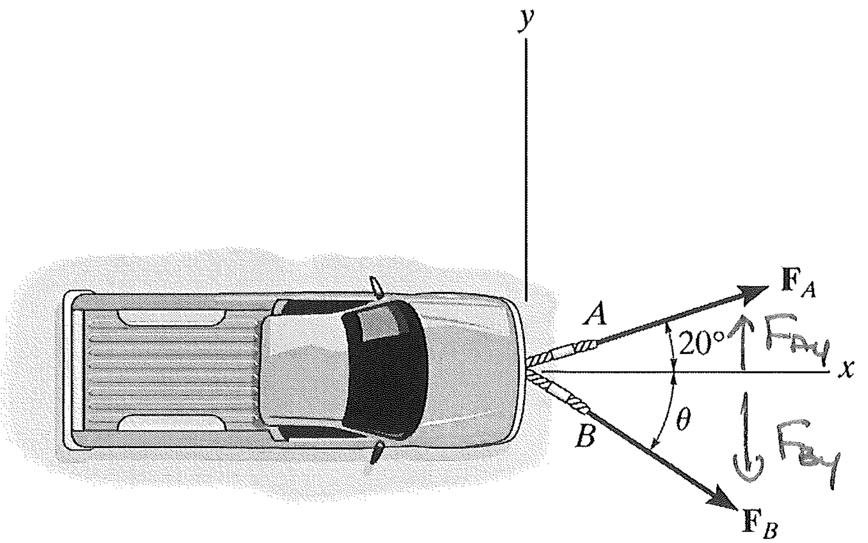
(1.) A truck is being towed using two ropes, $A$ and $B$. Rope $A$ exerts a force of $\vec{\mathbf{F}}_A = 5000\,N$ at 20°. Rope $B$ exerts a force whose magnitude is $F_B = 2500\,N$. The truck is accelerating in the $x$-direction only. What angle $\theta$, below the horizontal, is rope $B$ pulling? (Assume all values are know to three significant figures.)



NOTE: GRAVITY IS IN THE Z-DIRECTION AND IS BEING CANCELED BY A NORMAL FORCE, SO WE DON'T WORRY ABOUT IT.

| | | | | |
|---|---|---|---|---|
| (a) 20° | (b) 40° | [✓ (c) 43.2°] | (d) 55.2° $N$ | (e) 65.8° |

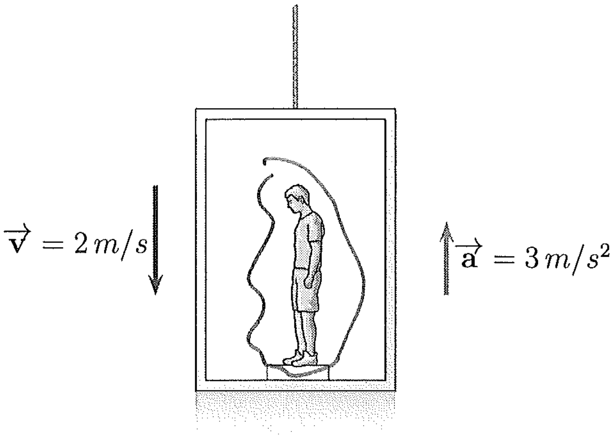
NO ACCELERATION IN $y \Rightarrow \Sigma F_y = 0 \Rightarrow F_{Ay} + F_{By} = 0$

$\Rightarrow F_A \sin 20° - F_B \sin\theta = 0 \Rightarrow \sin\theta = \frac{F_A}{F_B}\sin 20°$

$\Rightarrow \sin\theta = \frac{5000N}{2500N}\sin 20° = 0.684 \Rightarrow \theta = \sin^{-1}(0.684)$

$= 43.16°$

(2.) A 65 $kg$ man rides in an elevator which moves as shown. What is his apparent weight?



