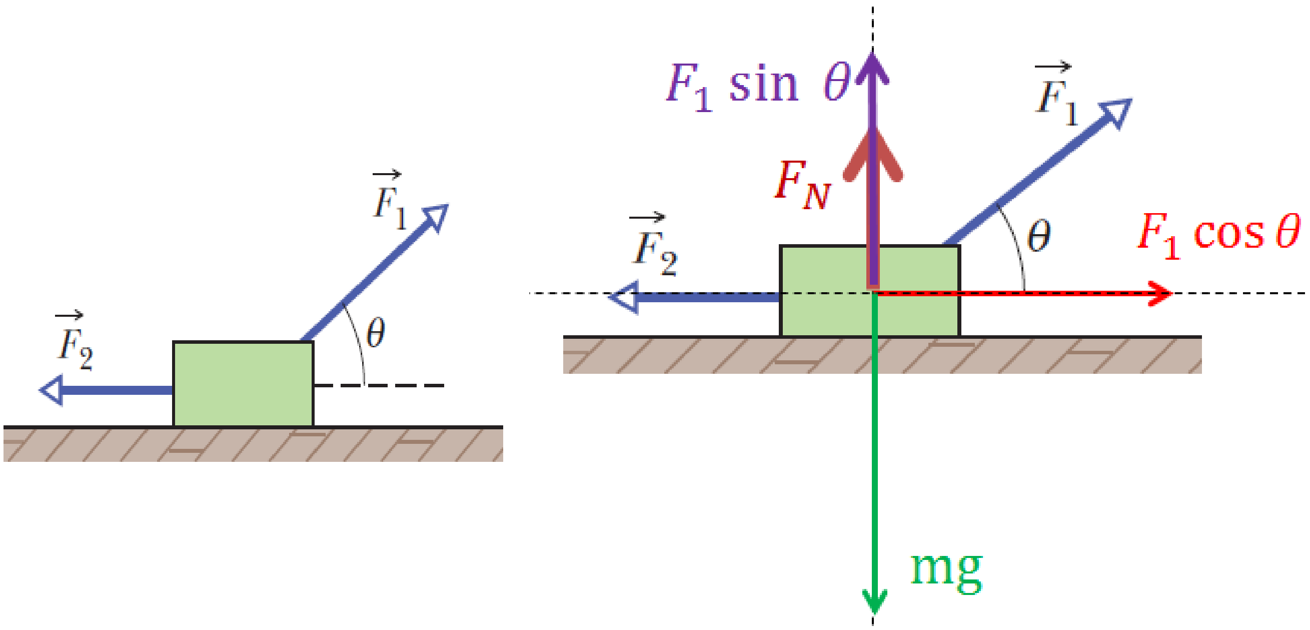
Chapter 5: Force and Motion 1

Q-3) In the below figure, forces $\vec{F}_1$ and $\vec{F}_2$ are applied to a lunchbox as it slides at constant velocity over a frictionless floor. We are to decrease angle θ without changing the magnitude of $\vec{F}_1$. For constant velocity, should we increase, decrease, or maintain the magnitude of $\vec{F}_2$?



$$F_{net,x} = F_1 \cos\theta - F_2 = m\, a_x$$

$$F_{net,y} = F_N + F_1 \sin\theta - mg = m\, a_y$$

A lunchbox slides at constant velocity over a frictionless floor: zero Acceleration ($a_x = a_y = 0$)

