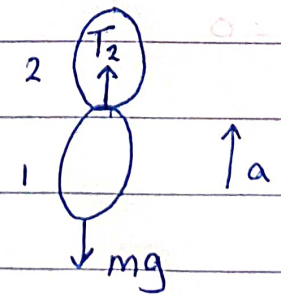
$N = F \sin\theta + mg \cos\theta$
$= 650.7 \sin 30 + 115 \times 9.8 \cos 30$
$= 1301\ N$

problem 43:

$m_1 = m_2 \ldots = m_5 = m = 0.1\ kg$
$a = 2.5\ m/s^2$

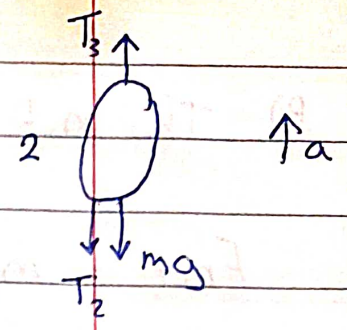


a) The force on link 1 from link 2?



$\Sigma F = ma$
$T_2 - mg = ma$
$T_2 = m(a+g)$
$= 0.1(2.5 + 10)$
$= 1.25\ N$

b) The force on link 2 from link 3?



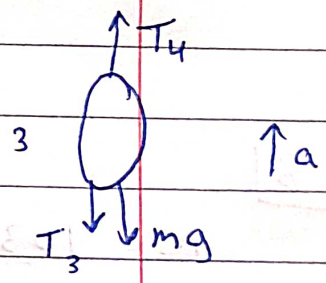
$$\Sigma F = ma$$

$$T_3 - T_2 - mg = ma$$

$$T_3 = T_2 + m(a+g)$$

$$= 1.25 + 1.25 = 2.5\ N$$

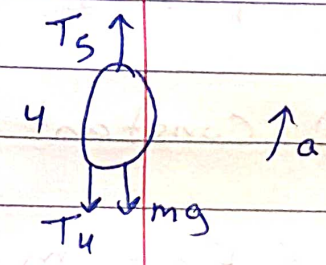
c) The force on link 3 from link 4?



$$T_4 - T_3 - mg = ma$$

$$T_4 = 3.75\ N$$

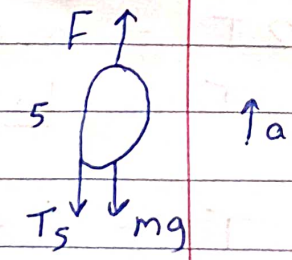
d) The force on link 4 from lin 5?



$$T_5 - T_4 - mg = ma$$

$$T_5 = 5\ N$$

e) The force $\bar{F}$?



$$F - T_5 - mg = ma$$

$$F = 6.25\ N$$

f) The net force on the chain?

$F_{net} = m_{tot}\, a = 5(0.1) \times 2.5$

$= 1.25\ N$

g) The net force on each link?

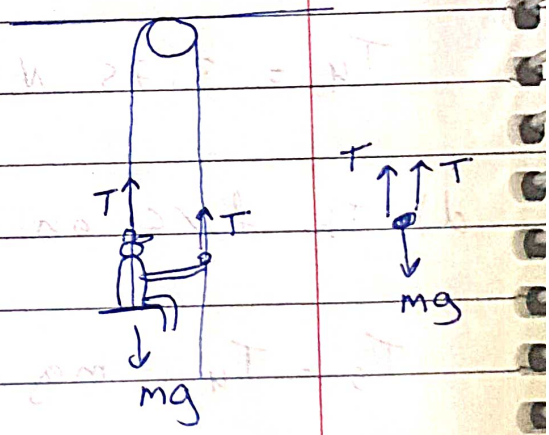
$F_{net} = m a = 0.1 \times 2.5$

$= 0.25\ N$

58)

$m = 103\ kg$

Find the force (pull on the rope) if he is to rise:



a) Constant velocity:

$\Sigma F = ma$

$T + T - mg = ma$

$2T = m(g + a)$

$T = \frac{103(10 + 0)}{2}$

$T = 515\ N$ (pull force on the rope = Tension)

b) $a = 1.3 \text{ m/s}^2$ (upward)

$$T = \frac{m(g+a)}{2} = \frac{103(10+1.3)}{2}$$

$$= 581.9 \text{ N}$$

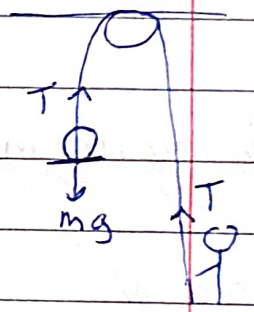
c) $\Sigma F = ma$

$$T - mg = ma$$

$$T = m(g+a) \quad a = 0$$

$$T = 103(10)$$

$$= 1030 \text{ N}$$

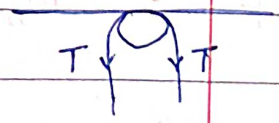


d) $T = m(g+a)$, $a = 1.3 \text{ m/s}^2$ up

$$= 103(10+1.3)$$

$$= 1163.9 \text{ N}$$

* Find the force on the ceiling (i.e. ||)



→ in part a:

$$\Sigma F = 2T$$

$$= 2(515) \text{ N}$$

→ part b:

$$\Sigma F = 2(581.9) \text{ N}$$

→ in part c :

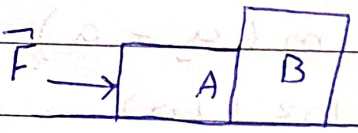
$\Sigma F = 2(1030)\ N$

→ in part d :

$\Sigma F = 2(1163.9)\ N$

Sampk probkm 5.07 :-

$\vec{F} = 20\ N$



$m_A = 4\ kg$, $m_B = 6\ kg$

a) what is th acclcration of th blocks ?

$\Sigma F_x = m a_x$ (The motion along x-axis)

$F = (m_A + m_B)\ a$ (The two blocks move togather)

$20 = (4 + 6)\ a$

$a = 2\ m/s^2$

b) what is the force $\vec{F}_{BA}$ on block B from block A ?

$\vec{F}_{BA}$, $\vec{F}_{AB}$ are action & reaction forces acts on two bodies equal in magnitude & opposite in direction.

* on mass B :

$$\Sigma F_x = m_B a_x$$

$$F_{BA} = m_B a$$
$$= 6 \times 2$$
$$= 12\ N$$

* on mass A :

$$\Sigma F_x = m_A a_x$$

$$F - F_{AB} = m_A a \quad , \quad \boxed{F_{BA} = F_{AB}}$$

$$20 - 12 = 4 \times 2 \quad \checkmark$$