[✓ (a) 832 $N$]

(b) 637 $N$

(c) 507 $N$

(d) 442 $N$

(e) 195 $N$

FORCES ON MAN: $\vec{n}$ up, $\vec{w}$ DOWN. $n = ?$, $w = mg$

$\uparrow \vec{n}$

•

$\downarrow \vec{w}$

$$\sum F_y = ma_y \Rightarrow n - w = ma_y \Rightarrow n = w + ma_y$$

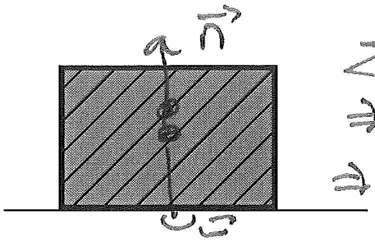
$$\Rightarrow n = mg + ma_y = m(g + a_y)$$

<u>ACCELERATING</u> up $\Rightarrow a_y = +3\,m/s^2$

$$\Rightarrow n = 65\,kg(9.8\,m/s^2 + 3\,m/s^2) = 832\,N$$

(3.) For the three situations shown below, which is the correct ranking, from smallest to largest, of the normal force magnitude acting on the crate. In all cases, assume the crate has the same mass and is at rest. (In case #3, an external 50-$N$ downward force is being applied to the crate.)

(1)

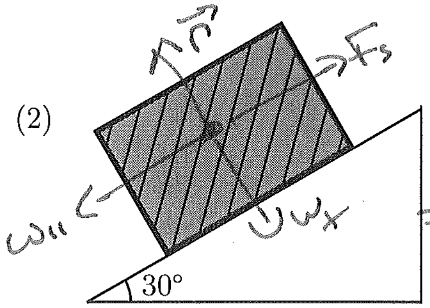


$\sum F_y = 0$

$\Rightarrow n - w = 0$

$\Rightarrow n = w$

(2)



$\sum F_\perp = 0$

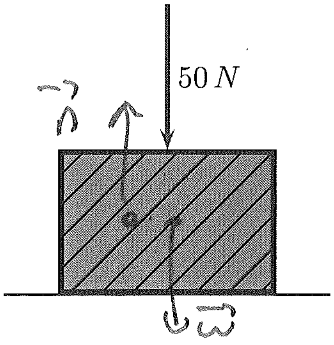
$\Rightarrow n - w_\perp = 0$

$\Rightarrow n = w_\perp$

$= w \cos 30°$

$= 0.866w$

(3)



$\sum F_y = 0$

$\Rightarrow n - w - 50N = 0$

$\Rightarrow n = w + 50N$

(a) 2, ~~1~~ 3, ~~3~~ 1

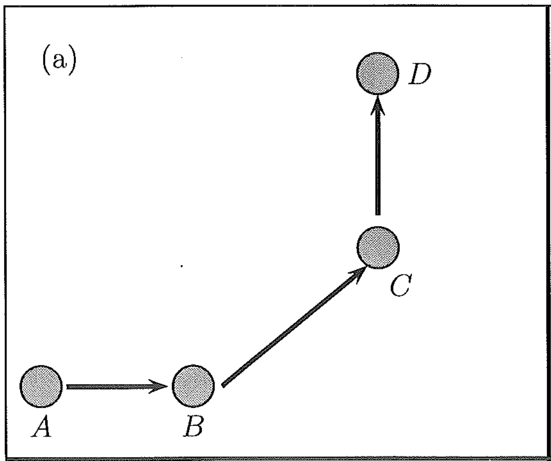
(b) 1, 3, 2

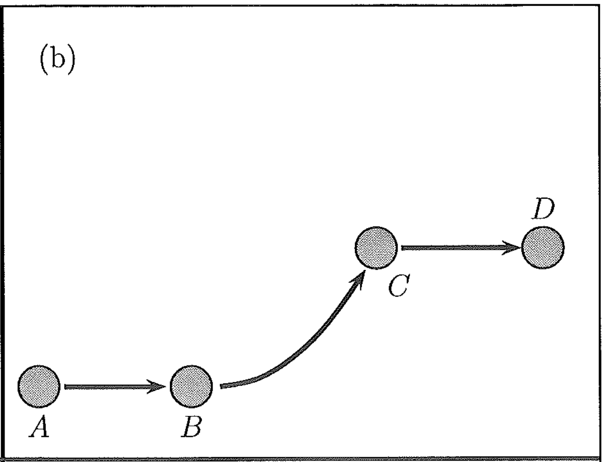
(c) 3, 1, 2

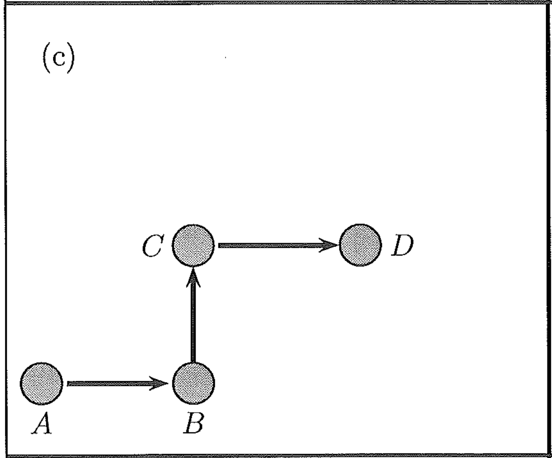
[✓ (d) 2, 1, 3]

