Lecture 10

(Ch4:3-4)

Chapter 4:Force and Newton's Laws
Newton's Laws and Uniform Circular Motion

$$\vec{F}_{net} = m \cdot \vec{a}, \text{ in SI: } \frac{1\,\text{kg} \cdot 1\,\text{m}}{1\,s^2} = 1\,\text{N}$$

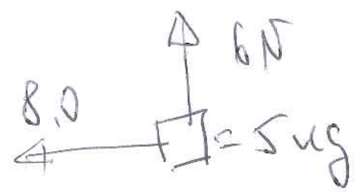
In uniform circular motion

$a = \frac{v^2}{R}$, the centripetal acceleration

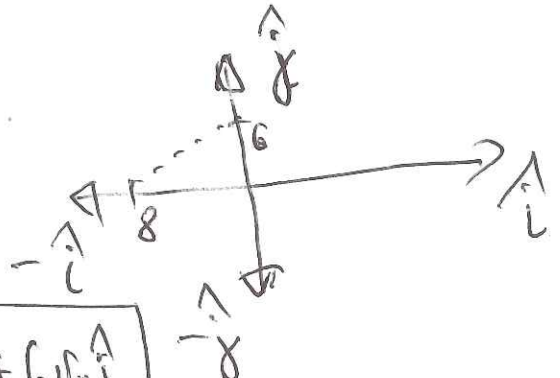
$F_r = m \cdot a = \frac{m \cdot v^2}{R}$, the centripetal force

32. Two forces are applied to a 5.0-kg object; one is 6.0 N to the north and the other is 8.0 N to the west. The magnitude of the acceleration of the object is:

1) 0.50 m/s^2
2) 2.0 m/s^2
3) 2.8 m/s^2
4) 10 m/s^2



$|\vec{a}| = ?$



$$\vec{F}_{Net} = -8N * \hat{i} + 6N * \hat{j}$$

$$|\vec{F}| = \sqrt{8^2 + 6^2} = 10N$$

$$|\vec{F}| = m|\vec{a}|$$

$$\frac{|\vec{F}|}{m} = |\vec{a}|$$

$$2\frac{m}{s^2} = \frac{10N}{5kg} = \frac{|\vec{F}|}{m}$$

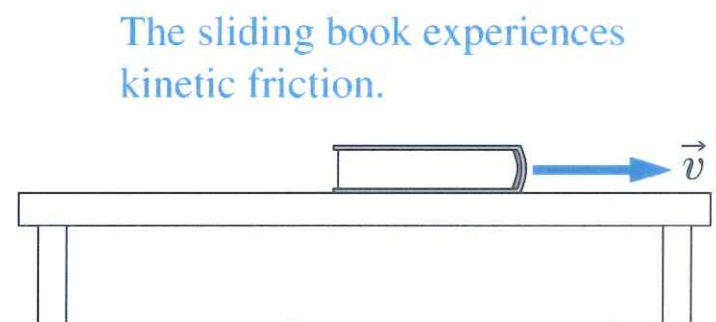
Chapter 4:Force and Newton's Laws
Kinetic friction (sliding friction)

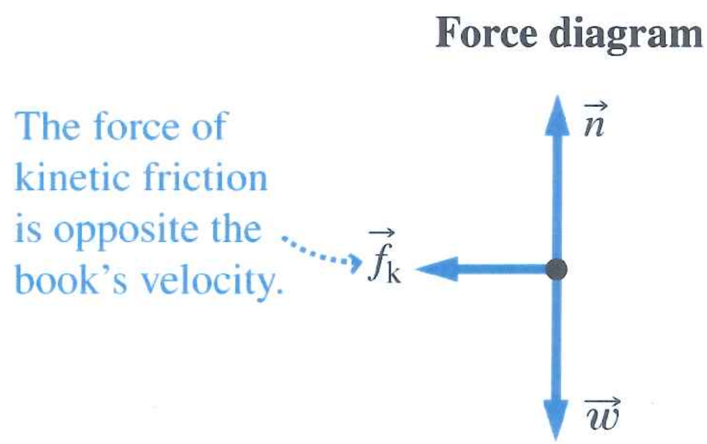
The kinetic friction appears when sliding on a surface.