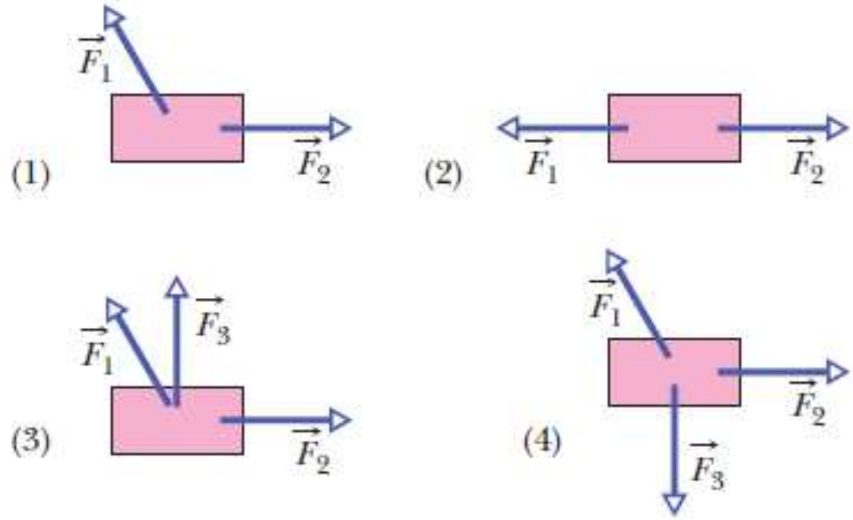
$$F_1 \cos\theta = F_2$$

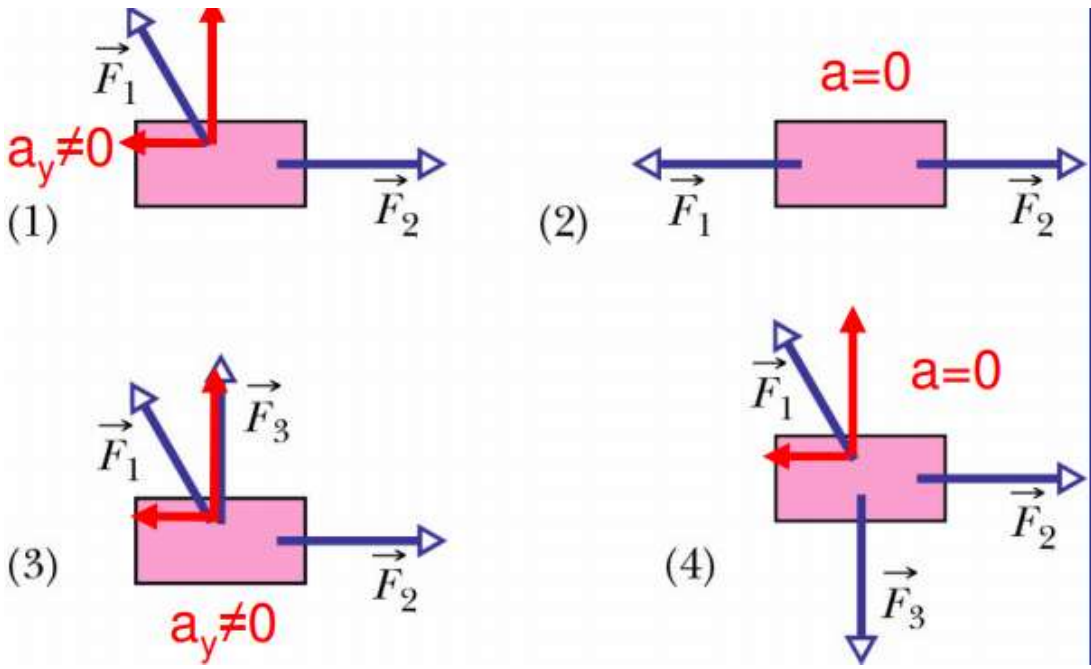
$$F_N + F_1 \sin\theta = mg$$

$$F_1 = \frac{F_2}{\cos\theta} = constant$$

When θ decreases, the $\cos\theta$ increases. So F_2 must increase to keep F_1 as magnitude constant.

Q-5) The below figure shows overhead views of four situation in which forces act on block that lies on a frictionless floor. If the force magnitudes are chosen properly, in which situations is it possible that the block is (a) stationary and (b) moving with a constant velocity ?

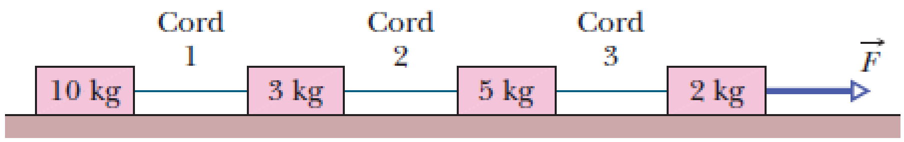




(a) 2 and 4

(b) 2 and 4

Q-9)The below figure shows a train of four blocks being pulled across a frictionless floor by $\vec{F}$. What total mass is accelerated to the right by (a) force $\vec{F}$, (b) cord 3, and (c) cord 1? (d) Rank the blocks according to their accelerations, greatest first. Rank the cords according to their tension, greatest first.



$$\vec{F} = (10 + 3 + 5 + 2)\,\vec{a} = (20\,Kg)\,\vec{a}$$

(a) 20 Kg

(b) 18 Kg

(c) 10 kg

(d) All tie, same acceleration $\vec{a}$

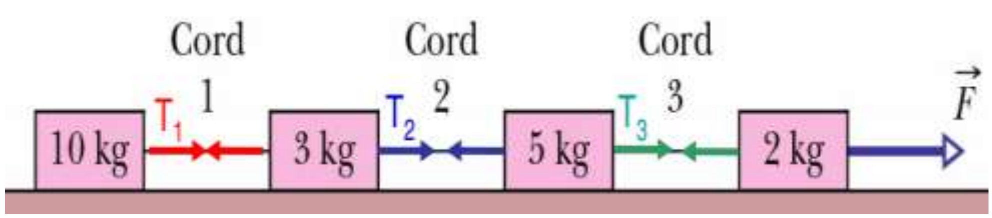
(e) Newton's 2nd law on 10 Kg: $T_1 = 10\,a$

Newton's 2nd law on 3 Kg: $T_2 - T_1 = 3\,a \rightarrow\rightarrow T_2 = 13\,a$

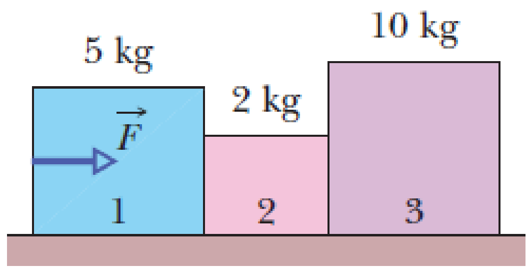
Newton's 2nd law on 5 Kg: $T_3 - T_2 = 5\,a \rightarrow\rightarrow T_3 = 18\,a$