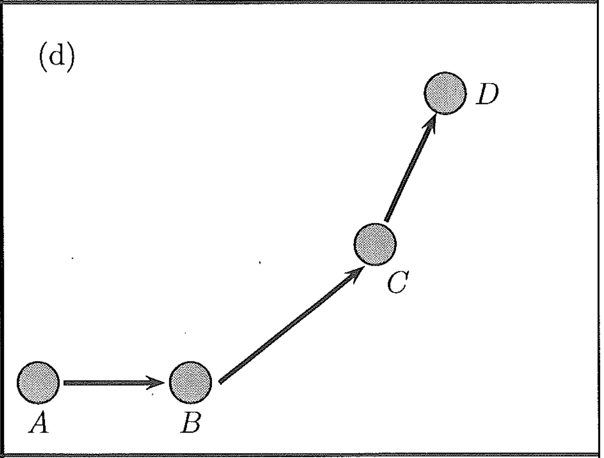
(e) The normal force is the same for each

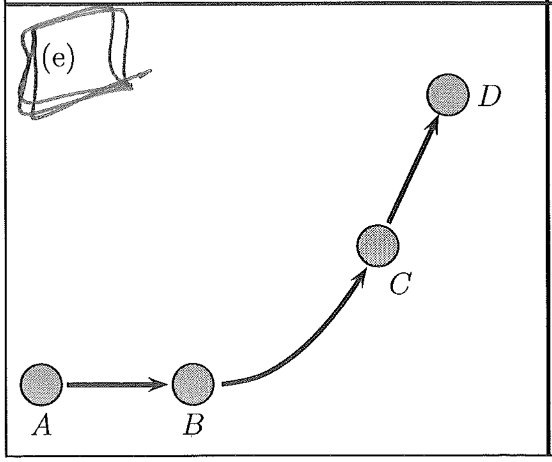
(4.) A hockey puck is sliding in the $x$-direction from points $A$ to $B$ over a frictionless ice rink. At $B$, a player exerts a constant force in the $y$-direction on the puck and moves it to point $C$. At $C$, the player removes his force from the puck, and it slides to point $D$. Which of the following pictures correctly shows the trajectory of the hockey puck from points $A$ to $D$? ~~(Note: In reality, a hockey player would probably change the direction of their applied force, so don't rely on what you've seen on TV.)~~



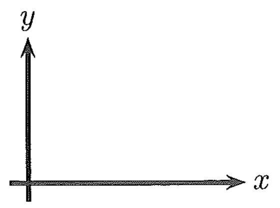







[✓ (e)]

In all pictures:

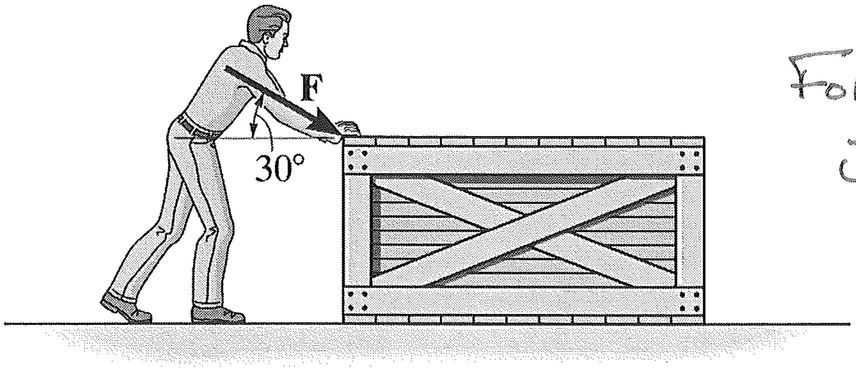


A→B: No force so straight-line motion

B→C: Acc. in y only = curved motion

C→D: Back to straight line but with non-zero x and y velocity.