$f_k = \mu_k \cdot n$, in SI units: N

n measured in N

μ_k, the kinetic friction coefficient is dimensionless





Exercise:

$$v_0 = 1.8\frac{m}{s}, \qquad \mu_k = 0.19$$

Find the acceleration and the distance until stopped.

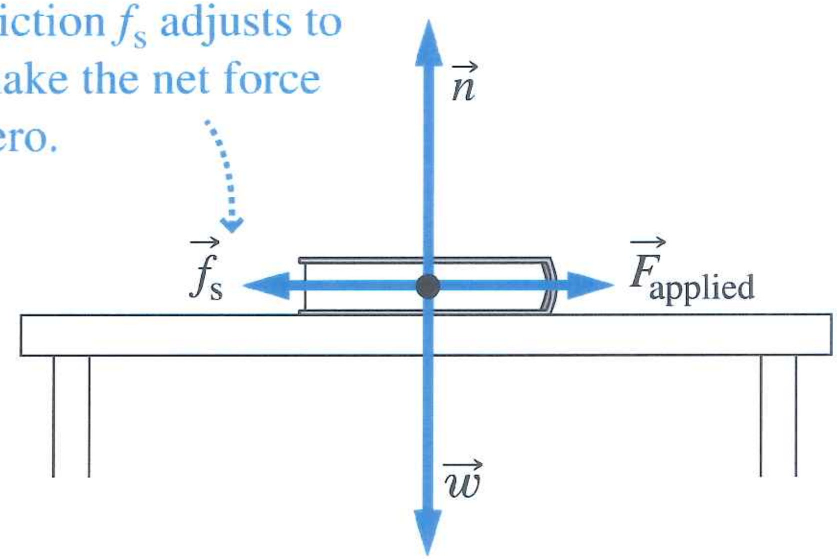
Chapter 4:Force and Newton's Laws
Static friction

Static friction resists the onset of motion.

$f_s \leq \mu_s \cdot n$, in SI units: N

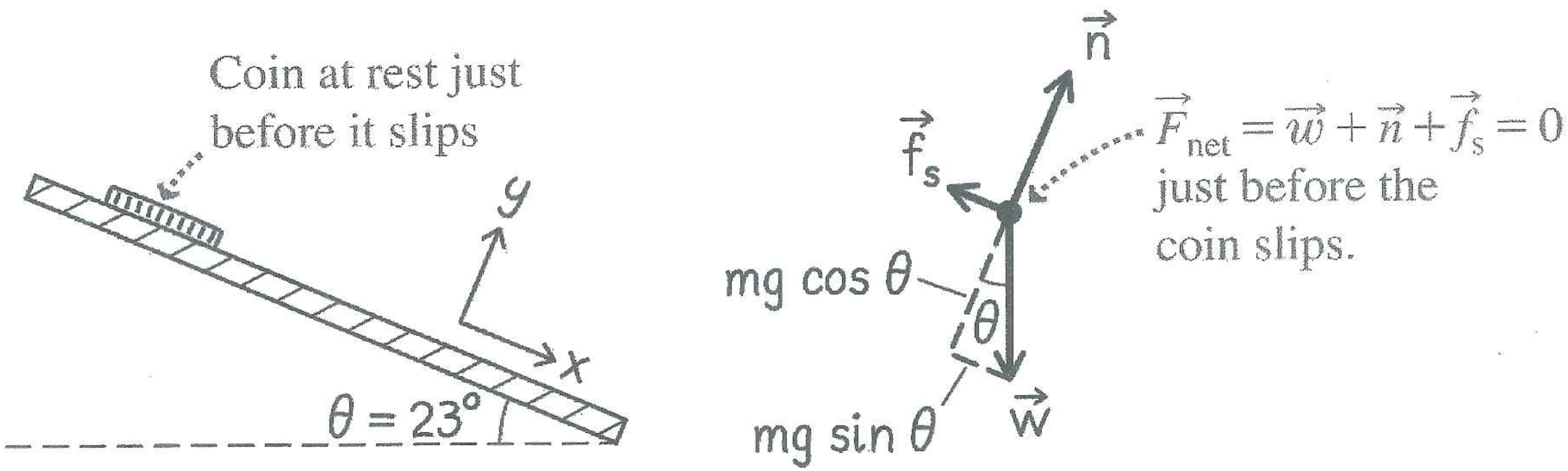
n measured in N

μ_s, the static friction coefficient



The static friction increases from 0 to a maximum value. Once the applied force exceeded the maximum value of the friction force, the object starts moving with an acceleration proportional to the net force.

