Printout

October 16, 2016 4:34 PM

F_g , Tension (rope/wire), F_f (surface), F_N (⊥ surface), F_{apply} ⇒ $\vec{F}_{net}$

Dynamics Notes

1 – Newton's Laws

In 1665 Sir Isaac Newton formulated three laws that dictate the motion of objects. These three laws are universal and apply to all forces in the universe.

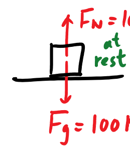
Newton's 1st Law:
An object… in motion will stay in motion

and an object… at rest will stay at rest

unless… an outside Force is applied [$F_{net} = 0$]

aka: Law of Inertia

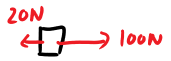
Example:



Newton's 2nd Law: The acceleration of a body is proportional to the Force and inversely proportional to the mass.

As a formula: $\vec{F}_{net} = ma$

Example:



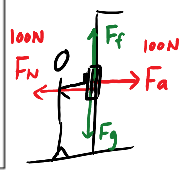
F_{net} = 80N [E]

$a = \frac{F_{net}}{mass}$

Newton's 3rd Law:
For every… action force there is an equal and opposite reaction force.

As a formula: $F_{action} = - F_{reaction}$

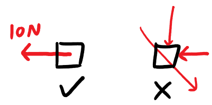
Examples:



Free Body Diagrams: (Draw one for **EVERY force question**)

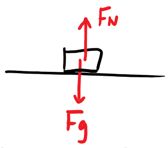
1) Represent the object… a box
2) Represent all forces… as arrows

- arrows are vectors so dir. is critical
- start in the center and draw outward.
- The size of arrow represent magnitude of force.



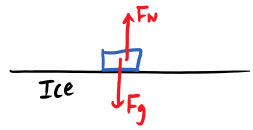
Examples: Draw FBDs for each situation

1. A textbook sits motionless on a table.

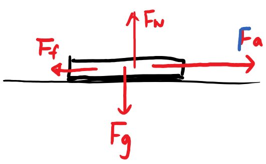


2. A coconut falls from a tree (no air friction)

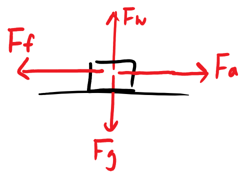
3. A puck slides along frictionless ice. v→



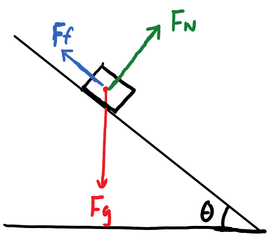
4. A ~~dragster~~ car accelerates (a) from rest.



5. A car drives at a constant velocity. a = 0 ⇒ F_{net} = 0

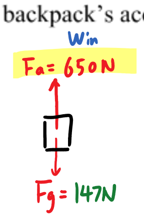


6. A block of wood slides down an incline



FBD → F_{net} → a

1. A student pulls straight upwards with a force of 650 N on their 15 kg backpack. What is the backpack's acceleration?



depends on FBD; always

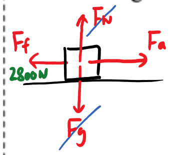
$F_{net} = F_a - F_g = ma$

$650N - 147N = 15kg\,(a)$

$a = 33.5\ m/s^2$

$F_g = mg = (15kg)(9.8) = 147\ N$

2. A 1200kg car accelerates at 5.85 m/s². If the force of friction acting on the car is 2800 N, how much force does the engine exert?



y dir. $F_{net} = 0$

x: $F_{net} = F_a - F_f = ma$

$F_a - 2800\ N = (1200\ kg)(5.85)$

$F_a = 9820\ N$

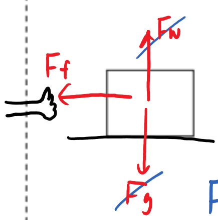
Trickery Alert!
Just when you though you were done with kinematics, they sneak back in. You will be expected to use kinematics to solve for acceleration to use in force problems and vice

Even More Trickery!
Remember that when determining the forces working on an object we need to consider their *directions*. If a force is working in the direction of acceleration we need to break it down into components.

Ex:
A 2.10 kg curling rock is hurled down ice at 6.5 m/s. It comes to a stop in 12.0 s. What is the force of friction between the ice and the rock?