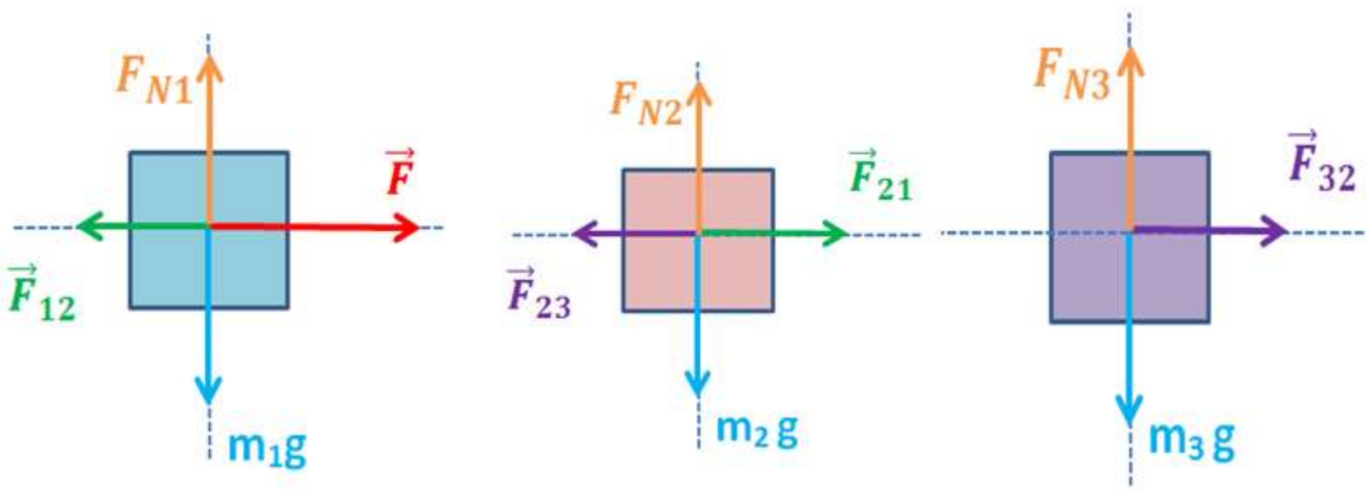
Newton's 2nd law on 2 Kg: $F - T_3 = 2\,a \rightarrow\rightarrow F = 20\,a$

$$T_3 > T_2 > T_1$$



Q-10)The below figure shows three blocks being pushed across a frictionless floor by horizontal force $\vec{F}$. What total mass is accelerated to the right by (a) force $\vec{F}$, force $\vec{F}_{21}$ on block 2 from block 1, and (c) force $\vec{F}_{32}$ on block 3 from block 2 ? (d) Rank the blocks according to their acceleration magnitudes, greatest first. (e) Rank forces $\vec{F}$, $\vec{F}_{21}$ and $\vec{F}_{32}$ according to magnitude, greatest first.





Newton's 2nd law for block 1 (5 kg):

$$F_{net,x;1} = F - F_{12} = 5\,a \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

Newton's 2nd law for block 2 (2 kg):

$$F_{net,x;2} = F_{21} - F_{23} = 2\,a \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Newton's 2nd law for block 3 (10 kg):

$$F_{net,x;3} = F_{32} = 10\,a \ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ldots\ldots\ldots\ldots..\ldots.(3)$$

$F_{net,y} = F_N - mg = zero$, no motion in y direction (for the three blocks)

$$\vec{F} = (5 + 2 + 10)\,\vec{a} = (17\,Kg)\,\vec{a}$$

(a) 17 Kg, all three blocks are effectively one unit.

(b) 12 Kg

$F_{32} = 10\,a \;\rightarrow\rightarrow\; F_{23} = 10\,a\;$ *but in the opposite direction.*

F_{23} and F_{32} are action and reaction pair

From equation (2): $F_{21} - F_{23} = 2\,a \;\rightarrow\rightarrow\; F_{21} - 10a = 2\,a \;\rightarrow\rightarrow\; F_{21} = 12\,a$

(c) 10 Kg (only the last block)

(d) All three accelerations are equal; all three blocks are effectively one unit.

(e) $F_{23} = 10\,a$, $F_{21} = 12\,a$

Equation (1) $F - F_{12} = 5\,a \;\rightarrow\rightarrow\;$ $F = 17\,a$

$$F > F_{21} > F_{32}$$

P-10) A 0.150 Kg particle moves along x axis according to $x(t) = -13.00 + 2.00\ t + 4.00\ t^2 - 3.00\ t^3$, with x in meters and t in seconds. In unit-vector notation, what is the net force acting on the particle at t=3.40 s ?

Newton's second law: $\vec{F} = m\,\vec{a} = m\,\frac{d\vec{v}}{dt} = m\,\frac{d^2x}{dt^2}\,\hat{\imath}$