(5.) A man pushes a 25-$kg$ crate across the floor with a $F = 200\,N$ force at 30° below the horizontal. The coefficient of kinetic friction between the crate and the floor is 0.40. What is the crate's acceleration?



Forces: $\vec{F}$, $\vec{n}$ up, $\vec{\omega}$ DOWN, $\vec{f}_K$ to left

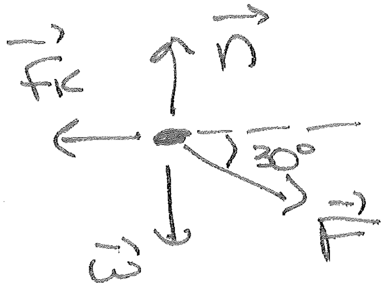
(a) $-0.46\,m/s^2$

(b) $-0.60\,m/s^2$

[✓ (c) $+1.4\,m/s^2$]

(d) $+3\,m/s^2$

(e) $+6.9\,m/s^2$



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

MOTION only IN x $\Rightarrow a_x = a = 0,\ a_y = 0$

$\sum F_y = 0 \Rightarrow n_y + F_y + \omega_y + \cancel{f_{Ky}}^{0} = 0$

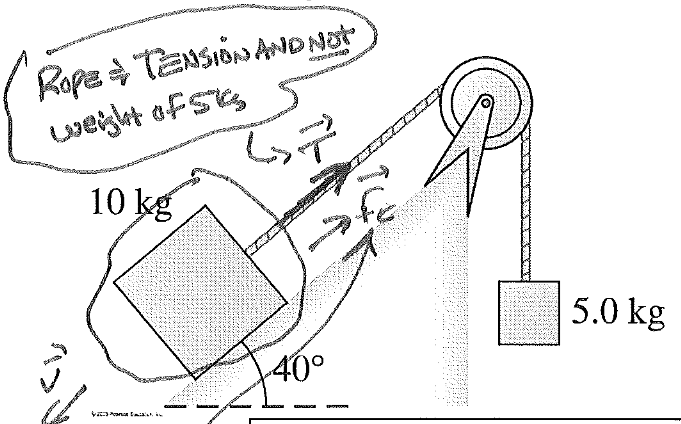
$\Rightarrow n - F\sin30° - \omega = 0 \Rightarrow n = F\sin30° + \omega = (200N)\sin30° + (25kg)(9.8\,m/s^2)$

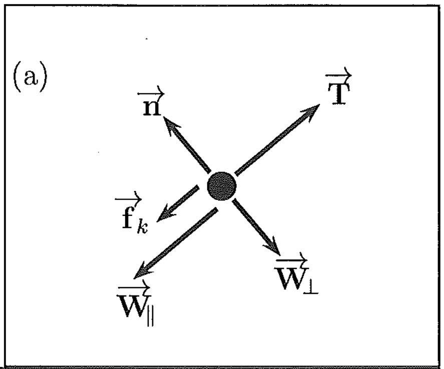
$\Rightarrow n = 345N$, $f_K = \mu_K n = 0.4(345N) = 138N$

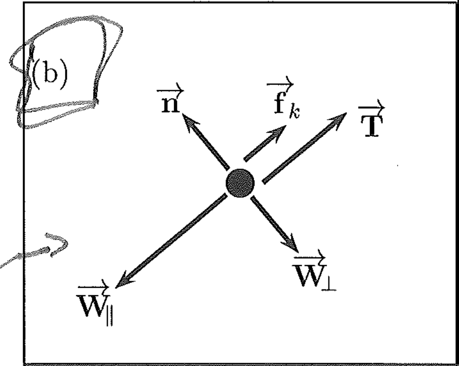
$\sum F_x = ma_x \Rightarrow \cancel{n_x} + F_x + \cancel{\omega_x} + f_{Kx} = ma_x \Rightarrow F\cos30° - f_K = ma$

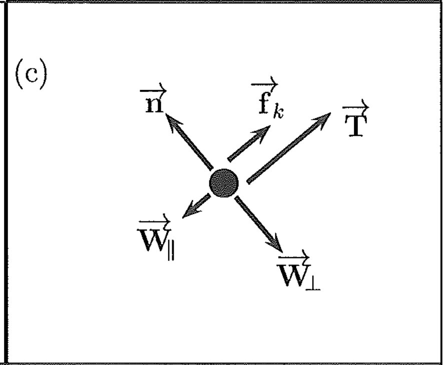
$\Rightarrow 200N\cos30° - 138N = 25kg\,a \Rightarrow a = \frac{35.210}{25kg} = 1.4082\,m/s^2$

