Notes:

PHYSICS 12

# Newton's Third Law

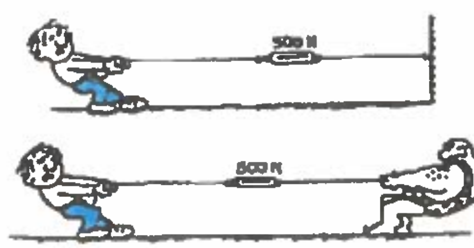
Whenever an object A exerts force on an object B, then the object B exerts force on the object A of equal magnitude but opposite direction.

In other words, the force of A on B is equal in magnitude and opposite in direction of the force of B on A.

In short: **For every action, there is an equal and opposite reaction.**

$$F_{A\ on\ B} = -F_{B\ on\ A}$$

All forces result from interactions = Forces always come in pairs.



There are two types of interactions:

1. Contact Interactions- Normal force, Friction, Push, Pull, tension
2. At-a-distance Interactions- gravity, magnetic force, electric force

Action-Reaction pairs:

Action: the tires on a car push on the road...
Reaction: The road pushes back on the tires.

Action: while swimming, you push the water backwards...
Reaction: Water pushes you forwards.

Action: a rocket pushes exhaust to the left...
Reaction: Exhaust pushes the rocket to the right.

Action: the earth pulls down on a ball...
Reaction The ball pulls the Earth up.

let F be the direction forward away from the rifle)

Example 1: When a rifle fires a bullet, the force the rifle exerts on the bullet is exactly the same (but in the opposite direction) as the force the bullet exerts on the rifle... so the rifle "kicks back". The bullet has a mass of 15 g and the rifle is 6.0 kg. The bullet leaves the 75 cm long rifle barrel moving at 70 m/s.

a) **Determine** the acceleration of the bullet.

G: $m_b = 15g = 0.015 kg$ $v_i = 0 m/s$

$m_r = 6.0 kg$ $v_f = 70 m/s$

$d_y = 0.75 m$ R: $a = ? [m/s^2]$

A: $v_f^2 = v_i^2 + 2ad$

$\rightarrow a = \frac{v_f^2 - v_i^2}{2d}$

S: $a = \frac{70^2 - 0^2}{2(0.75)}$

S: $\vec{a} = 3.3 \times 10^3 m/s^2 [F]$

b) **Determine** the force on the bullet.

A: $F_{net} = m\vec{a}$

$= (0.015)(3266.7)$

$= 49 N [F]$

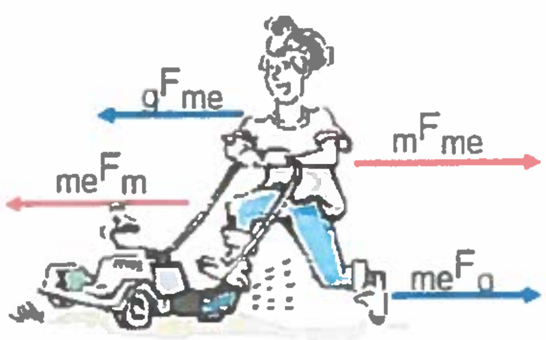
c) **Determine** the acceleration of the rifle.

$\vec{a}_r = \frac{F_{net}}{m_r} = \frac{-49}{6.0} = 8.2 m/s^2 [F] = 8.2 m/s^2 [B]$

d) **Explain** why the bullet accelerates more than the rifle if the forces are the same.

→ the bullet is much lighter and $\vec{a}$ is inversly proportional to the mass. (m↑ a↓)

Example 2: If I push on a lawn mower, it pushes back on me with an equal, but opposite force. **Explain** why we don't both just stay still.



