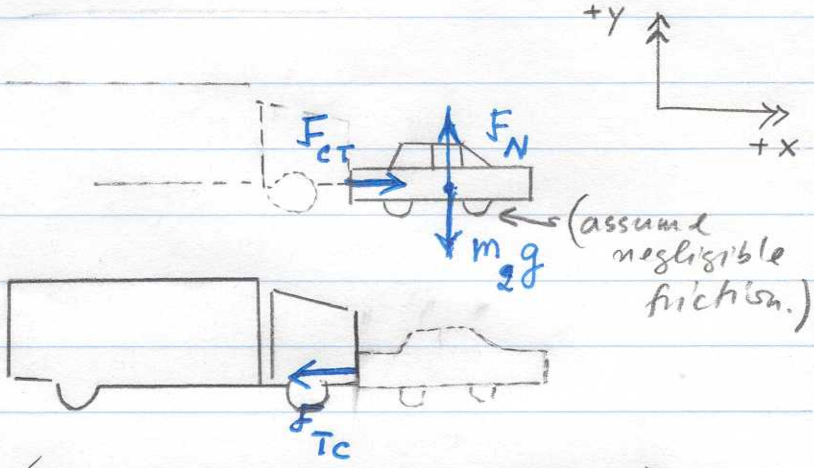
Solutions to HW4, Physics 161, SPG 2003

S1/ $F_{CT} \equiv$ force applied on the car by the truck.

$F_{TC} \equiv$ force applied on the truck by the car.



(*. Note: The free body diagram of the truck is NOT complete. Here, I am simply showing F_{TC} to answer the questions asked.)

a/. By N3 (Newton's third law),

$$\vec{F}_{CT} = -\vec{F}_{TC}.$$

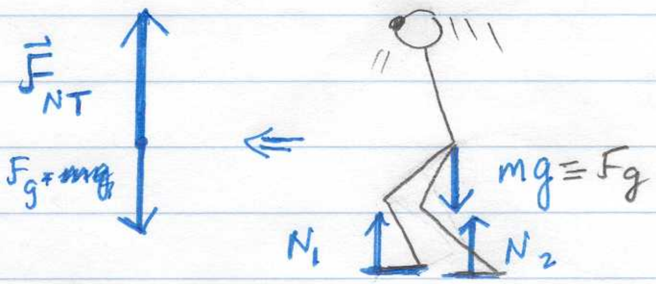
(3rd law partners.)

b/. Since the only force acting on the car in the x-direction is F_{CT} (in the absence of air drag), we have $\Sigma F_x = m_2 a$

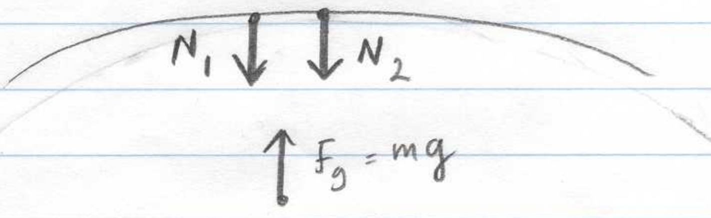
$\Rightarrow \boxed{F_{CT} = m_2 a}$ and from above, $\vec{F}_{CT} = -\vec{F}_{TC}$,

$$|\vec{F}_{CT}| = |\vec{F}_{TC}|.$$

S2/. $\vec{F}_{N\,Total} = \vec{N}_1 + \vec{N}_2$



The gravitation force on the person due to the earth & the gravitational force on the earth due to the person are 3rd law partners.



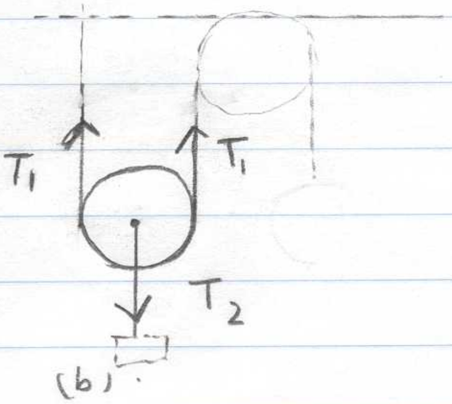
* Since the person is accelerating upwards $F_{N\,Total} > F_g$ since due to N2, we need a net upward force.

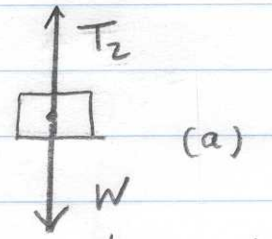
Also, $\vec{N}_1$(on person due to ground) $= -\vec{N}_1$(on ground due to person.)