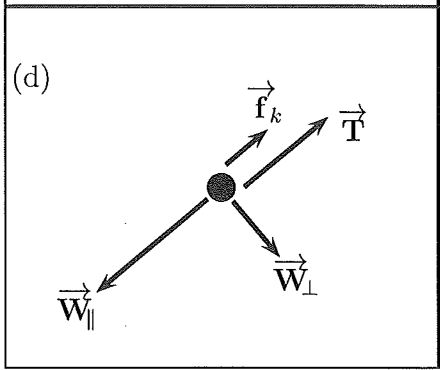
(6.) When released from rest, the 10-*kg* block shown slides down the ramp with increasing speed pulling the 5-*kg* block upwards. If there is kinetic friction between the 10-*kg* block and the ramp, which of the following is the correct free-body diagram for the 10-*kg* block as it slides down the ramp?

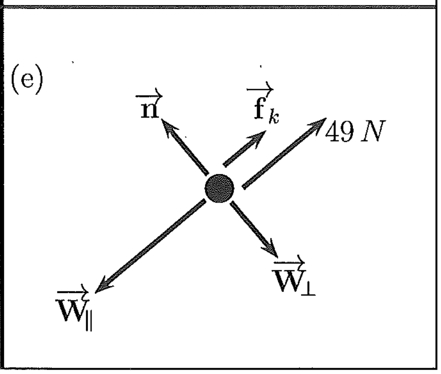








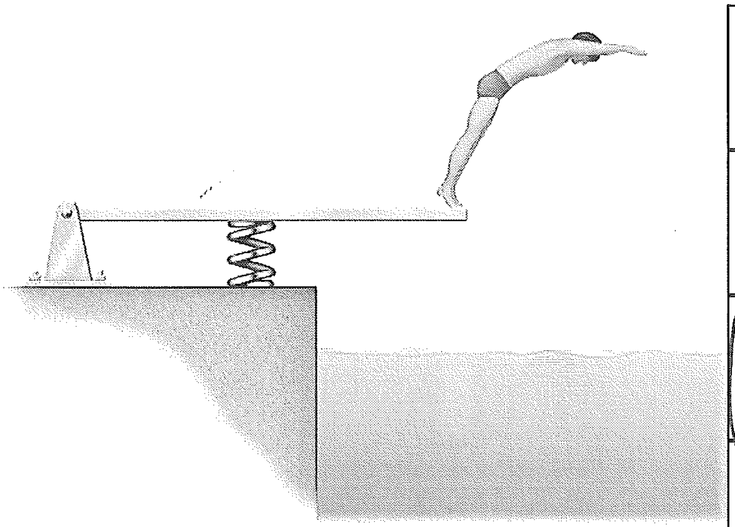




opposite to velocity

This also correctly shows $W_{\parallel} > f_k + T$ which is necessary for increasing speed down incline.

