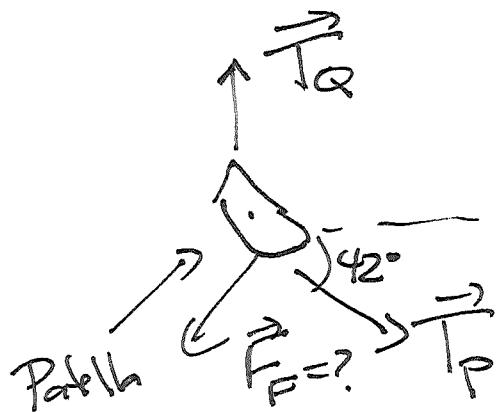


Physics 151

Hw #4

#1



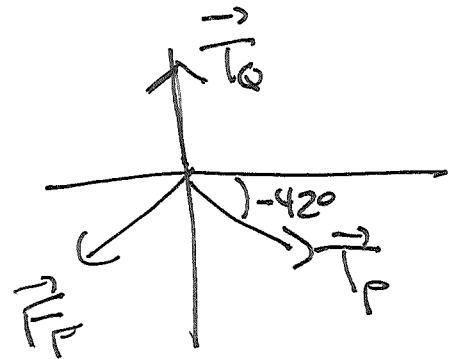
Forces on Patella:

\vec{T}_Q = upwards pull from Quadricep tendon, $\vec{T}_Q = 50N$

\vec{T}_P = pull at 42° (-42°) to be careful) from Patella Tendon, $\vec{T}_P = 50N$

\vec{F}_F = Force from Femur

Ignore weight of Patella



Find magnitude and direction of \vec{F}_F .

Patella not Accelerating $\Rightarrow \sum F_x = 0$ and $\sum F_y = 0$

$$\sum F_x = 0 \Rightarrow \vec{T}_Q, x + \vec{T}_P, x + \vec{F}_F, x = 0$$

\vec{T}_Q upwards

$$\Rightarrow \vec{T}_P \cos(-42^\circ) + \vec{F}_F, x = 0$$

Just solve for Components of \vec{F}

$$\Rightarrow 50N \cos(-42^\circ) + F_{F,x} \Rightarrow F_{F,x} = -50N \cos(-42^\circ) \\ = -37.157N$$

To get other component use $\sum F_y = 0$

$$\sum F_y = 0 \Rightarrow T_{Q,y} + T_{P,y} + F_{F,y} = 0$$

$$\Rightarrow +T_Q + T_P \sin(-42^\circ) + F_{F,y}$$

↑
upwards force
only has positive
y-component

$$\Rightarrow F_{F,y} = -T_Q - T_P \sin(-42^\circ) = -50N - 50N \sin(-42^\circ)$$

$$\Rightarrow F_{F,y} = -50N - 50N(-0.66913) = -50N + 33.456N$$

$$\Rightarrow F_{F,y} = -16.543N$$

$$F_F = \sqrt{(-37.157N)^2 + (-16.543N)^2} = \sqrt{(37.157N)^2 + (16.543N)^2} = \sqrt{1654.313N^2}$$