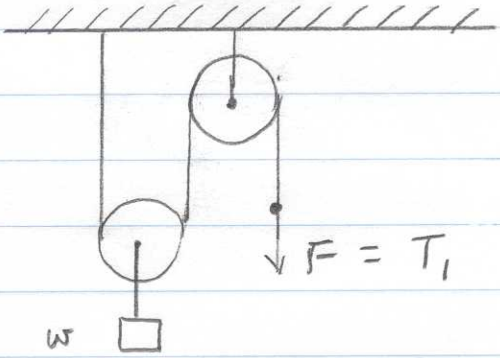
and $\vec{N}_2$(on person due to ground) $= -\vec{N}_2$(on ground due to person)

So $F_{N\,Total}$ (Person - Ground) and $F_{N,Total}$ (ground-person) are 3rd law partners.

S3/. The tension in the rope must be the same throughout the rope since we're assuming an ideal rope.







From N2, since the system is at rest, the block's acceleration is zero. i.e

$$F_{net} = m a^0$$

$$\Rightarrow T_2 - W = 0 \Rightarrow \boxed{T_2 = W}$$

Applying N2 to the pulley, we know that

$$F_{net} = m_{pulley}\, a$$

$$2T_1 - T_2 = 0$$

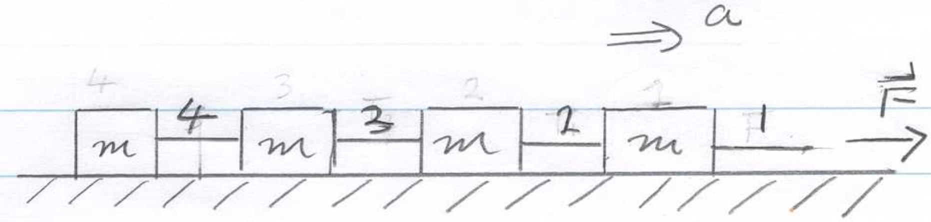
$$\Rightarrow 2T_1 = T_2 \Rightarrow T_1 = \frac{T_2}{2} \Rightarrow \boxed{T_1 = \frac{W}{2}}$$

Now F is basically the tension in the rope i.e $F = T_1$.

So $F = \frac{W}{2}$. so we need to apply a force equal to only half the weight of the block to hold it at rest.

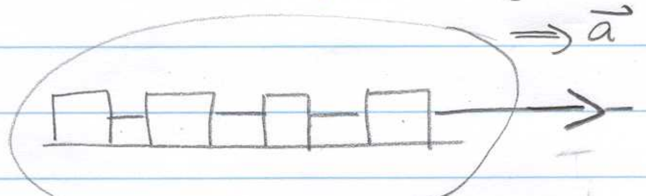
S3b/. The person must pull the rope by <u>2 meters</u> to be able to lift the weight up by 1 meter.

54.



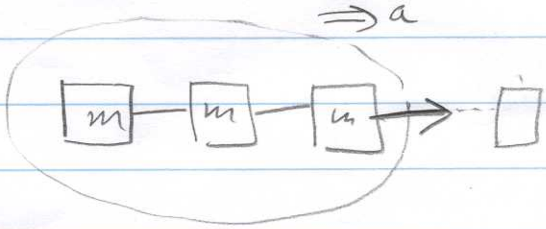
(a). Since each object has the same acceleration a, and each object has the same mass m, the <u>net</u> force acting on each object must be the <u>same</u>.

(b) Let's see how the tension in each string to the left compares to that on the right.