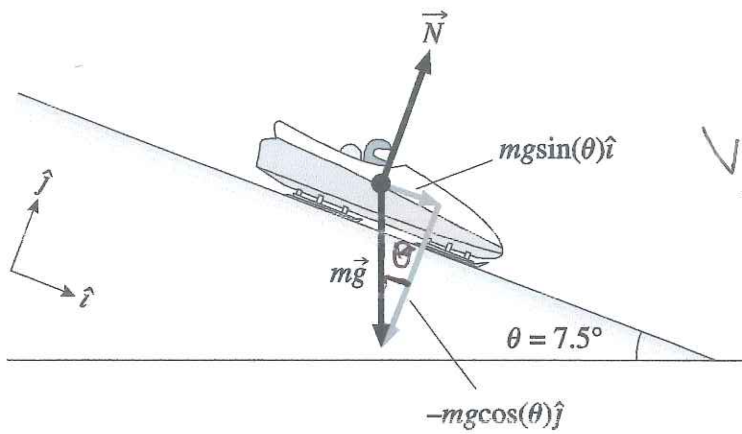
Figure 4.24



$\mu = tg^{-1}(\theta)$

No friction!

51. **ORGANIZE AND PLAN** Draw a diagram of the situation that includes all the forces involved. Compute the net force and use Newton's law to calculate the acceleration. From this we can find the final speed.



$V_f = ?$ if $V_0 = 0$ at $t = 25$ s.

Known: $\theta = 7.5°$; $t = 25$ s; $g = 9.8$ m/s^2

SOLVE The net force is [Eq. 1] $\vec{F}_{net} = mg\sin(\theta)(\hat{i})$. From Newton's second law, this gives an acceleration of [Eq. 2]

$W_x = F_x = mg\sin\theta = ma_x$

$$\vec{a}_x = \vec{F}_{net}/m = g\sin(\theta)(\hat{i})$$

$$\vec{a} = (9.8 \text{ m/s}^2)\sin(7.5°)(\hat{i}) = 1.3 \text{ m/s}^2(\hat{i})$$

After 25 s, the final speed will be [Eq. 3]

$$\vec{v}_f = \vec{v}_0 + \vec{a}t = 0 + (1.3 \text{ m/s}^2)(25 \text{ s})(\hat{i}) = 32 \text{ m/s}(\hat{i}) .$$