$$\Rightarrow F_F = 40.67N > \underline{\underline{41N}}$$

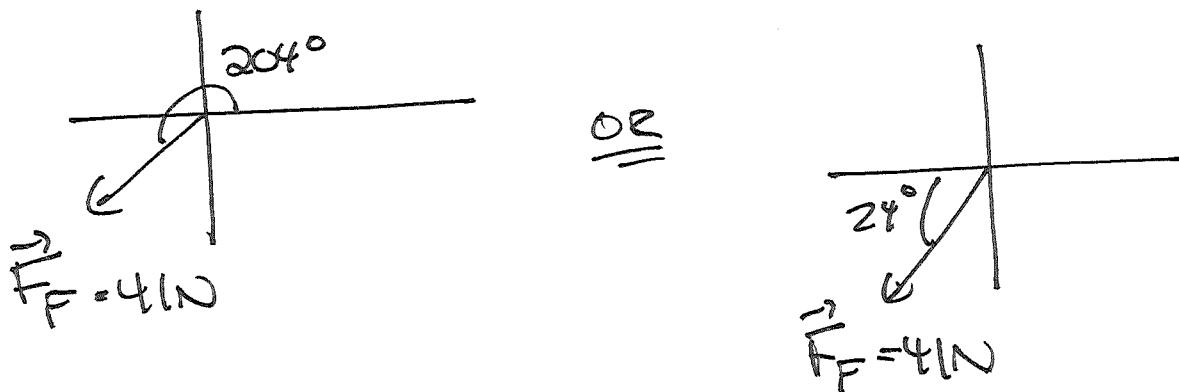
Negative X- AND Negative Y- Component

⇒ 3RD QUADRANT

So if we want the standard angle, Calculator will be wrong by 180°

$$\Rightarrow \theta = \tan^{-1}\left(\frac{F_{Fy}}{F_{Fx}}\right) + 180^\circ = \tan^{-1}\left(\frac{-16.543}{-37.157}\right) + 180^\circ$$

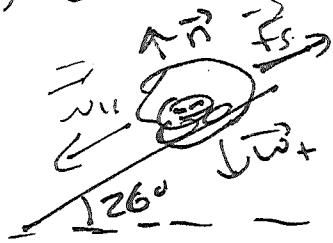
$$\Rightarrow \theta = 24^\circ + 180^\circ = 204^\circ$$



#2

A 0.4kg Bullfrog is sitting on a ~~log~~ log that is tilted at ~~at~~ 26° Above the horizontal. $\mu_s = 0.65$.

a.) What are ~~normal~~ forces on frog?



Forces: Log \Rightarrow Normal Force, \vec{n} at 90°

Log also exerts a static frictional force \vec{f}_s "up" otherwise frog would slide down log

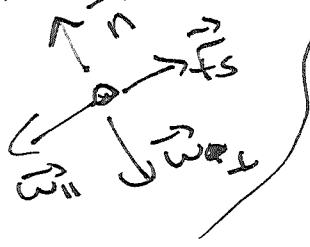
ON incline \Rightarrow Split weight into

$$w_{\parallel} = mg \sin \theta = (0.4 \text{ kg})(9.8 \text{ m/s}^2) \sin 26^\circ = 1.718 \text{ N}$$

$$w_{\perp} = mg \cos \theta = (0.4 \text{ kg})(9.8 \text{ m/s}^2) \cos 26^\circ = 3.523 \text{ N}$$

Notice: Problem in no way implies that static friction is at its max value \Rightarrow Don't use $f_{s,\text{max}}$

b). free body diagram c. what is normal force?



Frog NOT moving $\Rightarrow \sum F_{\parallel} = 0$ And $\sum F_{\perp} = 0$

\vec{f}_s , and \vec{w}_{\parallel} only parallel

\vec{n} and \vec{w}_{\perp} only perpendicular

$$\sum F_{\parallel} = 0 \Rightarrow N_{\parallel} + f_{s\perp} + \cancel{f_s \perp} - \bar{\omega}_{\parallel} \cancel{- \omega_{\parallel}} = 0$$

Negative because
"down" incline

$$\sum F_{\perp} = 0 \Rightarrow +N_{\perp} + \cancel{f_{s\perp}} - \omega_{\perp} - \cancel{-\omega_{\perp}} = 0$$

\uparrow \downarrow

Away from
incline \Rightarrow position Inclined \Rightarrow Negative

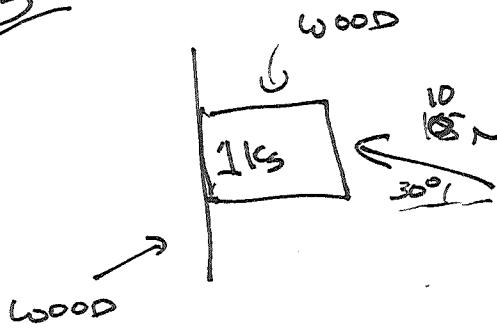
$$so \quad n = \omega_{\perp} \Rightarrow \underline{n = 3.523N}$$

$$b) \quad f_s - \omega_{\parallel} = 0 \Rightarrow f_s = \omega_{\parallel} \Rightarrow \underline{f_s = 1.718N}$$

Notice that $\mu s n = 0.65(3.523N) = 2.29N$

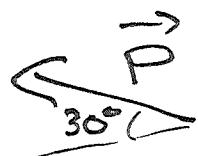
the actual amount of static friction
needed to hold the frog in place
is much smaller.