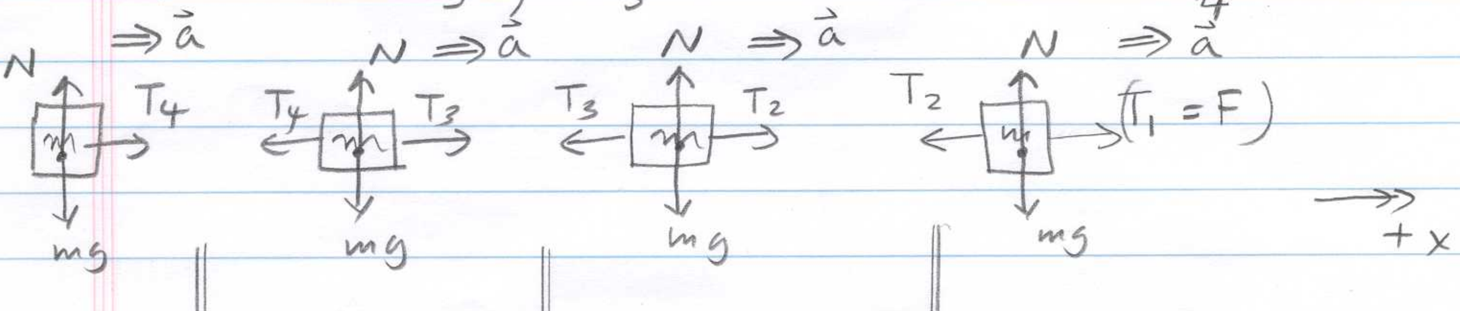
If we consider all 4 masses to be one system then string ① is pulling all 4 of them to the right with tension $T_1 = F$ and $F = (4m)a$ from Newton's 2nd law.

string 2 is pulling three masses so



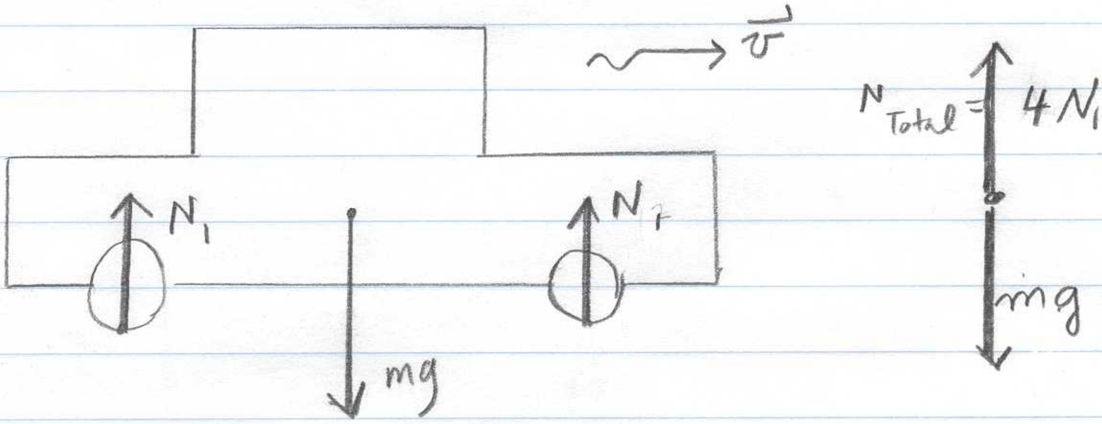
$$\boxed{T_2 = (3m)a}.$$

By similar reasoning, $T_3 = 2ma$ and $T_4 = ma$.

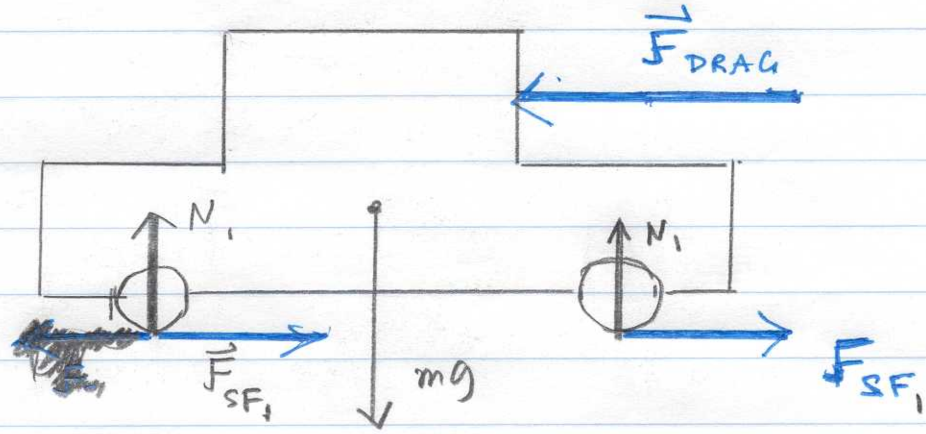


$T_4 = ma$	$T_3 - T_4 = ma$	$T_2 - T_3 = ma$	$T_1 - T_2 = ma$
			$T_1 = T_2 + ma$
	$T_3 = T_4 + ma$	$T_2 = T_3 + ma$	$\Rightarrow T_1 > T_2$
	$\Rightarrow T_3 > T_4$	$\Rightarrow T_2 > T_3$	

55.1, This was not asked for, but for a moment let's consider a car travelling on a straight road, traveling at constant velocity in the ABSENCE of air drag. In that case, the free body diagram simply looks like fig 55b (assuming that the tires have negligible rolling friction acting on them.)