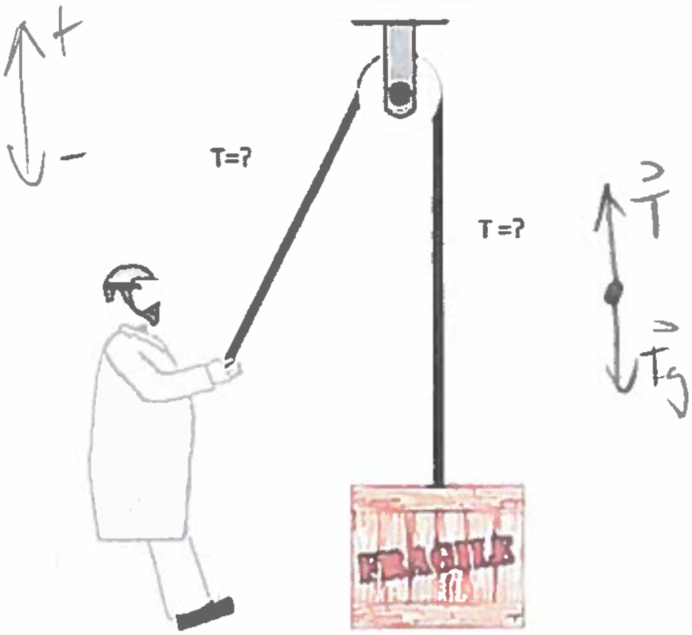

| |
|---|
| me → me |
| m → mower |
| g → ground |

Forces act on different objects.

# TENSION

Tension is a force that is transmitted along a string, wire, rope, cable or a chain when they are acted upon by forces from both ends making the string, wire, rope, cable or chain tight.

- For simplicity, we assume that the string, wire, rope, cable or chain are massless, have no girth and are absolutely taut.




m= 24.0 kg

Find the tension in the rope if you the box is accelerating at 2.0m/s²[up]:

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

$= \vec{T} + \vec{F_g}$

$ma = T - mg$

$T = ma + mg$

$T = (24.0)(2.0) + (24.0)(9.8)$

$T = 2.8 \times 10^2\ N$

What is the force the person exerts on the rope?

$\vec{F_e} > 283.2\ N$

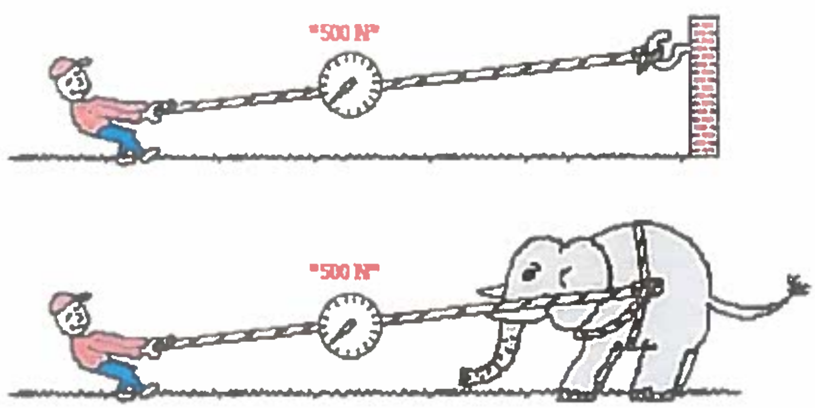
What is the acceleration of the rope at the end the person holds onto it?

$2.0\ m/s^2\ [D\theta°L]$

What is the acceleration of the rope at the end where it is attached to the box?

$\vec{a} = 2.0\ m/s^2\ [up]$

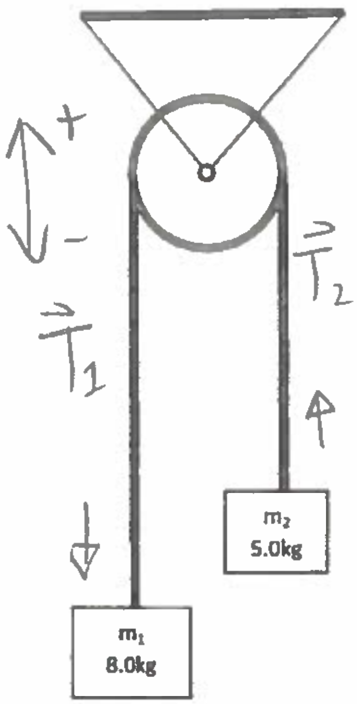
In the top picture (below), Kent Superstrong is pulling upon a rope that is attached to a wall. In the bottom picture, Kent is pulling upon a rope that is attached to an elephant. In each case, the force scale reads 500 Newton. Kent is pulling ...