#3



Does block move up, down or stay stationary?

Forces on Block: ON force. Let's call it \vec{P}

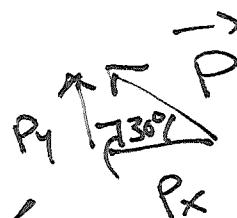


I normally don't do this so early but to figure out which way it might move, we need to split \vec{P} into components.

Triangle way:

$$\cos 30^\circ = \frac{P_x}{P}$$

$$\sin 30^\circ = \frac{P_y}{P}$$



P_x to left

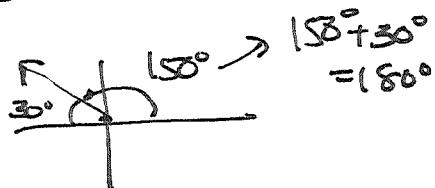
$$\Rightarrow P_x = -P \cos 30^\circ = -8.66 \text{ N}$$

$$= -10 \text{ N} \cos 30^\circ = -\cancel{8.66} \text{ N}$$

$$P_y \text{ up} \Rightarrow P_y = +P \sin 30^\circ$$

$$P_y = 10 \text{ N} \sin 30^\circ = +5 \text{ N}$$

Standard Angle way:



$$\text{So } P_x = 10 \text{ N} \cos 150^\circ = -\cancel{8.66} \text{ N}$$

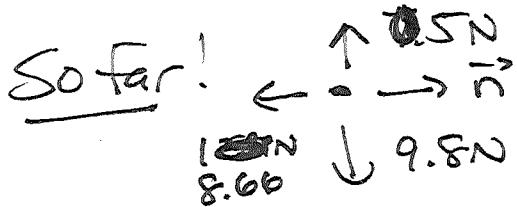
$$P_y = 10 \text{ N} \sin 150^\circ = +5 \text{ N}$$

Wall is ~~vertical~~ ^{vertical} \Rightarrow normal force is horizontal.

In fact, it's to right.

Finally, weight is down: \vec{w}

$$\omega = (1 \text{ kg})(9.8 \text{ m/s}^2) \\ = 9.8 \text{ N}$$



only forces in y-direction
are 10.5 N up and
9.8 N down.

So without friction Block would slide down wall
 \Rightarrow friction points upward.

To remain stationary, we would need enough friction to make $\sum F_y = 0$

$$\begin{array}{c} 10.5 \text{ N} \leftarrow \text{only } y \\ \uparrow \quad \uparrow f_s \quad \leftarrow \text{only } y \\ \leftarrow \quad \rightarrow N \\ 8.66 \text{ N} \quad \downarrow 9.8 \text{ N} \quad \text{only } x \\ \uparrow \quad \uparrow \\ \text{only } -x \quad \text{only } -y \end{array} \quad \begin{aligned} \sum F_y &= 0 \Rightarrow P_y + f_{sy} + w_y = 0 \\ \cancel{P_y} &\Rightarrow +10.5 \text{ N} + f_s - 9.8 \text{ N} = 0 \\ \Rightarrow f_s &= 9.8 \text{ N} - 10.5 \text{ N} = \cancel{-0.7 \text{ N}} \quad \frac{4.8 \text{ N}}{\cancel{0.7 \text{ N}}} \end{aligned}$$

The maximum static friction possible is $f_{s,\max} = \mu s N$

No acceleration in x either $\Rightarrow \sum F_x = 0$, N only has +x-comp.
 P_x only has -x-comp.

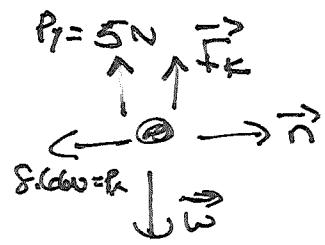
$$\Rightarrow N - \cancel{10.5 \text{ N}} = 0 \quad \Rightarrow N = \cancel{10.5 \text{ N}}$$

wood block and wood wall $\Rightarrow \mu s = 0.5$ ← thank ya table

$\Rightarrow f_{s,\max} = 0.5 (\cancel{10.5 \text{ N}}) = \cancel{5.25 \text{ N}} \quad \begin{matrix} 4.33 \text{ N} \\ \text{NO} \end{matrix} \Rightarrow \text{so } \cancel{\text{the static friction}} \quad 5.1$
can't hold it in place. It will ^{not} stay stationary. It will slide down.

b.)

