Tues: Discussion / Quiz

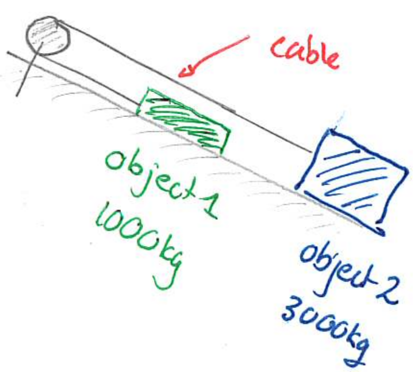
Ex: 182, 190, 191, ~~194~~ 193, 195, 201, 203

Weds: Group Exercise!

Interacting Objects

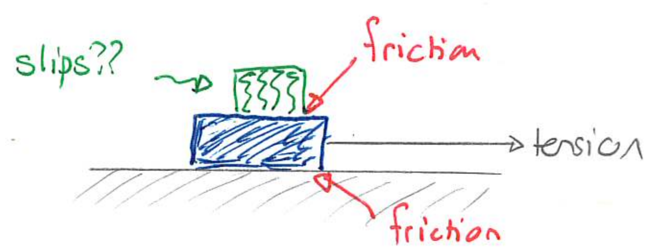
In many physical situations there will be two or more objects that interact with each other. The motion of one object will be related to the motion of the other via forces that they exert on each other.

Objects moving "together"



DEMO: Wikipedia Duquesne Incline

Objects not moving "together"

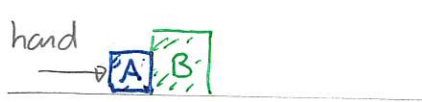


Distinct friction forces

* max tension without top block slipping
* acceleration for either tension

We need rules that relate the forces exerted by or on the interacting objects.

Warm Up 1



We assume that

* there is no friction between the blocks + surface
* the blocks move together with the same acceleration

Qualitatively we have:

When considered as a single object block A and B accelerate → $a = \dfrac{F_{hand}}{m_A + m_B}$

↓

Block B accelerates and the net force on block B is non-zero. Block A must supply this force → $F_{A\,on\,B} = m_B a = \dfrac{m_B}{m_A+m_B} F_{hand}$

↓

If the only force acting on block A is that of the hand then

$$a = \frac{F_{hand}}{m_A}$$

⇒ $\dfrac{F_{hand}}{m_A} > \dfrac{F_{hand}}{m_A + m_B}$

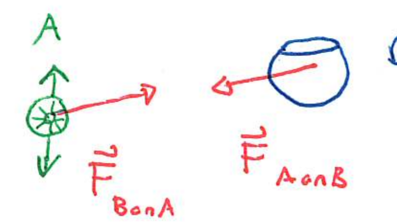
↓

Impossible! Thus block B exerts a force on block A

This is an example of <u>Newton's Third Law</u>

Consider two objects A and B.
If object A exerts a force on object B then:

1) object B exerts a force on A
2) the force vectors have equal magnitude and opposite direction



Note: 1) The forces in Newton's Third Law are exerted by <u>different</u> objects and act on <u>different</u> objects

2) the forces are called an <u>action/reaction</u> pair

3) It is always true that $\vec{F}_{B\,on\,A} = -\vec{F}_{A\,on\,B}$.

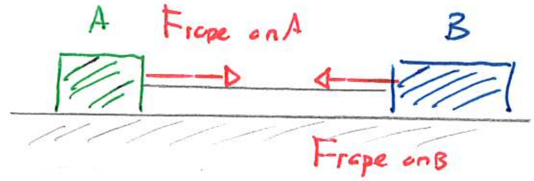
Quiz 1 20% — 60% } 20%

Quiz 2 50%

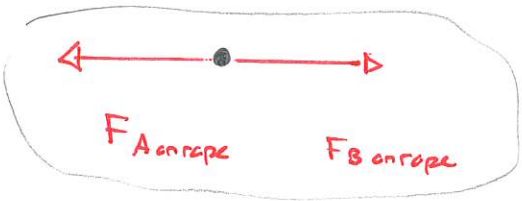
Objects Connected by Ropes

We will consider situations where objects are connected by ropes. We will assume:

1) the rope does not stretch and is taut
2) the rope is massless



We see that the rope exerts a force on either object and we identify these by the object. Now consider the rope. By Newton's Third Law each object exerts a force on the rope