A) with more force when the rope is attached to the wall. B) with more force when the rope is attached to the elephant. C)the same force in each case.

1. a) What is the tension in the rope? $T = 6.0 \times 10^{1}\,N$

b) How much and at what direction will the objects accelerate? $\vec{a}_1 = 2.3\,m/s^2\,[D]$, $\vec{a}_2 = 2.3\,m/s^2\,[U]$




$\|\vec{a}_1\| = \|\vec{a}_2\| = a$

$\|\vec{T}_1\| = \|\vec{T}_2\| = T$

$m_1$

$\vec{F}_{net} = m_1\vec{a}$

$\vec{F}_{net} = \vec{F}_g + \vec{T}$

$-m_1 a = -m_1 g + T$

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

$a = \frac{-78.4 + T}{-8.0}$

$a = \frac{78.4 - T}{8.0}$

$a = \frac{78.4 - 60.3}{8.0} \doteq 2.3\,m/s^2$

$m_2$

$\vec{F}_{net} = m_2\vec{a}$

$\vec{F}_{net} = \vec{F}_g + \vec{T}$

$m_2 a = -m_2 g + T$

$m_2 a + m_2 g = T$

$(5.0)\left(\frac{78.4 - T}{8.0}\right) + (5.0)(9.8) = T$

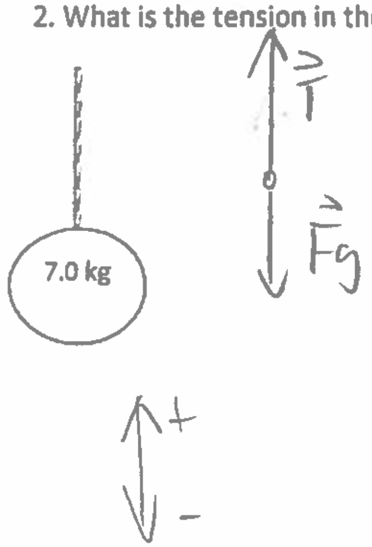
$49 - \frac{5}{8}T + 49 = T$

$98 = 1T + \frac{5}{8}T$

$\frac{98}{1.625} = \frac{1.625T}{1.625}$

$T = 60.3\,N$

2. What is the tension in the string if the object accelerates 5.0m/s²[up]?




$\vec{F}_{net} = \vec{F}_g + \vec{T}$

$ma = -mg + T$

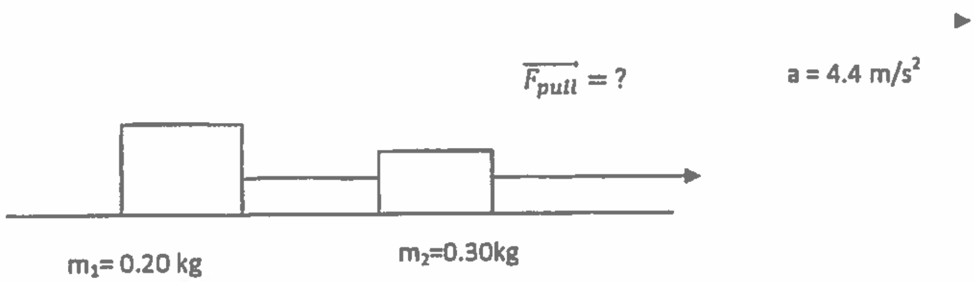
$T = ma + mg$

$T = (7.0)(5.0 + 9.8)$

$T = 103.6\,N$

$\therefore$ T in the rope is $1.0 \times 10^{2}\,N$.