WHEN block slides down the wall, the static friction becomes kinetic friction.



NO Acceleration in x -direction since block moves straight down (only in y -direction)

$$a_x = 0 \Rightarrow n = 8.66\text{N} \text{ still.}$$

We can always use $f_k = \mu n$

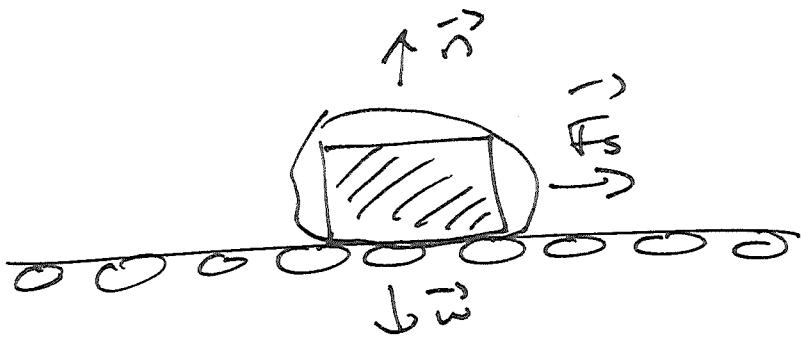
Table 5.1 gives $\mu_k = 0.2 \Rightarrow f_k = \cancel{\frac{1}{8.66\text{N}}} = 0.2(8.66\text{N})$
 $= 1.732\text{N}$

$$\sum F_y = m a_y \Rightarrow P_y + f_k - \omega = m a_y$$

$$\Rightarrow 5\text{N} + 1.732\text{N} - 9.8\text{N} = (1\text{kg})a_y$$

$$\Rightarrow -3.068\text{N} = (1\text{kg})a_y \Rightarrow a_y = \frac{-3.068\text{N}}{1\text{kg}} = -3.068\text{m/s}^2 \\ = -3.1\text{m/s}^2$$

#4



$$m = 12 \text{ kg}$$

$$\mu_s = 0.6$$

$$\mu_k = 0.35$$

a.) Draw f.b.d. if Crate moves with Constant speed.

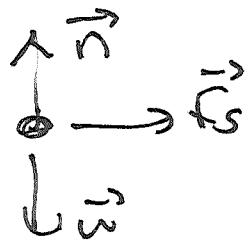
At Constant speed the crate will not be sliding across the conveyor belt. It will move with it.

Since there is no motion between the crate and the belt there will static friction between them.

When necessary the static friction will push the crate to the right $\Rightarrow f_s$ to right,

Other forces are Normal force up, \vec{n}
Crate's weight, \vec{w} down

$$w = mg = \cancel{(12 \text{ kg})(9.8 \text{ m/s}^2)} = 117.6 \text{ N}$$

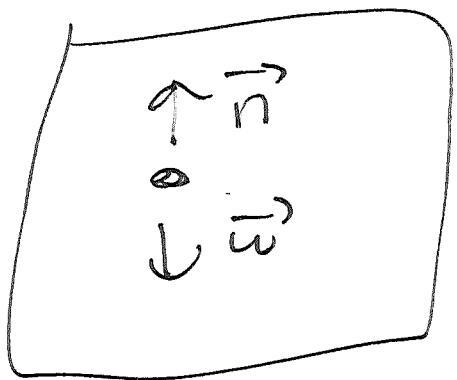


So notice f_s is the only force with ~~Ax~~-component. It's to the Right

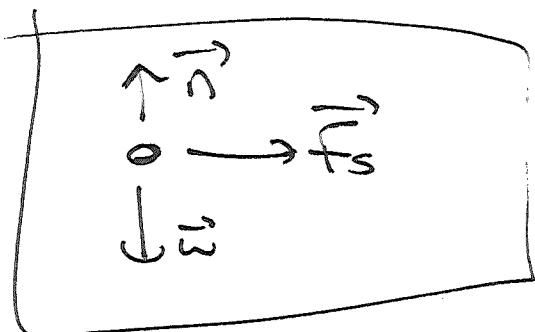
$$\therefore \sum F_x = \max \quad \overset{+}{f_s} = \max \\ \Rightarrow D \overset{+}{f_{s,x}} + \cancel{w} = \max$$