$$\frac{dx}{dt} = +2.00 + 8.00\ t - 9.00\ t^2$$

$$a_x = \frac{d^2x}{dt^2} = +8.00 - 18.00\ t$$

$$a_x(t = 3.40\ s) = -53.2\ m/s^2$$

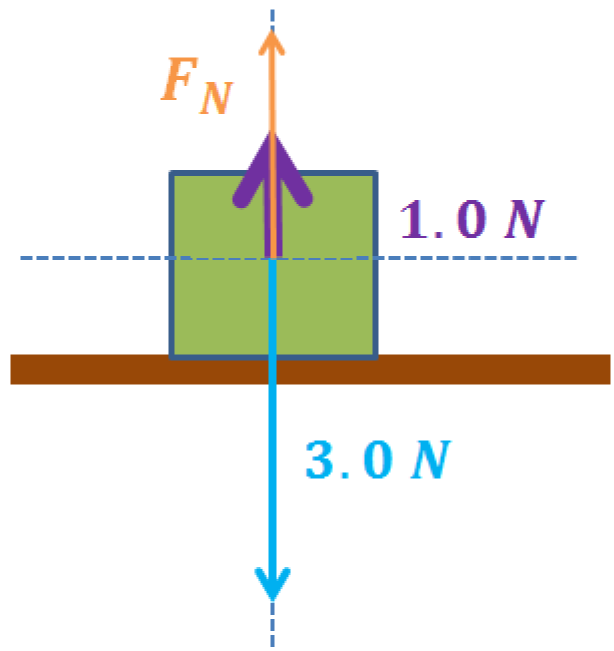
$$\vec{a} = -53.2 m/s^2\,\hat{\imath}$$

$$\vec{F} = m\,\vec{a} = 0.150\ Kg\ (-53.2\ m/s^2\,\hat{\imath}) = (-7.98\ N)\hat{\imath}$$

P-14) A block with a weight of 3.0 N is at rest on a horizontal surface. A 1.0 N upward force is applied to the block by means of an attached vertical string. What are the (a) magnitude and (b) direction of the force of the block on the horizontal surface?

We have three vertical forces:

- The weight (3.0 N) – The Earth pulls down the block with a gravitational force.
- Elastic force (1.0 N) – A string pulls up the block.
- The Normal force - The surface pushes up the block with normal force.



There is no acceleration because the block is at rest.

$$F_{net,y} = F_N + F_{string} - mg = zero$$

$$F_{net,y} = F_N + 1.0\ N - 3.0\ N = zero$$

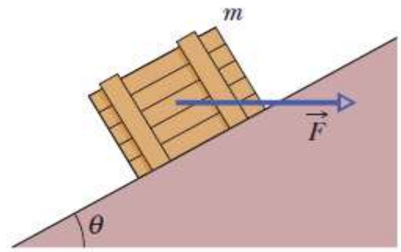
$$F_N = 2.0\ N$$

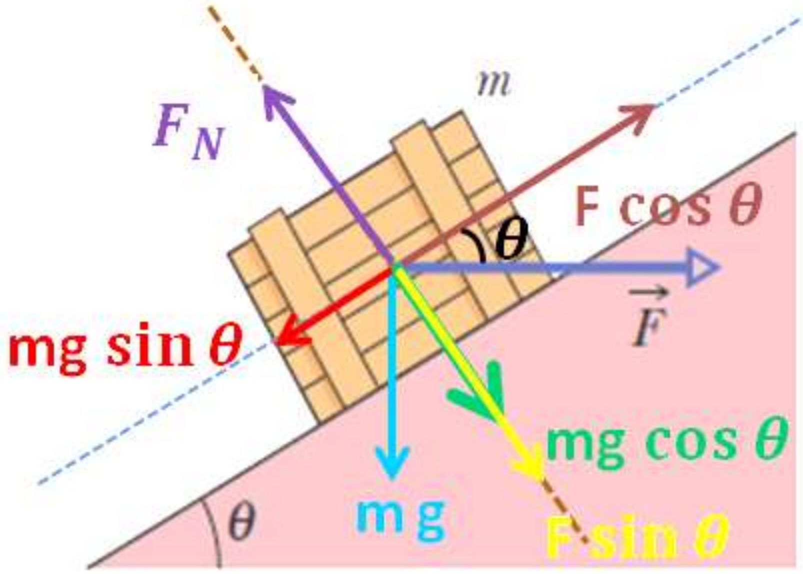
(a) The force of the block on the horizontal surface = 2.0 N down

By Newton's third law, the force exerted by the surface on the block (F_N) equals the force exerted by the block on the surface but in the opposite direction.

(b) The force of the block on the horizontal surface $= (-2.0\ N)\hat{j}$

P-34) In the below figure, a crate of mass m = 100 Kg is pushed at constant speed up a frictionless ramp ($\theta = 30.0^{\circ}$) by a horizontal force $\vec{F}$. What are the magnitudes of (a) $\vec{F}$ and (b) the force on the crate from the ramp?





$$F_{net,x} = \mathbf{F}\ \cos\boldsymbol{\theta} - \mathbf{mg}\ \sin\boldsymbol{\theta} = m\,a_x$$

$$F_{net,y} = \boldsymbol{F_N} - \mathbf{mg}\ \cos\boldsymbol{\theta} - \mathbf{F}\ \sin\boldsymbol{\theta} = m\,a_y$$

The block is pushed at constant speed means the block has ZERO acceleration.