$\sum \vec{F} = m\vec{a} = 0$ since $m = 0$

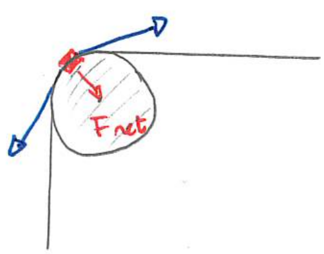
⇓

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

Newton's Second Law for rope

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

Thus the magnitude of the force exerted by either end of the rope has the same magnitude. This magnitude is called the tension in the rope. When there is a bend in the rope caused by a pulley, then the analysis applies if



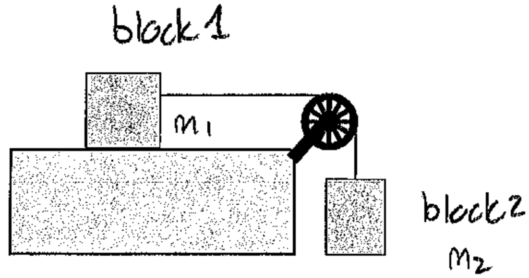
* the rope slides across the pulley without friction
* if there is friction, the pulley is massless.

Thus

The forces exerted by either side of a massless rope have the same magnitude provided that there are no sharp bends in the rope

Warm Up 2

217 Level/suspended blocks without friction



Two blocks are connected by a string, which runs over a massless pulley. One block, with mass 3.0 kg is suspended and the other block, with mass 7.0 kg can move along a frictionless horizontal surface. The string connected to the block on the surface runs horizontally. *(131F2024)*

a) Draw a free body diagram for the *box on the surface.*

b) Write Newton's Second Law in component form for the *box on the surface,* i.e. write

$$F_{\text{net } x} = \Sigma F_x = \cdots \tag{17}$$

$$F_{\text{net } y} = \Sigma F_y = \cdots \tag{18}$$

Insert as much information as possible about the components of acceleration at this stage. The resulting equations will generate much of the algebra that follows.

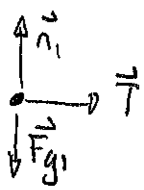
c) List all the components of all the forces for the box on the surface.

d) Use Eqs. (21) and (22) and the components to obtain an equation relating the tension in the rope and the acceleration of the box. Can you solve this for acceleration at this stage?

e) Repeat parts a) to d) for the *suspended crate.* Be careful about the acceleration!

f) Combine the equations for the two objects to obtain the acceleration and the tension in the rope.

a)



b) $\sum F_{1x} = m_1 a_{1x}$

$\sum F_{1y} = m_1 a_{1y} = 0$

c)

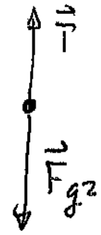
	x	y
$\vec{F}_g$	0	$-m_1 g$
$\vec{n}$	0	n_1
$\vec{T}$	T	0

d) $\rightarrow$ $T = m_1 a_{1x}$

$-m_1 g + n_1 = 0 \Rightarrow n_1 = m_1 g$

Cannot solve for acceleration.

e)



$$\sum F_{iy} = m_2 a_{2y}$$

$$\Rightarrow \boxed{T - m_2 g = m_2 a_{2y}}$$

Now let a = magnitude of acceleration of each block. Then

$$a_{1x} = a$$

$$a_{2y} = -a$$

f) $T = m_1 a$

$$T - m_2 g = -m_2 a$$

These give

$$m_1 a - m_2 g = -m_2 a \Rightarrow m_1 a + m_2 a = m_2 g$$

$$\Rightarrow (m_1 + m_2) a = m_2 g$$

$$\Rightarrow \boxed{a = \frac{m_2}{m_1 + m_2} g}$$

$$T = m_1 a \Rightarrow \boxed{T = \frac{m_1 m_2}{m_1 + m_2} g}$$

In this case $m_1 = 7.0\text{kg}$, $m_2 = 3.0\text{kg}$ $\Rightarrow$ $\boxed{a = \frac{3}{10} g = 2.94\text{m/s}^2}$

$$\boxed{T = \frac{21\text{kg}^2}{10\text{kg}} g = 19.6\text{N}}$$

Note that $m_2 g = 3\text{kg} \times 9.8\text{m/s}^2 = 29.4\text{N}$ and $T \neq m_2 g$