At a Constant Speed $\Rightarrow \ddot{a}_x = 0$

$\therefore f_s = 0 \Rightarrow$ we don't need friction to go at constant speed. So only \vec{n} and $\vec{\omega}$!



b.) Conveyor speeding up $\Rightarrow \ddot{a}_x \neq 0$ so do need friction



In both cases $\sum F_y = 0 \Rightarrow n_y + f_{s,y}^0 + w_y = 0$

$$\Rightarrow n - \omega = 0 \Rightarrow n = \omega = 117.6 \text{ N}$$

C.) Maximum Acceleration without slipping?

MAX Acceleration \Rightarrow static friction at max value.

$$\Rightarrow f_s = f_{s,\max} = \mu_s n = 0.6(117.6N) = 70.56N$$

$$\text{So } f_s = \max \Rightarrow a_x = \frac{f_s}{m} = \frac{70.56N}{12kg} = \underline{\underline{5.88m/s^2}}$$

d.) If acceleration of belt exceeds $5.88m/s^2$
what is crate's acceleration.

So Crate will slip \Rightarrow sliding across belt \Rightarrow
Static friction becomes Kinetic friction

on a perfectly smooth belt the
crate would slide backwards (relative
to the belt) so friction is opposite to that
velocity

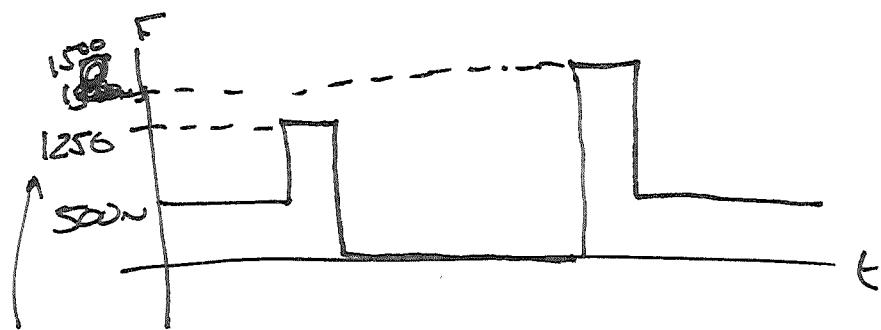
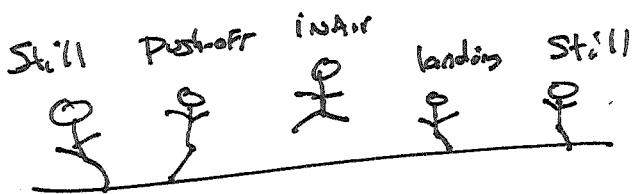
$$\sum F_y = 0 \text{ still } \Rightarrow n = w = 117.6N \quad f_k = \mu_k n = 0.35(117.6N) = 41.6N$$

$$\sum F_x = \max \Rightarrow f_k = \max \Rightarrow a_x = \frac{f_k}{m} = \frac{41.6N}{12kg} = \underline{\underline{3.43m/s^2}}$$

So belt will be going faster than crate. It will appear to slide backwards
if you are riding on the belt, but will move forward if you are ~~sitting~~ ^{not} on the belt.

#5

Woman on force plate.