$$\mathbf{F}\ \cos\boldsymbol{\theta} = \mathbf{mg}\ \sin\boldsymbol{\theta}$$

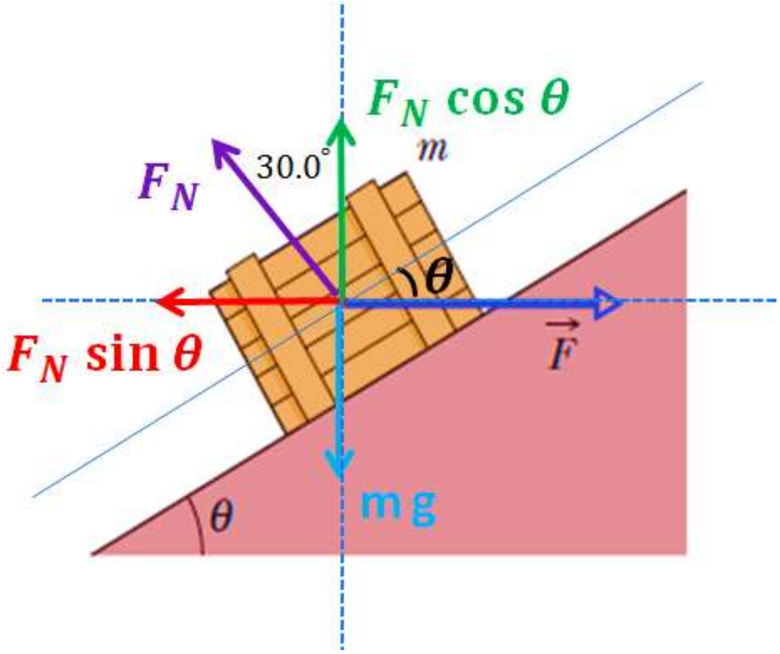
$$\boldsymbol{F_N} = \mathbf{mg}\ \cos\boldsymbol{\theta} + \mathbf{F}\ \sin\boldsymbol{\theta}$$

$$(a) \to \to \mathbf{F} = \frac{\mathbf{mg}\ \sin\boldsymbol{\theta}}{\cos\boldsymbol{\theta}} = 100\,Kg\ (9.8\,m/s^2)\tan(30.0^{\circ}) = 565.8\,N$$

$(b) \to \to \boldsymbol{F_N} = \mathbf{mg}\ \cos\boldsymbol{\theta} + \mathbf{F}\ \sin\boldsymbol{\theta}$ **; The force on the crate from the ramp**

$$\boldsymbol{F_N} = 100\,Kg\ (9.8\,m/s^2)\cos(30.0^{\circ}) + 565.8\,N\sin(30.0^{\circ}) = 1.13\,KN$$

Another solution:



$$F_{net,x} = \mathbf{F} - \boldsymbol{F_N}\ \mathbf{sin}\,\boldsymbol{\theta} = m\,a_x$$

$$F_{net,y} = \boldsymbol{F_N}\ \mathbf{cos}\,\boldsymbol{\theta} - \mathbf{mg} = m\,a_y$$

The block is pushed at constant speed means the block has ZERO acceleration.

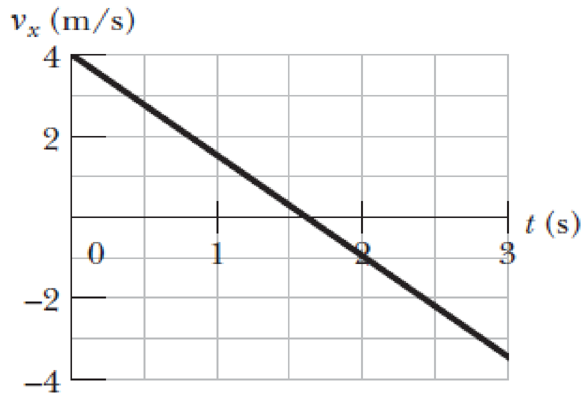
$$\mathbf{F} = \boldsymbol{F_N}\ \mathbf{sin}\,\boldsymbol{\theta}$$

$$\boldsymbol{F_N}\ \mathbf{cos}\,\boldsymbol{\theta} = \mathbf{mg}$$

$$F_N = \frac{\text{mg}}{\cos\theta} = \frac{100\ Kg\,(9.8 m/s^2)}{\cos 30.0^\circ} = 1.13\ KN$$

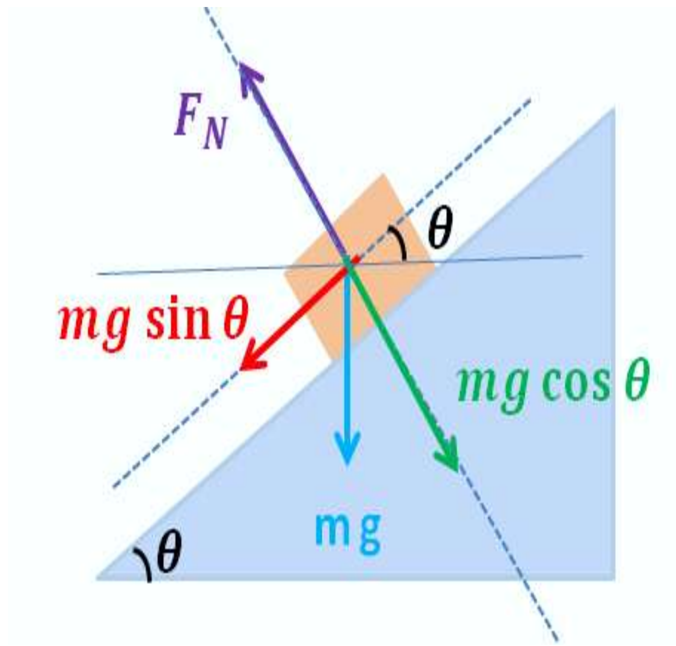
$$\mathbf{F} = \boldsymbol{F_N}\ \mathbf{sin}\,\boldsymbol{\theta} = 1.13\ KN \sin(30.0^\circ) = 565.8\ N$$

P-40) A dated box of dates, of mass 5.00 kg, is sent sliding up a frictionless ramp at an angle of θ to the horizontal. The below figure gives, as a function of time t, the component v_x of the box's velocity along an x axis that extends directly up the ramp. What is the magnitude of the normal force on the box from the ramp?