In the presence of air drag, the engine must be rotating the tires at all times for the tires to have enough F_{SF} (static friction) with the ground to counteract the force of air drag.



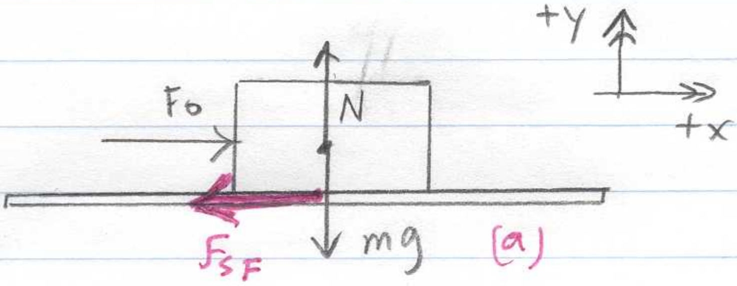
Note that since the car is moving with constant velocity, $\vec{a} = 0$ so $\boxed{\vec{F}_{DRAG} = -\vec{F}_{SF,Total}}$.

Q: Are F_{Drag} & $F_{SF,Total}$ 2nd law partners or 3rd law partners?

P2/. $m = 2.0\,kg$
$\mu_s = 0.60$
$\mu_K = 0.40$

Note that since there is no acceleration in the y-direction, $N - mg = 0$ so $N = mg = (2.0\,kg)(9.8\,m/s^2) = 19.6\,N$.

a/. $F_0 = 10\,N$.



The maximum force of static friction between the block and the floor is

$F_{s,max} = \mu_s F_N$
$= (0.60)(19.6\,N)$
$= 11.76\,N$. This means that we need a force bigger than 11.76 N to get the box to accelerate from rest. For any force less than 11.76 N, the force of static friction is equal and opposite in direction. (see fig P2(a) above.)

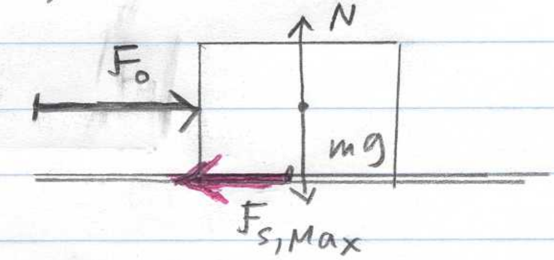
(2) since $F_{SF} = F_0$, $a_x = 0$.

(3). The box remains at rest, so $v = 0$.

b/(i) when the applied force is increased to 13 N, That force is enough to get the box started. Precisely at $t = t_b$, $F_{SF} = F_{SF,max} = 11.76\,N$.

So at $t = t_b$: $\Sigma F_x = m a_x$

$F_0 - F_{SF,max} = m a$



$\Rightarrow \dfrac{13N - 11.76N}{(2.0\,kg)} = a$

(ii) $\boxed{\vec{a} = 0.62\,m/s^2\,\hat{i}}$

(iii) $\vec{v}$ is to the right.

c) After $t = t_b$, the box is moving to the right. It's now got kinetic friction acting on it, as opposed to static friction. So $F_{Kf} = \mu_K N = (0.40)(19.6\,N)$