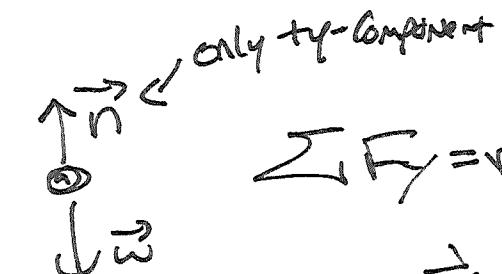
Halfway
Between
1000 and 1500

a) What was her acceleration during push off



Forces on woman: \vec{n} up and weight \vec{w} down

The scale reads the normal force acting on her!



$$\sum F_y = m a_y \Rightarrow n_y + w_y = m a_y$$

$$\Rightarrow n - w = m a_y$$

Only -y-component

This problem is sneaky! When she is still, $a_y = 0 \Rightarrow n - w = 0 \Rightarrow n = w$ then

The graph shows us that $n = 500N$ when

Still $\Rightarrow \omega = 500N$

$$\omega = mg \Rightarrow m = \frac{\omega}{g} = \frac{500N}{9.8\text{m/s}^2} = 51\text{kg}$$



EVEN SNEAKIER.

During push off, $\vec{\omega}$ is still there!

$$\therefore n - \omega = may \Rightarrow 1250N - 500N = 51\text{kg} a_y$$

$$\Rightarrow 750N / (51\text{kg}) a_y \Rightarrow a_y = \underline{\underline{\frac{750N}{51\text{kg}}}} = 14.7\text{m/s}^2$$

b. What speed? This Acceleration is constant!

$$\Rightarrow (V_y)_f = (V_y)_i + a_y \Delta t$$

Known: At the start of a jump, you are at rest $\Rightarrow (V_y)_i = 0$

From graph, $\Delta t = 0.25s$. $a_y = 14.7\text{m/s}^2$

$$\Rightarrow (V_y)_f = 0 + (14.7\text{m/s}^2)(0.25s) = 3.675\text{m/s} = 3.7\text{m/s}$$

c.) What is Acceleration while in the air?

Not touching ground is why $n = 0$ but still have gravity $\Rightarrow n - w = m\alpha_y$

$$\Rightarrow 0 - w = m\alpha_y \Rightarrow \cancel{m\alpha_y} \text{ in free fall}$$

Since gravity only force $\Rightarrow \alpha_y = -g = -9.8 \text{ m/s}^2$

d.) What was acceleration during landing?

SAME $n - w = m\alpha_y$ but $n = 1500 \text{ N}$ when landing

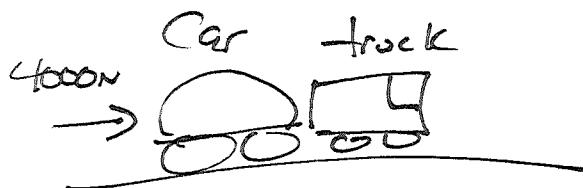
↑
gravity is
always on

$$\Rightarrow 1500 \text{ N} - 500 \text{ N} = (51 \text{ kg})\alpha_y \Rightarrow 1000 \text{ N} = (51 \text{ kg})\alpha_y$$

$$\Rightarrow \alpha_y = \frac{1000 \text{ N}}{51 \text{ kg}} = 19.6 \text{ m/s}^2$$

Notice that the plus sign for α_y is correct. When coming back down, her velocity is negative. Slowing down \Rightarrow Acceleration is opposite to velocity \Rightarrow positive Acceleration.

#6
A 1500kg car pushes a 2500kg truck.



Wheels of car pushes back with 400N

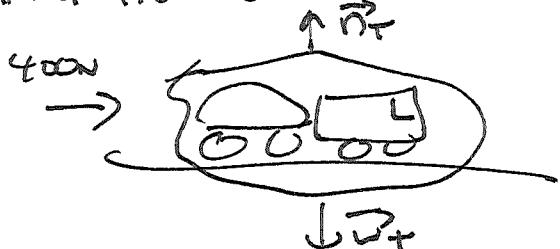
3rd Law \Rightarrow Force on Car is 4000N forward.

a.) What is force that car exerts on truck. Ignore any drag or ~~sliding~~ friction.

Since there is nothing acting against the 4000N,

the car/truck combo will accelerate. So we better find that first.

Treat the combo as one single object.