Vi; t

want "a" → F_{net}



$V_i = 6.5$
$V_f = 0$
$t = 12$
$a = ?$

$V_f = V_i + at$

$0 = 6.5 + a[12]$

$a = -0.542\ m/s^2$

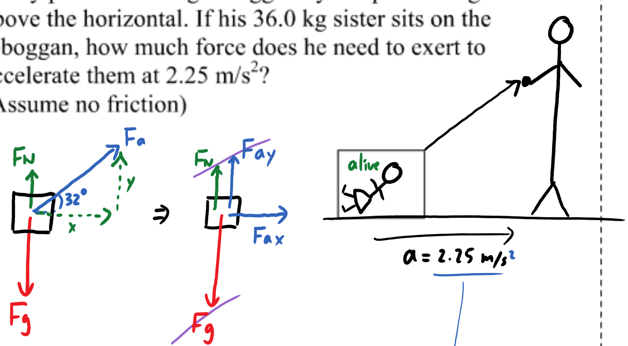
$F_{net} = F_f = ma$

$F_f = (2.1kg)(-0.542)$

$F_f = -1.1\ N$

NOTE:

Ex:
A boy pulls his 8.0 kg toboggan by a rope that angles 32° above the horizontal. If his 36.0 kg sister sits on the toboggan, how much force does he need to exert to accelerate them at 2.25 m/s²?
(Assume no friction)



$F_{net} = F_{ax} = ma$

$F_a \cdot \cos(32°) = (36\ kg + 8\ kg) \cdot [2.25\ m/s^2]$

$F_{apply} = 116.7\ N$

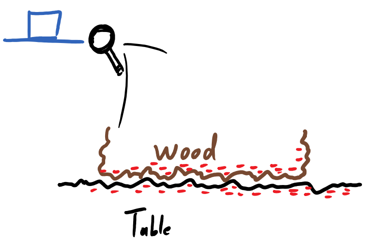
HW : WS #1 Q 1-9

Dynamics Notes

2 - Friction

Friction is created whenever… the surface of one object is in contact with another

On the microscopic level…



Force of friction (F_f) is given by the equation:

$$F_f = \mu F_N$$

Where:

F_N = normal Force ($\perp$ to surface)

μ = Coefficient of friction

=

There are 2 types of friction:

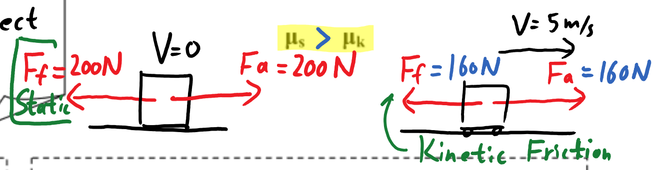
Static Friction: Amount of F_f to overcome when the object starts from rest ($V_i = 0$)

Kinetic Friction: F_f to overcome if the object is already in motion.

Note that the irregularities in a static object will tend to "dig in" more and generally:

Friction$_{static}$ > Friction$_{kinetic}$

$\mu_s > \mu_k$

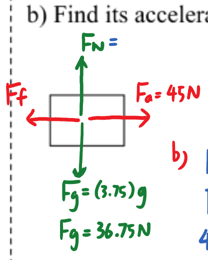


Ex 1:

A 3.75 kg block is pushed along a tabletop with a force of 45.0N. The coefficient of friction is 0.65.

a) Find the force of friction.

b) Find its acceleration. → $F_{net} = ma$



$F_N = F_g = 36.75N$

$F_f = \mu F_N = 0.65 [\;] = 23.9\ N$ a)

b) $F_{net} = ma$

$F_a - F_f = ma$

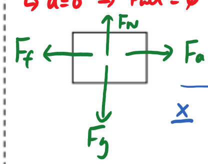
$45N - 23.9N = 3.75(a)$

$\vec{a} = 5.63\ m/s^2$ [right]

Ex 2:

A 0.200 kg puck is pushed along a sheet of ice with a force of 0.240 N. If it moves at a constant velocity, find the coefficient of friction