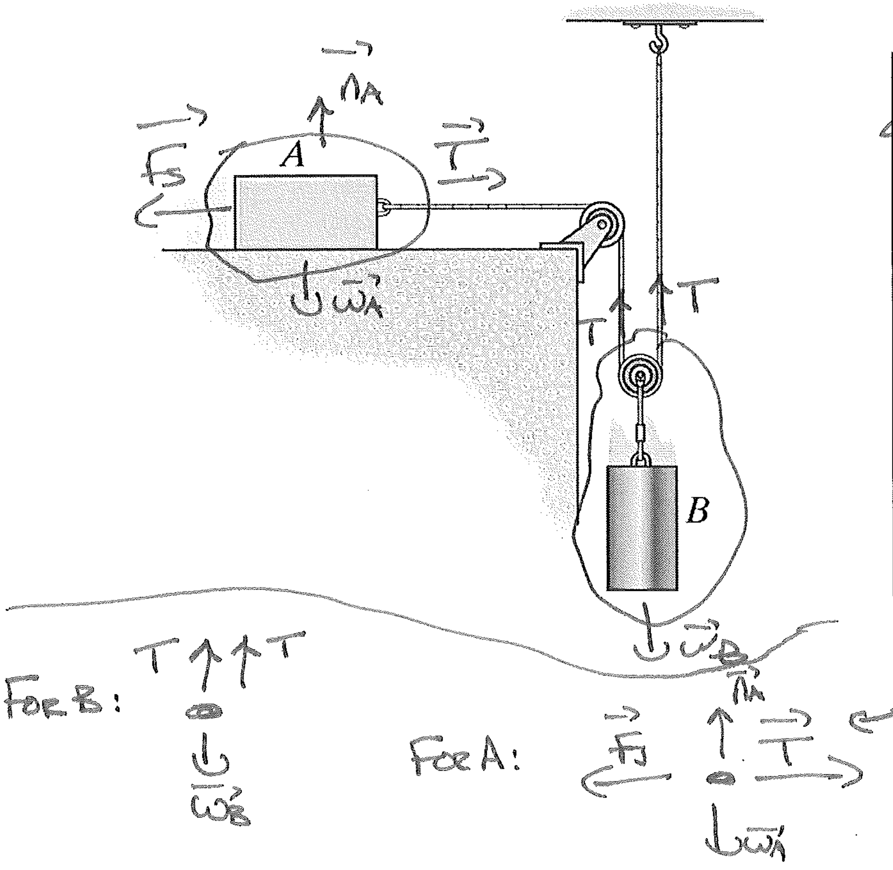
(7.) An 80 $kg$ man launches himself from a diving board with an acceleration $\overrightarrow{a} = 4.2\, m/s^2$ at 25°. At the instant shown, which of the following is a correct statement?



| | |
|---|---|
| (a) | The diving board is exerting a larger force on the man than the man is exerting on it. |
| (b) | The diving board is exerting a smaller force on the man than the man is exerting on it. |
| [✓ (c)] | The diving board is exerting an equal force on the man to the one that the man is exerting on it. |
| (d) | The relative sizes of the force exerted by the man and the diving board cannot be determined. |

REGARDLESS OF ACCELERATION, ACTION & REACTION ARE ALWAYS EQUAL

(8.) A 7-*kg* block $A$ is placed on a horizontal table. The coefficient of static friction between block $A$ and the table is 0.4. It is connected with massless ropes and perfect pulleys to 3-*kg* block $B$. After being connected, neither block moves. How much static friction is acting on block $A$?



← Same tension since massless rope & perfect pulley.

[✓ (a) 14.7 $N$]

(b) 24.5 $N$

(c) 27.4 $N$

(d) 29.4 $N$

(e) 34.3 $N$

No motion $\Rightarrow \sum F_x = 0, \sum F_y = 0$

From B: $\sum F_y = 0 \Rightarrow 2T - w_B = 0 \Rightarrow T = \frac{w_B}{2} = \frac{(3kg)(9.8m/s^2)}{2} = 14.7N$

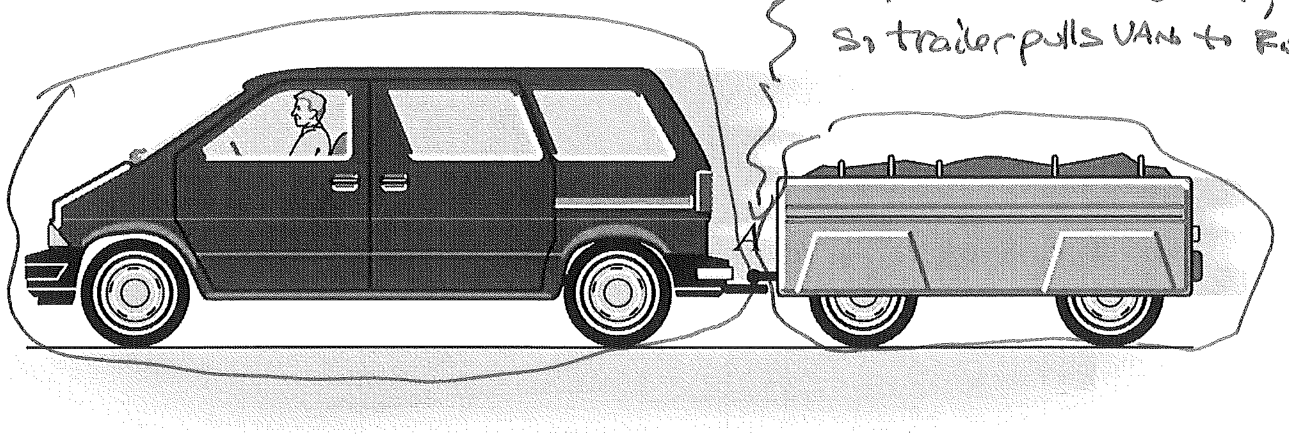
From A: $\sum F_x = 0 \Rightarrow T - f_s = 0 \Rightarrow \underline{f_s = T = 14.7N}$

Note: Problem never implied $f_s = f_{s\,max}$. In fact $f_{s,max} = \mu_s n_A = \mu_s w_A$

$f_{s,max} = 27.4N$ would cause A to slide left and B to rise.