$$F_{net,x} = -mg\ \sin\theta = m\,a_x$$

$$F_{net,y} = F_N - \text{mg}\cos\theta = m\,a_y = ZERO$$



The block is sliding up the ramp means the block has ZERO acceleration in the y direction $(a_y = 0)$

$-mg\ \sin\theta = m\,a_x$ ....(1)

$F_N = \text{mg}\cos\theta$ ....(2)

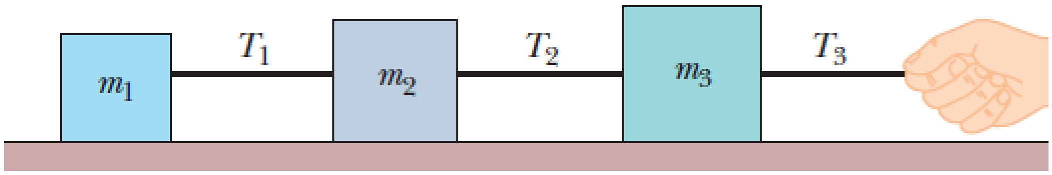
$a_x = \frac{dv_x}{dt} = slope\ of\ v_x\ versus\ t\ curve.$

$$a_x = \frac{4-(-3.5)}{0-3} = (-2.5\ m/s^2)\,\hat{\imath}$$

$Equation(1):$ $\sin\theta = \frac{-a_x}{g} = \frac{-2.5}{9.8}$ → → $\theta = 14.8^\circ$

$$F_N = \text{mg}\cos\theta = 5\ Kg\ (9.8\ m/s^2)\cos 14.8^\circ = 47.4\ N$$

P-53) In the below figure; Three connected blocks are pulled to the right on horizontal frictionless table by a force of magnitude $T_3 = 65.0\,N$. If $m_1 = 12.0\,Kg$, $m_2 = 24.0\,Kg$, and $m_3 = 31.0\,Kg$, calculate (a) the magnitude system's acceleration, (b) the tension T_1, and (c) the tension T_2



$$\vec{F} = T_3 = (m_1 + m_2 + m_3)\,\vec{a} = (67\,Kg)\,\vec{a}$$

$$\vec{a} = (0.97\ m/s^2)\ \hat{\imath}$$

(a) The magnitude of system's acceleration is 0.97 m/s^2) and for each of blocks individually.

Newton's 2nd law on 12.0 Kg: $T_1 = 12.0\,a = 12\,Kg\,(0.97\ m/s^2)\ \hat{\imath} = 11.64\,N$

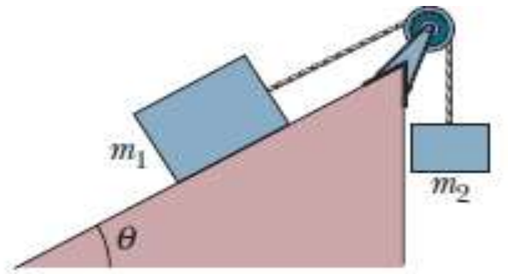
Newton's 2nd law on 24.0 Kg:

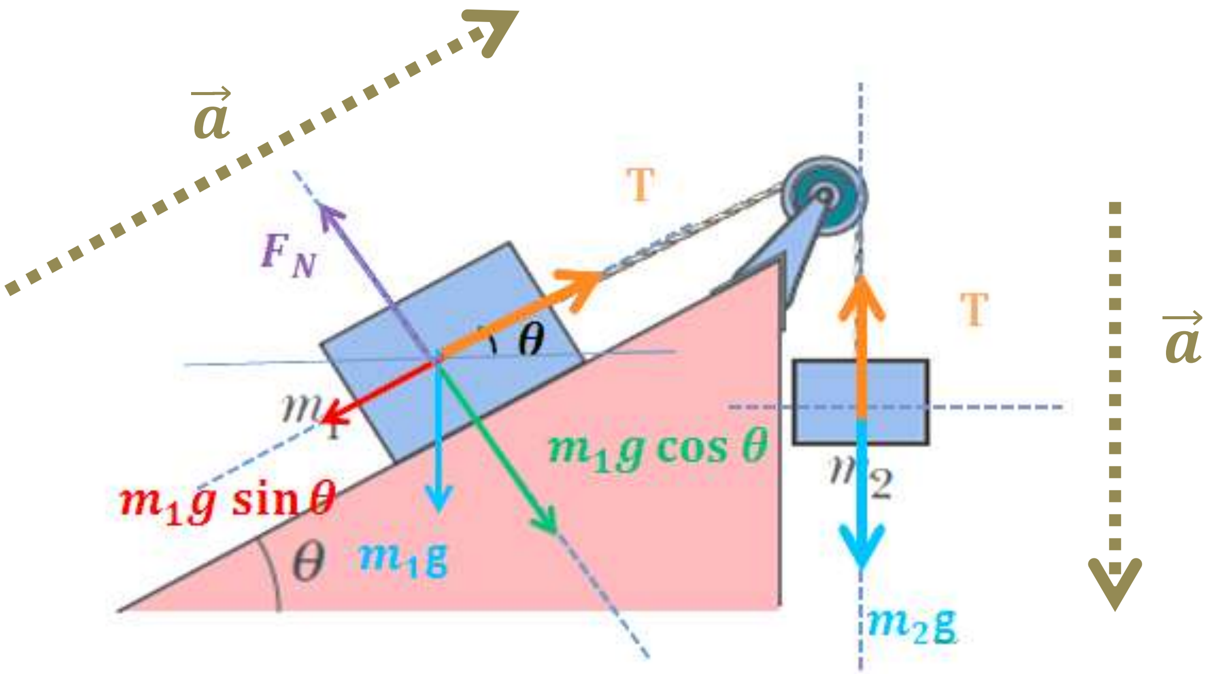
$T_2 - T_1 = 24.0\,a \rightarrow\rightarrow$ $T_2 = 36\,a = 36\,Kg\,(0.97\ m/s^2)\ \hat{\imath} = 34.92\,N$