↳ $a = 0$ → $F_{net} = \emptyset$



$F_g = mg = (0.2\ kg)g = 1.96\ N$

$F_N = F_g = 1.96N$

x: $F_{net} = 0$ ⇒ $F_f = F_a = 0.24N$

$F_f = \mu F_N$ $\quad \mu = \frac{F_f}{F_N}$ $\quad \mu = \frac{0.24N}{1.96N} = 0.122$

Ex 3:

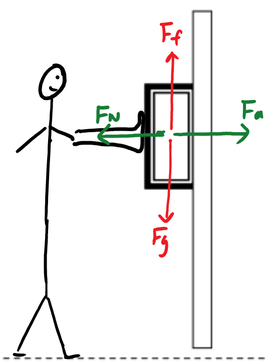
A 1.12 kg textbook is pushed horizontally against a wall with a coefficient of friction of 0.465. What is the least amount of force required to keep the book from slipping?

y: $F_g = mg = (1.12\ kg)g = 10.98\ N$ $\quad F_f = F_g = 10.98N$

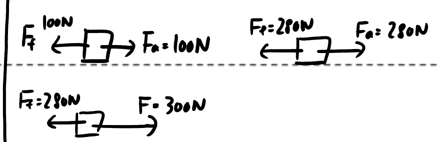
$\mu = 0.465$

$F_f = \mu F_N$ $\quad F_N = \frac{F_f}{\mu} = \frac{10.98N}{0.465} = 23.6N$

x: $F_{a\,min} = F_N = 23.6N$



$F_f = \mu F_N = 280N$



Dynamics Notes

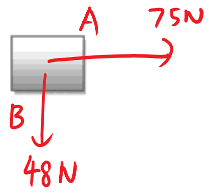
3 – Forces in 2-D

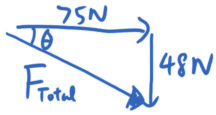
As with any vectors, forces must be resolved with consideration to both their magnitude and direction.

Ex

Two students push a crate across a frictionless surface. Student A pushes with 75 N East and Student B pushes with 48 N South.

What is the resultant force acting on the box?





$F_{Total} = \sqrt{75^2 + 48^2}$

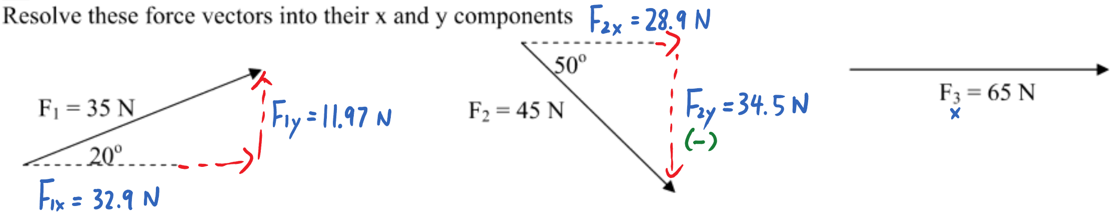
$F_{Total} = 89\ N$ //

$\theta = \tan^{-1}\left(\frac{48}{75}\right) = 32.6°\ [S\ of\ E]$

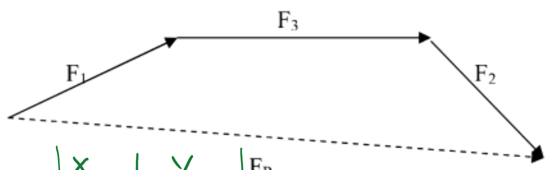
If there are more than two forces then it is best to solve for the resultant using the...

Ex

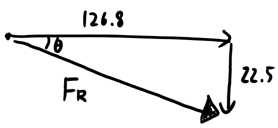
Resolve these force vectors into their x and y components



Ex 2 - Determine the resultant force if all three forces in the last example are applied to a single body.



	x	y
F_1	32.9	11.97
F_2	28.93	−34.47
F_3	65	0
$\vec{F}_R$	126.8	−22.5

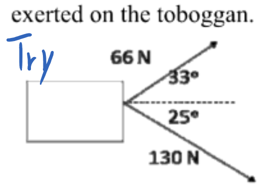


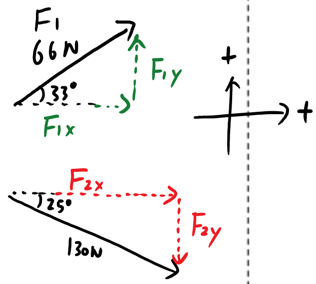
$F_R = 129\ N$

$\theta = 10°\ [S\ of\ E]$

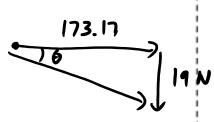
Ex 3: Two children pull a third child on a toboggan (shown from the top, assume up is north). Assuming that they pull on ropes that are parallel to the ground determine the magnitude of the force exerted on the toboggan.