Applications of Newton's Laws

if $m = 0$, then $T = T'$

Tension Forces

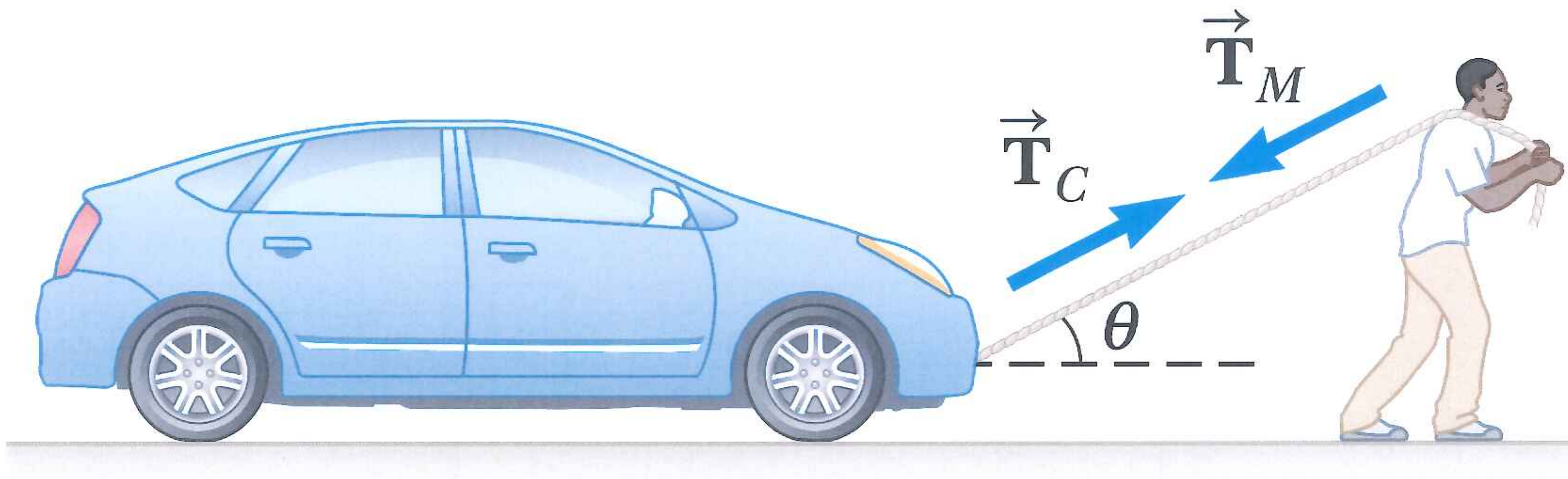
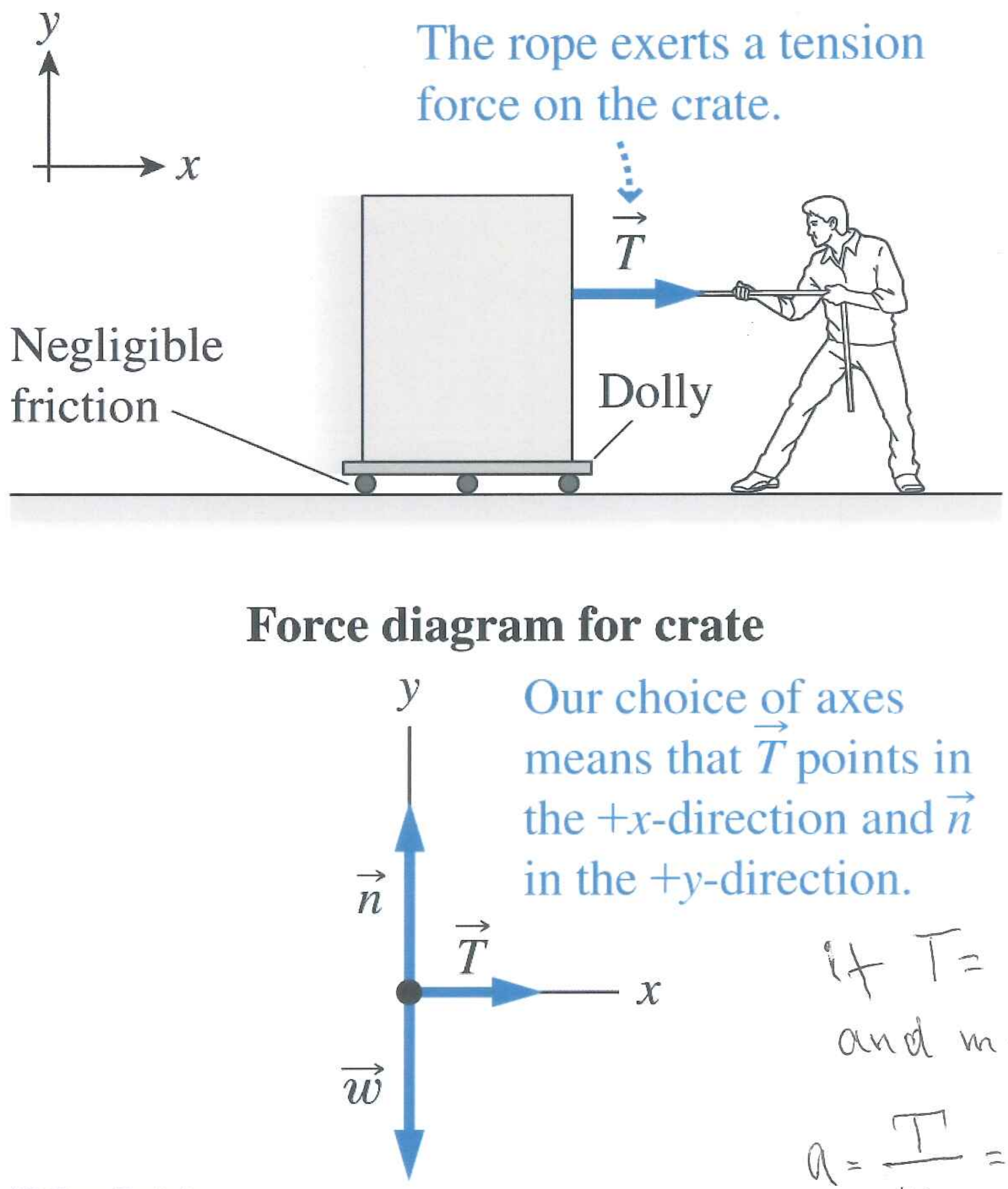