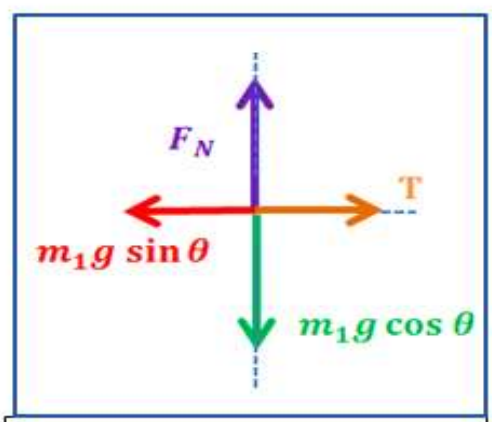
Newton's 2nd law on 31.0 Kg:

$T_3 - T_2 = 31\,a \rightarrow\rightarrow$ $T_3 = 67\,a = 64.99\,N$

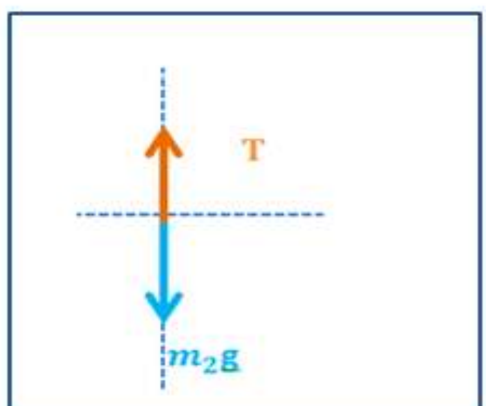
p-73) A block of mass $m_1 = 3.70$ Kg on a frictionless plane inclined at angle $\theta = 30.0^{\circ}$ is connected by a cord over a massless, frictionless pulley to a second block of mass $m_2 = 2.3$ Kg. What are (a) the magnitude of the acceleration of each block, (b) the direction of the acceleration of the hanging block, and (c) the tension in the cord?







Free Body diagram for m_1



Free Body diagram for m_2

Direction of motion:

m_1 moves UPWARD on the inclined plane and m_2 moves downward

$$(m_1 g \sin\theta = 18.13\ N) < (m_2 g = 22.54\ N)$$

Newton's 2nd law of mass 1:

$$F_{net,x} = T - m_1 g \sin\theta = m_1 a$$

$$F_{net,y} = F_N - m_1 g \cos\theta = zero \text{ , (No motion in y-direction)}$$

Newton's 2nd law of mass 2:

$$F_{net,y} = m_2 g - T = m_2 a$$

$$T - m_1 g \sin\theta = m_1 a \text{ ....(1)}$$

$$F_N = m_1 g \cos\theta \text{.................................(2)}$$

$$m_2 g - T = m_2 a \text{ ....(3)}$$

Equation (1) + Equation (3):

$$m_2 g - m_1 g \sin\theta = (m_1 + m_2)a$$

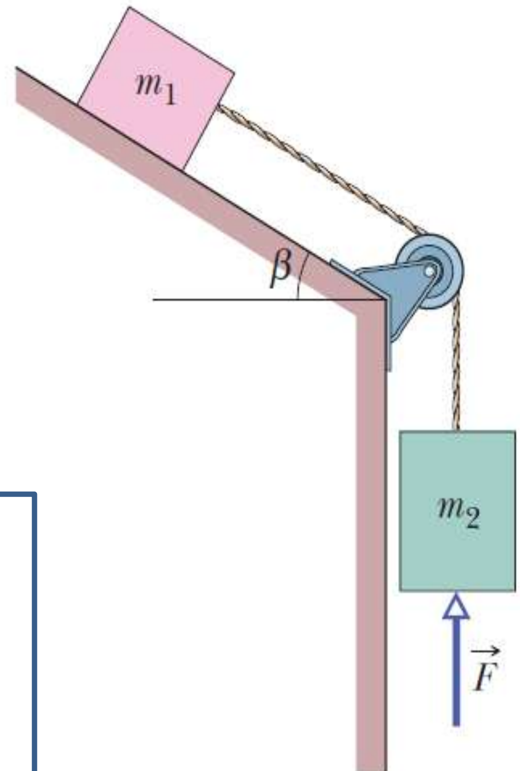
$$a = \frac{-m_1 g \sin\theta + m_2 g}{m_1 + m_2} = \frac{(2.3 \times 9.8) - (3.70 \times 9.8 \times \sin 30.0^\circ)}{3.7 + 2.3} = 0.74\, m/s^2$$