Try





	x	y
F_1		
F_2		
F_R	173.17	−19

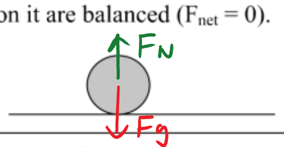


HW: WS# 2.2 Q 1–4

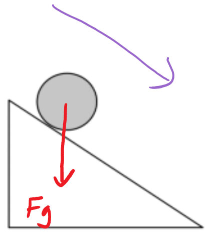
Dynamics Notes

4 – Inclines

A ball sitting on a level surface will not roll because the forces on it are balanced ($F_{net} = 0$).

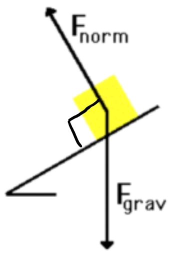


However, when the ball is placed on an *inclined plane* it will roll down the plane.



Although the F_g pulls **straight down** at all times…

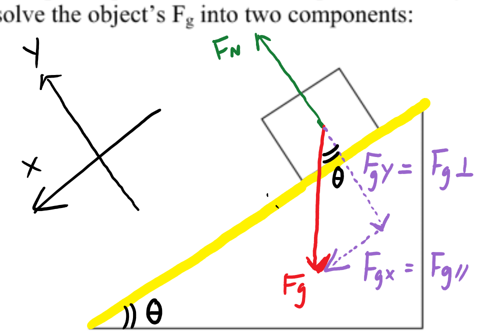
FN does not push straight up!



F_N is always… ⊥ to surface

$F_g > F_N$

For inclined plane questions our first step should always be to resolve the object's F_g into two components:



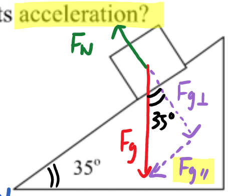
Two important things to notice:

1) Only the parallel component of Fg ⇒ Fg// pulls down the ramp.

2) The perpendicular component Fg⊥ is equal and opposite to FN.

Ex

An 8.0 kg block slides down the frictionless inclined plane shown. What is its acceleration?



$F_g = mg$

$F_g = 8(9.8)$

$F_g = 78.4\,N$

$F_{net} = F_{g//} = F_g \sin(35°)$

$ma = 78.4\,N(\sin 35)$

$8a = 44.97$

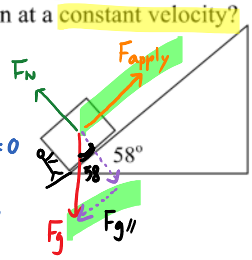
$a = 5.6\,m/s^2$ down the slope

Does the mass actually matter?

No! Not for acceleration!!

Ex

How much force is required to push an 11 kg block up the frictionless ramp shown at a constant velocity?



$a = 0$

$F_{net} = 0$

$F_{apply} - F_{g//} = 0$

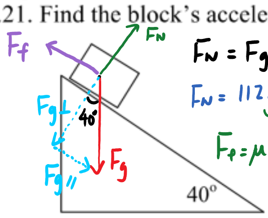
$F_{apply} = F_{g//}$

$F_a = mg \sin(58°)$ (11 kg)

$F_a = 91\,N$

Ex $F_{g\perp} \to F_N \to F_f$

A 15 kg block sits on an inclined ramp whose coefficient of friction is 0.21. Find the block's acceleration.



$F_N = F_{g\perp} = mg\cos(40°)$ (15 kg)

$F_N = 112.6\,N$

$F_f = \mu F_N = 23.6\,N$

$F_{net} = F_{g//} - F_f$

$= mg \sin(40°) - 23.6\,N$

$ma = 70.84\,N$ (15 kg)

$a = 4.7\,m/s^2$

Mass doesn't matter for "accel"

WS #3 Quiz next time!!