Figure 4.15



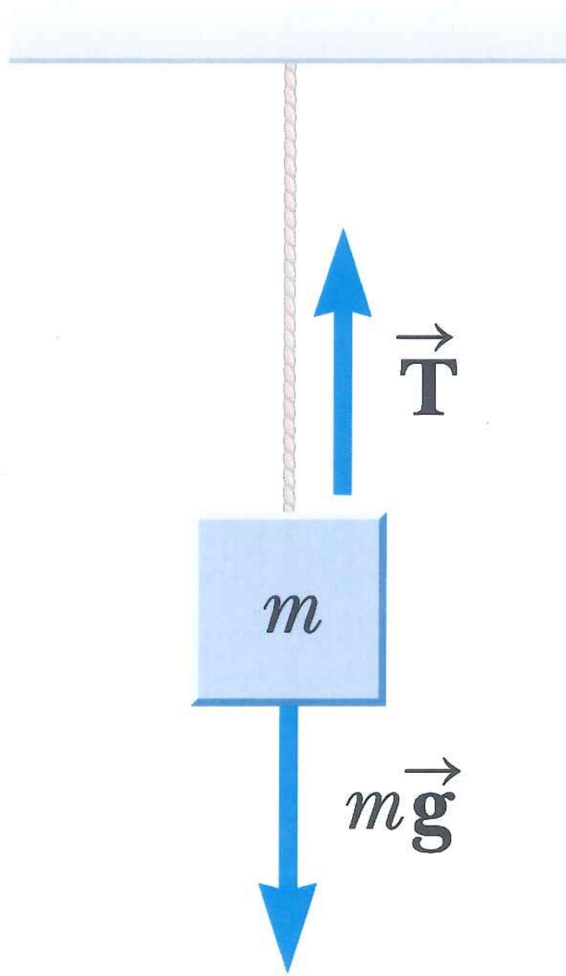
in x direction

if $T = 420\,N$ and $m = 120\,kg$

$$a = \frac{T}{m} = \frac{420\,N}{120\,kg} = 3.5\,\frac{m}{s^2}$$

No motion in y direction

Case 1: Vertical Tension Forces on a Static Object



$$\Sigma F_y = ma_y$$

$$T - mg = 0 \rightarrow T = mg$$

51. A 5.0-kg bucket of water is raised from a well by a rope. If the upward acceleration of the bucket is $3.0\ m/s^2$, find the force exerted by the rope on the bucket.

4.51 The forces on the bucket are the tension in the rope and the weight of the bucket, $mg = (5.0\ kg)(9.80\ m/s^2) = 49\ N$. Choose the positive direction upward and use Newton's second law:

$$\Sigma F_y = ma_y$$

$$T - 49\ N = (5.0\ kg)(3.0\ m/s^2)$$

$$T = \boxed{64\ N}$$

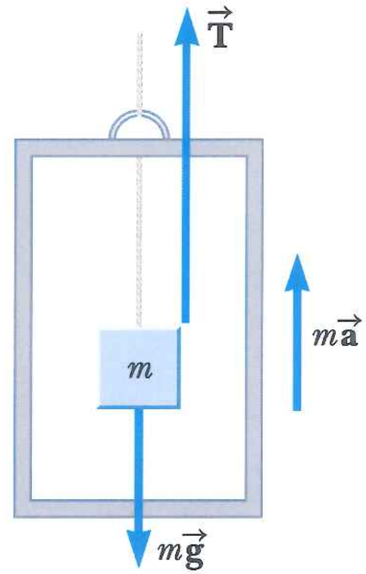
Topic Summary

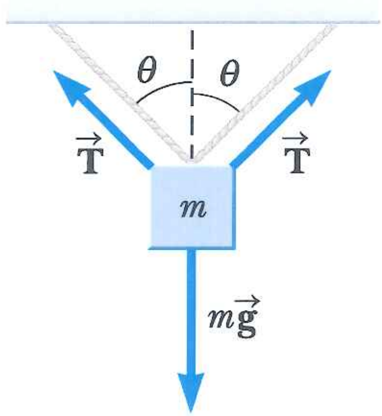
- **Tension Forces**
  - **Case 2**

$$T = m\left(a_y + g\right)$$

  - **Case 3**

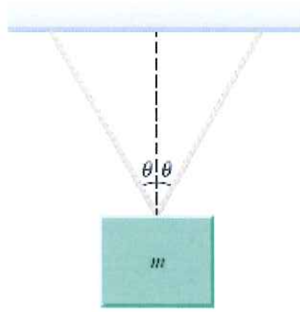
$$T = \frac{mg}{2\cos\theta}$$





32. Two identical strings making an angle of $\theta = 30.0^\circ$ with respect to the vertical support a block of mass $m = 15.0$ kg (Fig. P4.32). What is the tension in each of the strings?

Figure P4.32



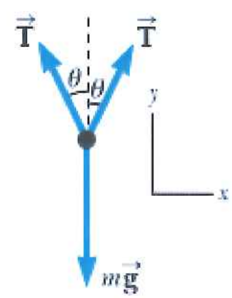
4.32 The strings make the same angle θ on opposite sides of the vertical, so their tensions must be equal. From the free-body diagram, the vertical component of each tension force is $T\cos\theta$. Applying the y-component of Newton's second law gives