3. The system of blocks shown in the diagram below is being accelerated to the right at 4.4 m/s$^2$.




~~m1=0.20kg~~

Provided that the coefficient of kinetic friction is 0.35, what is the magnitude and direction of the pulling force?

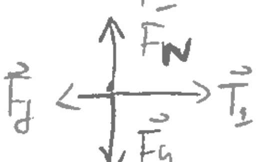
G: $\mu_k = 0.35$
$\vec{a} = 4.4\ m/s^2\ [R]$
$m_1 = 0.20\ kg$
$m_2 = 0.30\ kg$

• $T_1 = T_2 = T$
• $a_1 = a_2 = a$

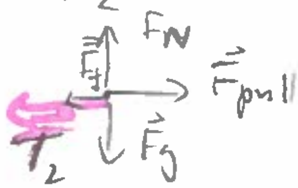
R: $F_{pull} = ?\ [N]$

A:

$m_1$




$m_2$



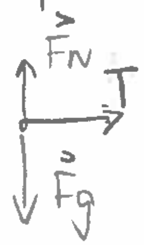

$m_1$:
$\vec{F_{net}} = \vec{F_g} + \vec{F_N} + \vec{T} + \vec{F_f}$
$m_1 a = 0 + T - F_N \mu_k$
$T = (0.20)(4.4) + (0.20)(9.8)(0.35)$
$T = 1.566\ N$

$m_2$:
$m_2 a = \vec{F_g} + \vec{F_N} + \vec{T} + \vec{F_f} + \vec{F_{pull}}$
$\vec{F_{pull}} = (0.30)(4.4) - 1.566 - (0.30)(9.8)(0.35)$
$= 3.915\ N = 3.9\ N\ [R]$

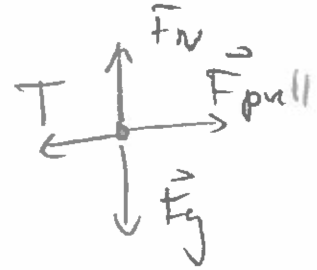
4. A 5.0×10$^4$kg engine is pulling a freight car whose mass is 1.0×10$^4$kg.

a) If the engine accelerates at 0.50 m/s$^2$ [forward], what is the tension in the coupling linking the engine and the car? Assume zero friction. Include a FBD.

$m_1 = 10000\ kg$




$m_2$




$T = ?\ [N]$
$m_1 a = \vec{F_g} + \vec{F_N} + T$
$T = (10000)(0.50)$
$T = 5.0 \times 10^3\ N$

b) What is the force with which the engine pulls the freight car?

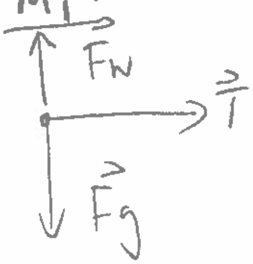
$\vec{F_{pull}}$:
$\vec{F_{net}} = \vec{F_g} + \vec{F_N} + \vec{F_{pull}} + \vec{T}$
$\vec{F_{pull}} = m_2 a + T$
$= (50\ 000)(0.50) + 5000$

$\therefore \vec{F_{pull}} = 3.0 \times 10^4\ N\ [R]$

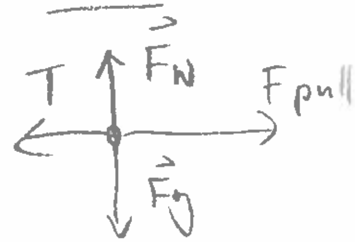
5. The system of masses shown below is accelerating to the right at 2.0 $m/s^2$.

a) Assume frictionless surfaces. What is the tension in the string at point P?

$m_1$:




$\vec{m_2}$:




$$\vec{F}_{net} = m_1 \vec{a}$$
$$= \vec{F_N} + \vec{F_g} + \vec{T}$$
$$T = (20)(2.0)$$
$$T = 40 \text{ N}$$

∴ Tension at point P is $4.0 \times 10^1$ N.

b) If the tension in the string at point P is 70 N, what is the coefficient of friction between the masses and the surface?