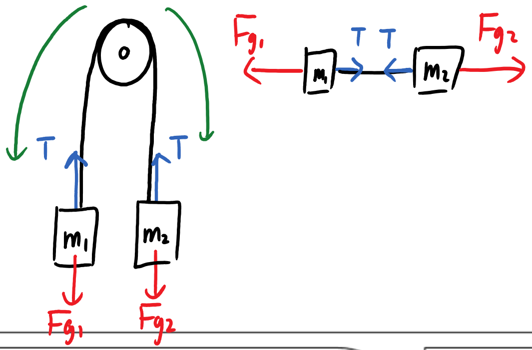
Dynamics Notes

5 – Two Objects and Tension

There are a number of common force problems that involve 2 objects, that you will be expected to be able to solve. We will focus on 3 of these.

1) Atwood's Machine: Two masses suspended by a pulley

Diagram: **Include all forces at work on the two masses.**



Both masses have a F_g that pull downwards, but since they are connected by a pulley those forces work in opposition to each other.

The masses will accelerate so that the…

larger mass wins

Since they are attached by a rope the acceleration of the masses must be

Equal.

Note that there is a force of *TENSION* (T) that exists along the rope. Tension acts the same as all other forces, with two important peculiarities:

1) It is an internal force, acting… in opposite direction at any point along the rope.

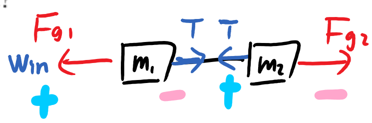
2) It cancels out… in $F_{net\ sys}$ Equation.

The Strategies:

- When solving these problems it is easiest for us to choose the direction … of the heavier mass (win) as positive.
- Remember that the acceleration on the two masses... must be equal.
- It can also be easier to conceptualize this problem if we "unfold" the masses and lay them out in a line, while keeping all of our forces as they are…I know that sounds weird so, here's an example.

Ex

Two masses are suspended from a lightweight rope over a frictionless pulley as shown. What will their acceleration be once released?

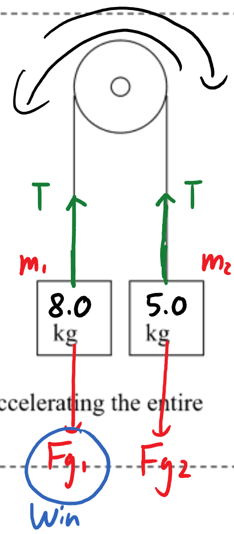


$F_{net\ sys} = F_{g1} - T + T - F_{g2}$

$M_{Total}\, a = (8\,kg)g - (5\,kg)g$

$(8+5\,kg)\ a = 29.4\ N$

$a = 2.26\ m/s^2$ down for 8kg



NOTE: When calculating the acceleration we use the Total Mass because the F_{net} is accelerating the entire system (both masses)!

Alright that wasn't too hard, but can you find the tension in the rope?

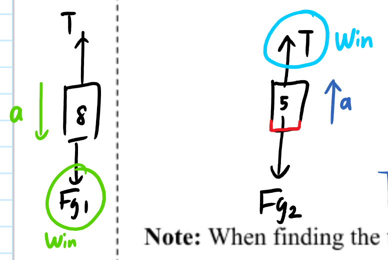
If we use the same force diagrams and equations as before we hit a snag. The two tension forces cancel !!!

This is because tension is an internal force.

In order to solve for tension we have to consider… one mass only

Strategy: To solve for tension chop your diagram in half and only consider one of the masses. Either one is fine because… both tensions are EQUAL!!

Ex - Find the tension in the rope in the preceding example.



Win – Lose

$F_{net} = T - F_{g_2}$

$ma = T - mg$

$(5\,kg)(2.26\,m/s^2) = T - (5)(9.8\,m/s^2)$

$T = 60.3\ N$

Note: When finding the tension we are only considering half of the equation therefore we only use mass of one box.