$$\Sigma F_y = ma_y$$

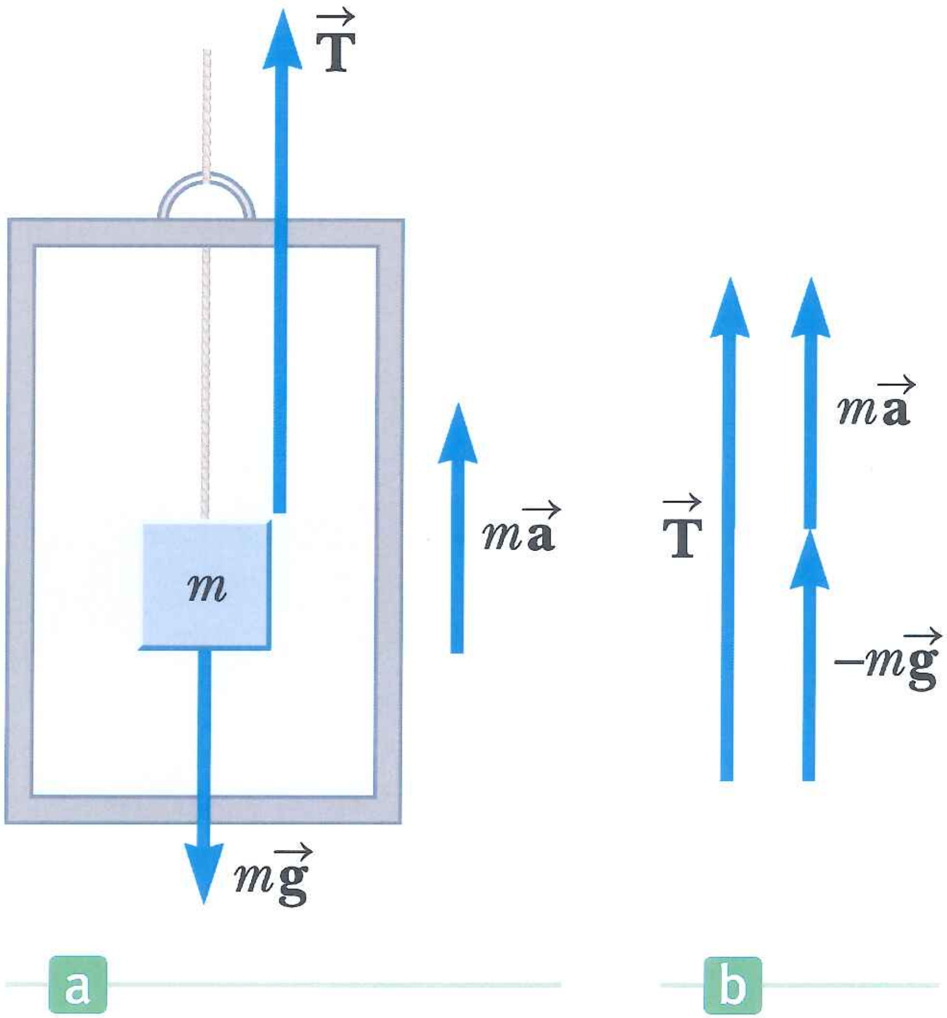
$$2T\cos\theta - mg = 0$$

$$T = \frac{mg}{2\cos\theta} = \frac{(15.0\text{ kg})(9.80\text{ m/s}^2)}{2\cos(30.0^\circ)}$$

$$= \boxed{84.9\text{ N}}$$



Case 2: Vertical Tension Forces on an Accelerating Object



$$ma_y = \Sigma F_y$$

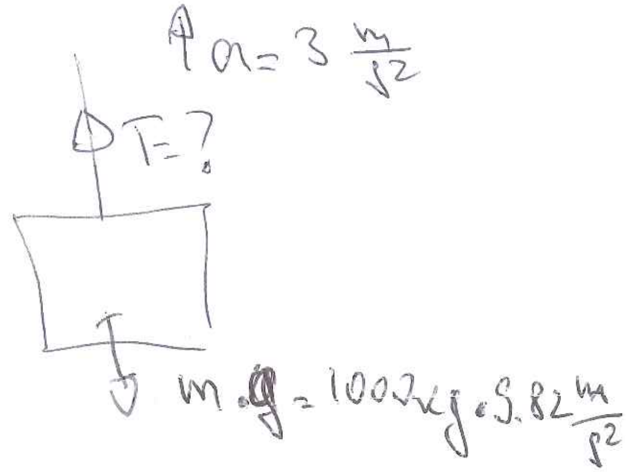
$$ma_y = T - mg$$

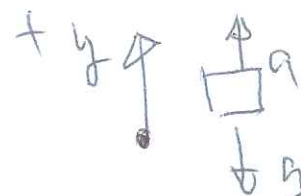
$$T = ma_y + mg$$

$$= m\left(a_y + g\right)$$

36. A 1000-kg elevator is rising and its speed is increasing at 3 m/s^2. The tension in the elevator cable is:

1) 1000 N
2) 3000 N
3) 9800 N
4) 12800 N





Ans 4!

$m\vec{a} = \vec{T} - m\vec{g}$ (F_{NET})

only for magnitudes $|T| = ma + mg$

$= m(a+g)$

$= 1000kg(3 + 9.82)$

$= 12,800\ N$

Tension Force

44. ORGANIZE AND PLAN The crane supplies an upward force on the beam, and gravity supplies a downward force. The net force will be the vector sum of the two. Once we find the net force, we can use Newton's second law to find the acceleration of the beam. We chose a coordinate system for this problem in which $\hat{j}$ is oriented vertically upward.
Known: $m = 185$ kg; $\vec{F}_{\text{crane}} = 1960\text{ N}(\hat{j})$; $\vec{g} = 9.8\text{ m/s}^2(-\hat{j})$

SOLVE The net force is the vector sum of all the forces on the beam, which in this case is gravity and the force applied by the crane [Eq. 1]:

$$\vec{F}_{\text{net}} = \vec{F}_{\text{crane}} + m\vec{g} = 1960\text{ N}(\hat{j}) + (185\text{ kg})(9.8\text{ m/s}^2)(-\hat{j}) = 147\text{ N}(\hat{j})$$

We insert this result into Newton's second law to find the acceleration of the beam [Eq. 2]:

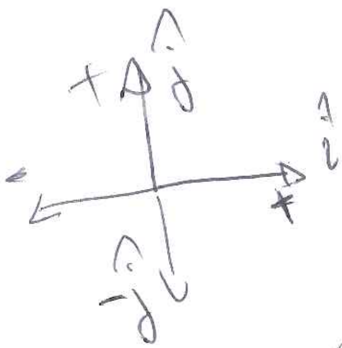
$$\vec{F}_{\text{net}} = m\vec{a},$$

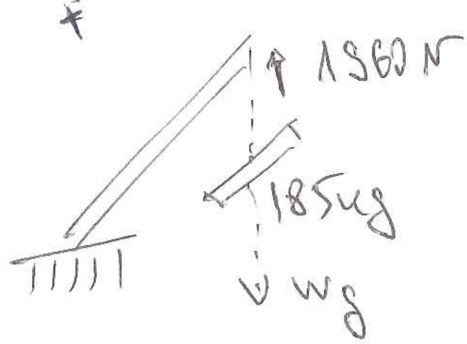
$$\vec{a} = \vec{F}_{\text{net}}/m = \frac{(147\text{ N})}{(185\text{ kg})}(\hat{j}) \approx 0.8\text{ m/s}^2(\hat{j})$$

$\vec{F}_N = 1960\text{N}(\hat{j}) - mg(\hat{j})$

$1813\text{N}(\hat{j})$

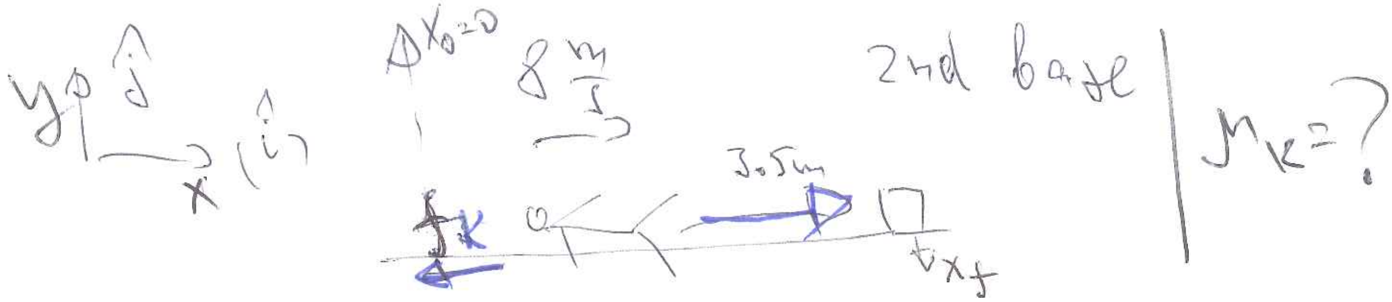
$= 147\text{N}(\hat{j})$





$F_N = ?$

$a = ?$



74. ORGANIZE AND PLAN Find the acceleration needed to stop the player within the given distance, then use Newton's second law to find the coefficient of kinetic friction needed to generate the necessary force, using Eq. 4.6 [Eq. 1]

$f_k = \mu_k n.$

Known: $\vec{v}_0 = 8.0\ m/s(\hat{i})$; $\vec{v}_f = 0$ m/s; $\vec{x}_f - \vec{x}_0 = 3.5(\hat{i})$

SOLVE The acceleration needed to stop the player can be found from

$$v_f^2 - v_0^2 = 2\vec{a}\,\Delta\vec{x} = 2\vec{a}(x_f - x_0)(\hat{i})$$

Solving for $\vec{a}$ gives [Eq. 4]

$$\vec{a} = -\frac{v_0^2}{2(x_f - x_0)}(\hat{i}) = -\frac{(8.0\text{ m/s})^2}{2(3.5\text{ m})}(\hat{i}) = 9.1\text{ m/s}^2(-\hat{i})$$

Using Newton's second law gives [Eq. 5]

along $\vec{x}$ axis

$$\vec{F}_{net} = \vec{f}_k = m\vec{a}$$

$$\mu_k mg(-\hat{i}) = m\vec{a} = m \cdot 9.1\ \frac{m}{s^2}(-\hat{i})$$

$$\mu_k = \frac{9.1\text{ m/s}^2}{9.8\text{ m/s}^2} = 0.93.$$