$m_1$:

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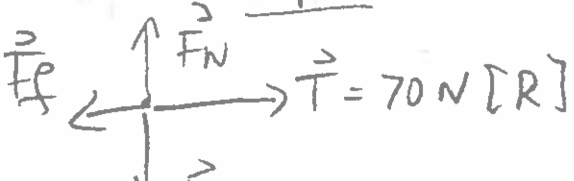
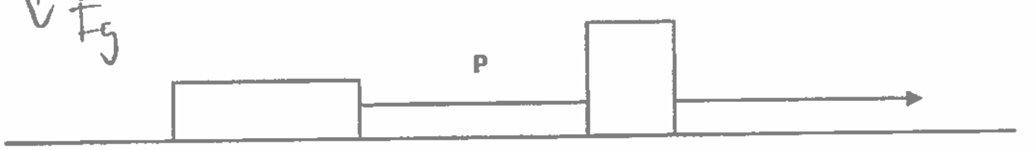



$m_1$ = 20 kg

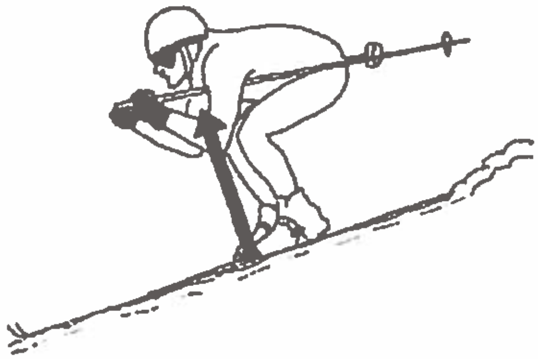
$m_2$ = 10 kg

$$\vec{F}_{net} = m_1 \vec{a}$$
$$= \vec{F_g} + \vec{F_N} + \vec{F_f} + T$$
$$F_f = m_1 a - T$$
$$= (20)(2.0) - 70$$
$$= -30 \text{ N}$$
$$= 30 \text{ N [L]}$$

$$F_f = F_N \cdot \mu_k$$
$$\mu_k = \frac{F_f}{F_N}$$
$$= \frac{30}{(20)(9.8)}$$
$$= 0.15$$

∴ The coefficient of friction is 0.15.

# Normal Force



Normal Force is always perpendicular to the surface of contact.

If there is no any other force with a vector component perpendicular to the surface of contact, magnitude of the normal force is equal to mg

$$||F_N||=mg$$

Direction: perpendicularly away from the surface of contact.

Example 1: What is the normal force acting on a 1.5-kg book that lies on a stricly horizontal desk?

$F_N = mg$

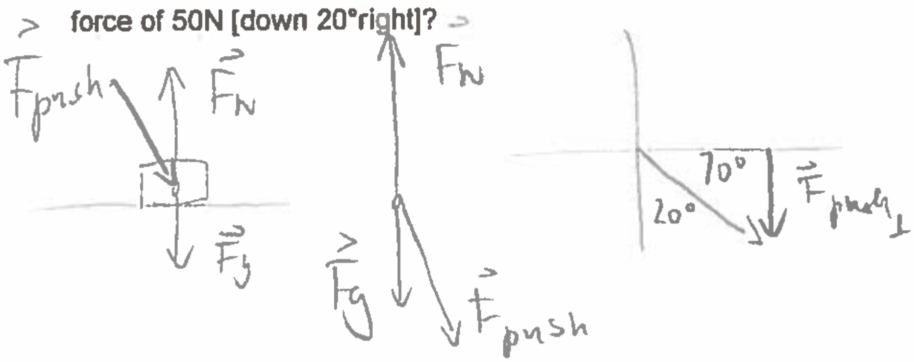
$= (1.5)(9.8)$

$= 14.7\ N$

$\therefore \vec{F_N} = 15N\ [up]$


Example 2: Scenario $F_N$>mg

What is the normal force acting on a 2.0 kg objcet thar lies on a strictly horizontal ground and is acted on by a force of 50N [down 20°right]?