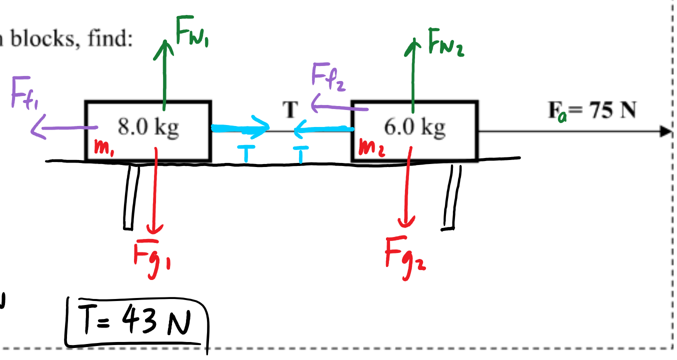
2) Multiple Horizontal Masses: Attached by a cord $F_{f_2} = \mu m_2 g = 0.25(6\,kg)(g) = 14.7$

Ex $F_{f_1} = \mu F_{N_1} = \mu m_1 g = 0.25(8\,kg)(g) = 19.6\,N$

Consider the masses shown. If μ = 0.25 for both blocks, find:

a. the acceleration of the entire system

b. the tension T in the rope between the blocks.



Sys: $F_{net} = F_a - F_{f_1} - F_{f_2}$

$M_T\,a = 75N - 19.6N - 14.7N$

$(14\,kg)\,a = 40.7\,N$

$a = 2.91\,m/s^2\ [R]$

b) $F_{net} = T - F_f$

$ma = T - 19.6N$

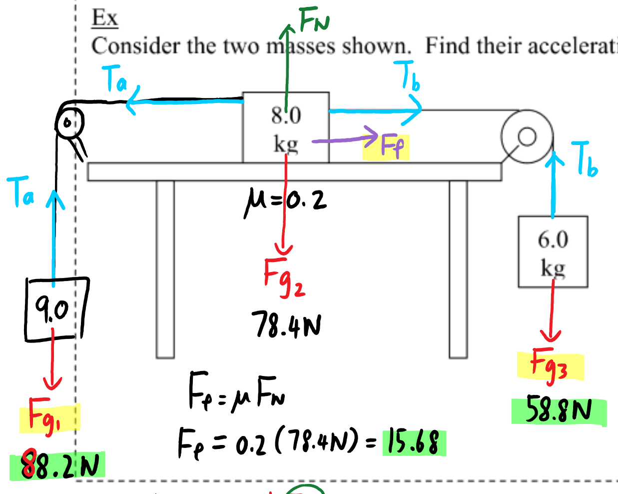
$(8)(2.91) = T - 19.6N$

$T = 43\,N$

3) The Hanging Mass: One mass hanging, one horizontal

Ex

Consider the two masses shown. Find their acceleration and the tension in the rope.



$F_f = \mu F_N$

$F_f = 0.2(78.4N) = 15.68$

$F_{net\,sys} = F_{g_1} - F_f - F_{g_3}$

$M_T\,a = 88.2 - 15.68 - 58.8\,N$

$(23\,kg)\,a = 13.72\,N$

$a = 0.60\,m/s^2$ 9kg box down

b) $F_{net} = T_b - F_g$

$T_b = F_{net} + F_g = ma + mg = 62.4\,N$ (6 kg, 0.6 m/s²)

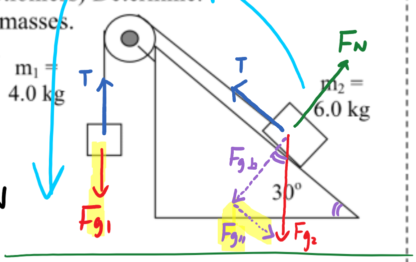
Dynamic Notes

6 – Two Objects and Inclines

Because one tricky concept is never enough, I give you… ***Two Objects AND an Incline***

Ex (Easy)

Two forces are attached by a rope over a frictionless pulley as shown.
(Assume the incline is frictionless) Determine:
a. The acceleration of the masses.
b. The tension in the rope.