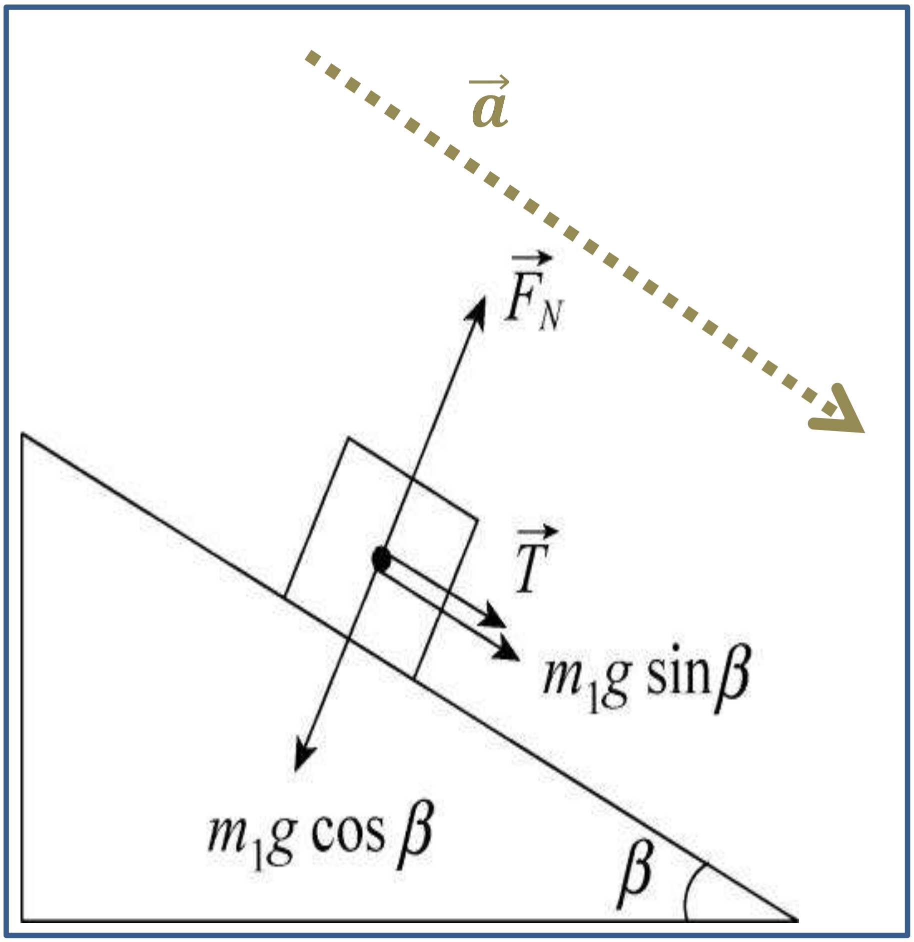
(b) The acceleration of block 1 is indeed up the incline and that the acceleration of block 2 is vertically down.

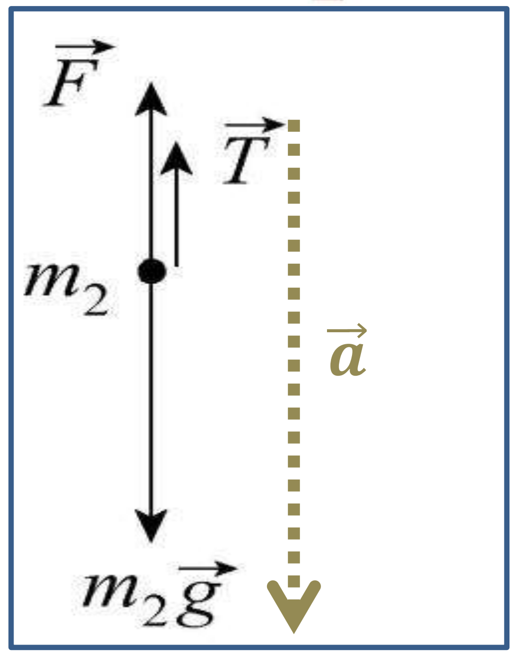
(c) From equation (2):

$$T = m_2 g - m_2 a = m_2(g - a) = 2.3(9.8 - 0.74) = 20.84\ N$$

P-73) In the below figure, a tin of antioxidants ($m_1 = 1.0Kg$)on a frictionless inclined surface is connected to a tin of corned beef ($m_2 = 2.0Kg$). The pulley is massless and frictionless. An upward force of magnitude F = 6.0 N acts on the corned beef tin, which has a downward acceleration of $5.5\,m/s^2$. What are (a) the tension in the connecting cord and (b) angle β ?







Newton's 2nd law of mass 1:

$$F_{net,x} = T + m_1 g \sin\beta = m_1 a$$

$$F_{net,y} = F_N - m_1 g \cos\beta = zero$$, (No motion in y-direction)

Newton's 2nd law of mass 2:

$$F_{net,y} = m_2 g - T - F = m_2 a$$

$$\mathrm{T} + m_1 g\ \sin\beta\ = m_1\ a \dots\dots\dots\dots\dots\dots\dots\dots\dots.(1)$$

$$F_N = m_1 g \cos\beta \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.\dots\dots.(2)$$

$$m_2 g - \mathrm{T} - \mathrm{F} = m_2\ a \dots\dots\dots\dots\dots..\dots\dots\dots\dots.(3)$$

Equation (3): $\mathrm{T} = m_2 g - m_2\ a - \mathrm{F} = 2.0(9.8 - 5.5) - 6.0 = 2.6\ N$

(a) The tension in the cord is 2.6 N

(b) Equation (1):

$$\sin\beta = \frac{m_1\ a - T}{m_1 g} = \frac{(1.0 \times 5.5) - 2.6}{1.0 \times 9.8} = 0.296$$

$$\beta = 17.2^{\circ}$$