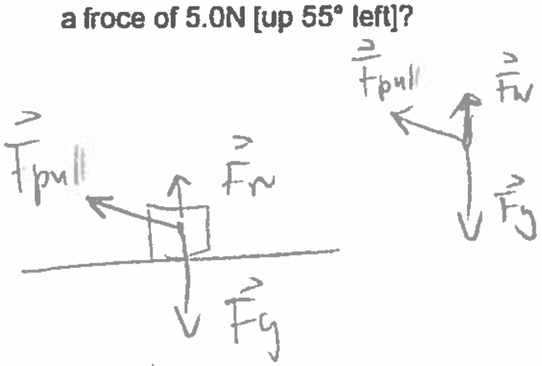

$F_N = mg + F_{push\perp}$

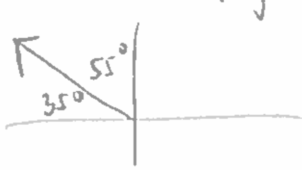
$= (2.0)(9.8) + 50\sin 70°$

$\vec{F_N} \doteq 67\ N\ [up]$

Example 3: Scenario $F_N$<mg

What is the normal force acting on a 2.0kg object that lies on a strictly horizontal ground and is being pulled by a froce of 5.0N [up 55° left]?



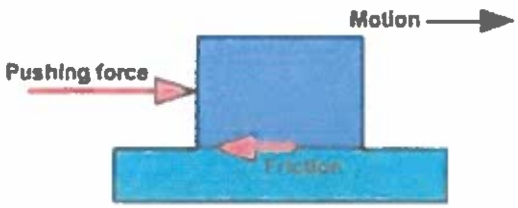

$F_N = mg - F_{pull\perp}$

$= (2.0)(9.8) - 5.0(\sin 35°)$

$= 16.7132\ N$

$\therefore \vec{F_N} = 17N\ [up]$

# Force of Friction




| |
|---|
| **Kinetic Friction** |
| → object in motion $F_{fk} = F_N \cdot \mu_k$ |
| **Static Friction** |
| → object at rest |
| $F_{fs} = F_N \cdot \mu_s$ |

- Force of friction always opposes the motion.
- Kinetic friction acts on moving objects – surfaces of contact exert the force of kinetic friction on one another when one or both surfaces of contact move
- Static friction acts on stationary objects– surfaces of contact exert force of static friction on another when there is no motion between the two surfaces

Frictional force depends on:

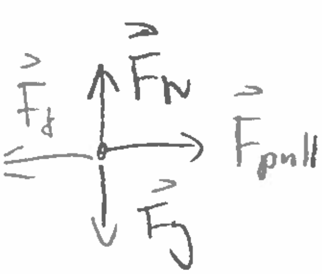
- Material the surfaces of contact are made of = expressed by the coefficient of friction
- On the magnitude of the normal force (directly proportional)

$\mu_s$ = static

$\mu_k$ = kinetic

$\mu_s > \mu_k$ → Why?

Example: How much horizontal force and at what direction is needed to move a 50.0-kg stationary object that rests on a horizontal floor? The coefficient of static friction between the surfaces is 0.18 and the coefficient of kinetic friction is 0.10?




$\vec{F}_{net} \geq 0$ N

$\vec{F}_{pull} \geq \vec{F}_{fs}$

$\geq F_N \cdot \mu_s$

$\geq mg\,\mu_s$

$\geq (50.0)(9.8)(0.18)$

$\geq 88.2$ N

∴ More than 88 N in the direction of intended motion is needed.

Bonus Question: Provided that frictional force exists between the surface of contact and an object, is it easier to push or pull the object at an angle 30° above horizontal? Explain. You may submit a full and well supported answer for marks.