Win – Lose

$F_{net\,sys} = F_{g_1} - F_{g_2 \parallel}$

$M_T a = 39.2\,N - 29.4\,N$

$(10\,kg)\, a = 9.8\,N$

$a = 0.98\ m/s^2$ down for box 1

b, $F_{net} = F_{g_1} - T$

$T = F_{g_1} - F_{net}$

$T = m_1 g - m_1 a$

$T = 4(9.8) - 4(0.98)$

$T = 35.3\,N$

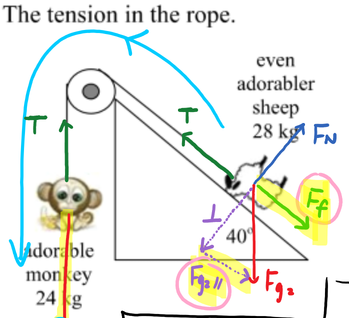
Problem: What direction will they accelerate?
In earlier pulley problems it was obvious, the bigger mass always wins. When an inclined plane is involved this is not always the case because for the mass on an incline only...

So determine the forces on each one separately and see which one is the winner.

Force 1 = F_{g_1}	Force 2 = $F_{g_2 \parallel}$
$F_{g_1} = m_1 g$	$F_{g_2\parallel} = F_{g_2} \sin(30°)$
$F_{g_1} = 39.2\,N$ (Win)	$= m_2 g \sin(30°)$
	$= (6)(9.8)\sin(30°)$
	$= 29.4\,N$

Ex

In the name of physics, a monkey is attached to a sleeping sheep on a ramp. Don't ask why.
As we all know, the coefficient of friction for a sleeping sheep on a ramp is precisely 0.15. Determine:
a. The acceleration of the system.
b. The tension in the rope.



Winner $F_{g_1} = m_1 g = 235.2\,N$ (Win)

$F_{g_2\parallel} = m_2 g \sin(40°) = 176.38\,N$

∴ F_f point down the slope!!

$F_f = \mu F_N = \mu F_{g_2\perp} = 0.15\,[210.2\,N]$

$F_{g_2\perp} = m_2 g \cos(40°) = 210.2\,N$

$F_f = 31.5\,N$

$F_{net\,sys} = F_{g_1} - F_{g_2\parallel} - F_f$ (Win, Lose, help.)

$M_T a = 235.2 - 176.38 - 31.5$

$(24+28)\, a = 27.32\,N$

$a = 0.525\ m/s^2$

Down for Monkey

b, $F_{net} = F_{g_1} - T$

$ma = mg - T$

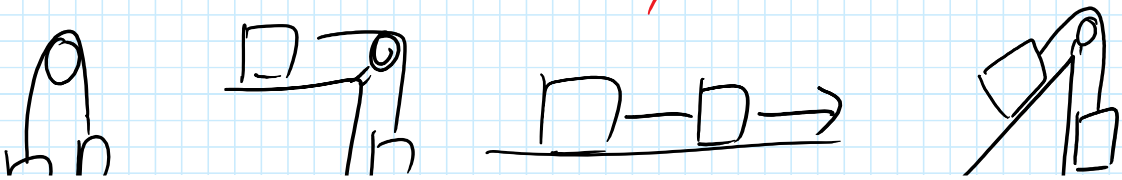
$T = mg - ma$

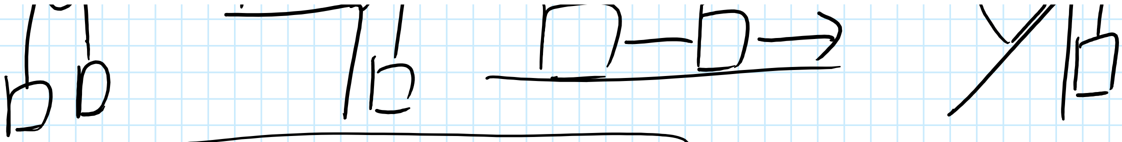
$T = (24)(9.8) - (24)(0.525)$

$T = 223\,N$

Strategies:
1. Find the forces acting on the two bodies separately to determine a winner
2. Determine the friction on the sheep. Friction can work **either** up or down the ramp, because it **always** opposes motion, so we don't know which direction it is acting until we know the winner.
3. Based on the winner find the acceleration using m_{total}
4. Choose either body and examine it separately to determine the tension in the rope

Quiz #2 Dynamic Day 5/6 next days.





with or w/o friction

Finish WS 2.4 and Extra WS (all Qs are fair)

Dynamics Test : Monday Nov 14^{th}