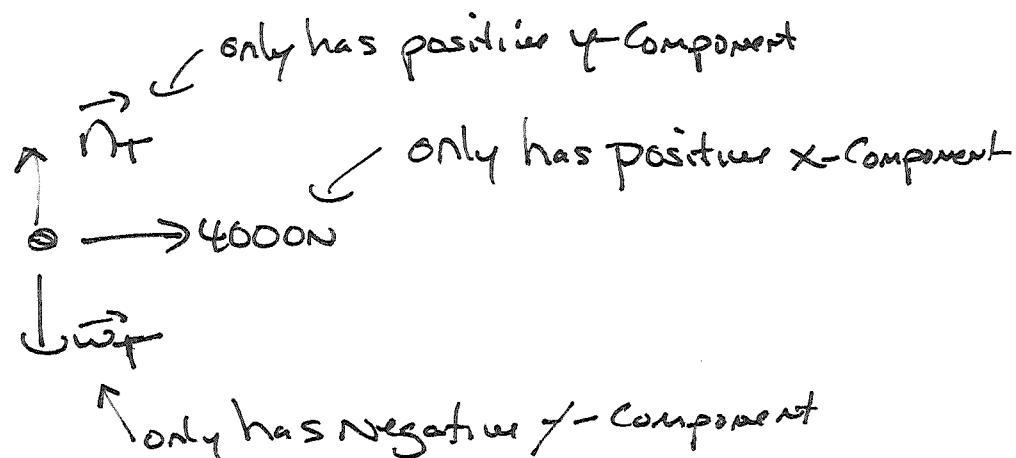
Forces: 4000N from the ROAD ON Car.

Weight of total $\Rightarrow \vec{W}$ down

Total mass: $s^M = 1500\text{kg} + 2500\text{kg} = 4000\text{kg}$

$$\Rightarrow W = m_F g = (4000\text{kg})(9.8\text{m/s}^2) = 39200\text{N}$$

Normal force on combo: \vec{N} Upward



$$\sum F_x = ma_x, \sum F_y = ma_y$$

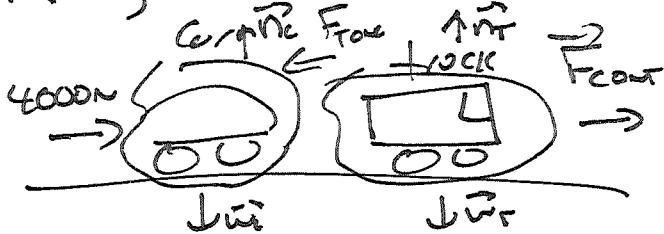
Not moving in y-direction $\Rightarrow a_y = 0, a_x = a = ?$

$$\therefore \sum F_x = ma \Rightarrow 4000\text{N} = 4000\text{kg} a \Rightarrow a = \frac{4000\text{N}}{4000\text{kg}}$$

$$= 1\text{m/s}^2$$

$$\sum F_y = 0 \Rightarrow N_T - w_T = 0 \Rightarrow N_T = w_T = 39200\text{N} \leftarrow \text{out}$$

Now, take the Car and Truck apart



Actually necessary but good to know.

Forces on Car: 4000N , to right

Normal Force \vec{N}_c up

Weight of Car: \vec{w}_c Down

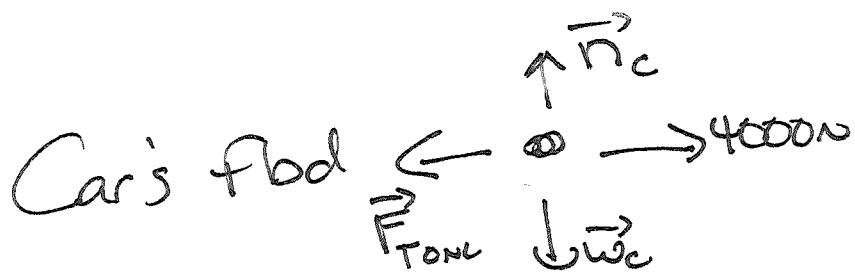
$$w_c = (1500\text{kg})(9.8\text{m/s}^2) = 14700\text{N}$$

just
the car's
mass

Car pushes truck to right

\Rightarrow truck pushes BACK

so \vec{F}_{onc} to left.