(9.) A 700-*kg* minivan is on a straight highway pulling a 400-*kg* trailer behind it. There is 600 *N* of drag force acting on the minivan but none on the trailer. Assume the hitch at point *A* connecting the minivan to the trailer acts like a massless rope.

VAN pulls trailer to left, so trailer pulls VAN to RIGHT



(a) Draw separate free-body diagrams for the van and for the trailer. For full points, all forces need to be listed off to the side and any action/reaction pairs between the van and trailer should use the notation $\vec{\mathbf{F}}_{V\text{ on }T}$ and $\vec{\mathbf{F}}_{T\text{ on }V}$. *Note:* The van and trailer are accelerating, so the engine will be exerting a force. *(+5pts)*

Forces on VAN:

Engine: $\vec{F}_E$ to left*

NORMAL: ~~B~~ $\vec{n}_V$ up

Drag: $\vec{D}$ RIGHT

Trailer: $\vec{F}_{TONV}$ RISHT

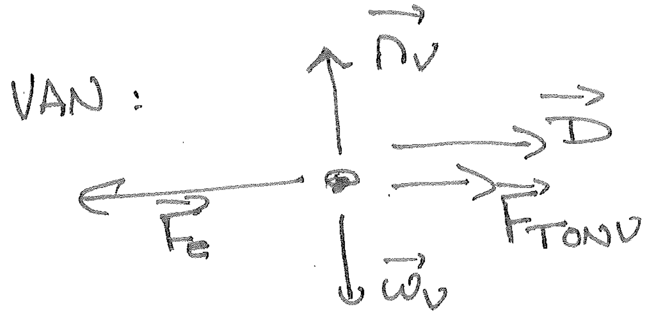
Gravity: $\vec{w}_V$ DOWN

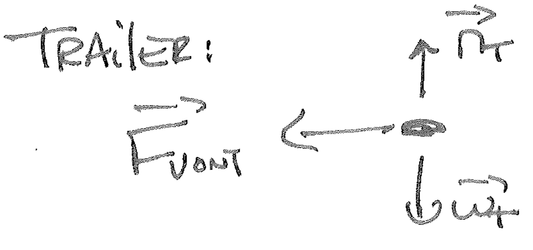
ON TRAILER:

NORMAL: $\vec{n}_T$ up

VAN: $\vec{F}_{VONT}$ left

Gravity: $\vec{w}_T$ DOWN





(Part (b) is on the back)

* of course, you realize that Engine Actually pushes wheels BACK ⇒ ground pushes VAN to LEFT, But 3RD LAW ⇒ SAME MAGnitude.

(b) The hitch will break if the force acting on it exceeds 500 $N$. What is the maximum acceleration of the van? What force is the engine exerting at that acceleration? *(+15pts)*

Force on Hitch $= F_{T\,ON\,V} = F_{V\,ON\,T} = 500N$ make left positive

FROM TRAiler: $\sum F_x = ma_x \Rightarrow F_{VONT} = M_T a_{TX}$

$\Rightarrow 500N = (400kg)\,a_{TX} \Rightarrow a_{TX} = \frac{500N}{400kg} = 1.25 m/s^2$

No motion in $y \Rightarrow a_T = a_{TX} = 1.25 m/s^2$

VAN AND TRAiler MUST HAVE SAME ACCELERATION $\Rightarrow \boxed{a_{VAN} = 1.25 m/s^2}$

Now VAN: $\sum F_x = ma_x \Rightarrow F_E - D - F_{TONV} = M_{VAN}\,a_{VAN}$

$\Rightarrow F_E - 600N - 500N = (700kg)(1.25 m/s^2)$

$\Rightarrow F_E - 1100N = 875N$

$\Rightarrow \boxed{F_E = 1975N}$