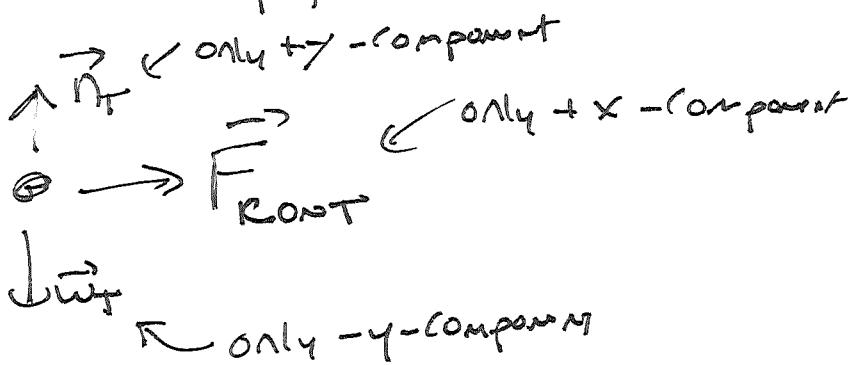
Forces on Truck: As discussed before, Car pushes

truck to Right $\Rightarrow \vec{F}_{Cont}$ to right.

By 3RD Law $\vec{F}_{Cont} = \vec{F}_{Tonc}$ (so when we finish
part a., part b. will be done too!)

$$\text{Weight of Truck, } \vec{w}_T \text{ Down, } w_T = (2500\text{kg})(9.8\text{m/s}^2) = 24500\text{N}$$

Normal force up, \vec{N}_T



Car and truck must have SAME Acceleration since
they are connected

$$\Rightarrow a_{C,x} = 1\text{m/s}^2 \quad a_{T,x} = 1\text{m/s}^2$$

$$a_{C,y} = 0 \quad a_{T,y} = 0$$

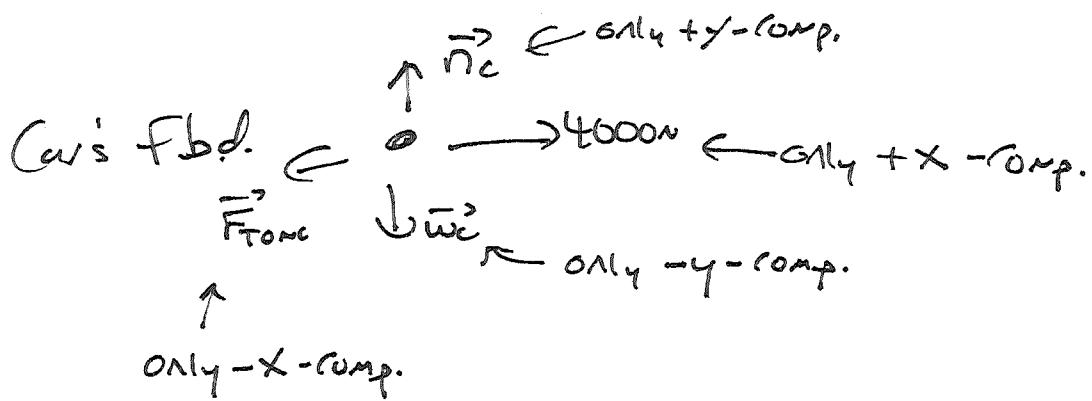
From Truck's Freebody Diagram : $\sum F_x = m_{\text{ax}}$

$$\Rightarrow F_{\text{cont}} = M_T a_{T,x}$$

↑
just MASS
of
TRUCK

$$\Rightarrow \underline{F_{\text{cont}} = (2500 \text{ kg})(\text{m/s}^2) = 2500 \text{ N}}$$

so $F_{\text{Tonc}} = 2500 \text{ N}$ too but as a check



$$\sum F_x = m_{\text{ax}} \Rightarrow 4000 \text{ N} - F_{\text{tonc}} = m_c a_{c,x}$$

$$\Rightarrow 4000 \text{ N} - \underline{F_{\text{tonc}}} = (1500 \text{ kg})(\text{m/s}^2)$$

$$\Rightarrow 4000 \text{ N} - F_{\text{tonc}} = 1500 \text{ N} \Rightarrow F_{\text{tonc}} = 4000 \text{ N} - 1500 \text{ N} = \underline{\underline{2500 \text{ N}}}$$