$\Rightarrow \quad F_{kf} = 7.84\,N.$

(ii) To find a_x, we use N2: $\Sigma F_x = m a_x$

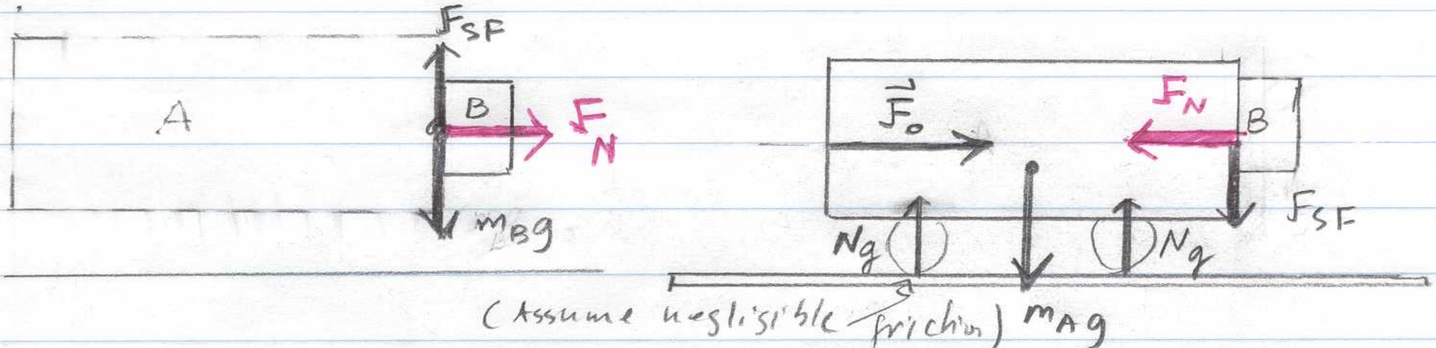
$$F_0 - F_{kf} = m a$$

$$\Rightarrow \quad \frac{10N - 7.84N}{m} = a$$

$$\Rightarrow \quad \frac{2.16\,N}{2.0\,kg} = a \quad \Rightarrow \quad \boxed{\vec{a} = 1.08\,m/s^2}$$

(iii) The box's velocity is to the right.

P3).



If box B is not to slide down, it must have a large enough force of static friction acting on it. Since the coefficient of static friction is fixed, the only way of ensuring a large enoug F_{SF} is to have a large enough normal force acting on block B. So, the larger the acceleration of block A, the larger the force F_N. We want F_N to just as large as is needed for F_{SF} to exactly balance $F_g = m_B g$.

b). $\Sigma F_x = m_B a_x$

$F_N = m_B a$

$\Sigma F_y = m_B a_y$, we want $a_y = 0$.

$F_{SF} - m_B g = 0$

$\Rightarrow \quad F_{SF} = m_B g$

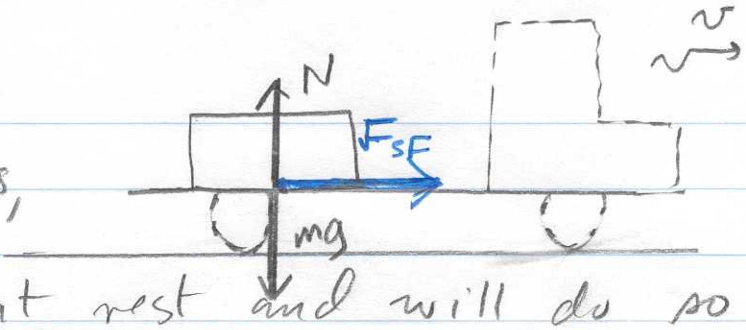
$\Rightarrow \quad \mu_s F_N = m_B g$

$\Rightarrow \quad \mu_s \cancel{m_B} a = \cancel{m_B} g$

c) $\boxed{a = g/\mu_s}$ wow! Doesn't depend on m_B at all!

P41.

a/. When the truck is at rest, so is the box. When the truck accelerates, from N1, we know that



the box wants to stay at rest and will do so unless there is a force on it that will give it the same acceleration as the truck in which case it will not slip & slide. In trying to figure out the direction of static friction, it is useful to imagine which way the box would slide <u>relative</u> to the truck if the truck bed were completely frictionless. Well, in that case the box will stay put where it is and the truck, sliding out from under it will pull away. So <u>relative to the truck</u> the box slides backwards in <u>the absence of friction</u>. When friction is present, the force of static friction acts IN THE DIRECTION OPPOSITE TO THE DIRECTION OF POTENTIAL SLIDE. So F_{SF} must act FORWARD on the bottom surface of the box in this case.

Also, note that this makes perfect sense – the box has to accelerate to the right if it not to slide & the only force <u>causing</u> that acceleration in the horizontal direction <u>is</u> F_{SF}. This is in perfect harmony with **N2**.

b/. Now remember that F_{SF} can only be so large. Its maximum value's given by $F_{SF,max} = \mu_S F_N$. In this problem both F_N and μ_S are <u>fixed</u>. So F_{SF} can only give the box an acceleration equal to: $\sum F_x = m a_x$

$$F_{SF,max} = m\, a_{max}$$

$$\mu_s F_N = m\, a_{max}$$

(we find $F_N = mg$ from $\sum F_y = 0$.) $\Rightarrow \mu_s \cancel{m} g = \cancel{m} a_{max}$

$$\Rightarrow \boxed{a_{max} = \mu_s g}$$

So, if the truck accelerates at a rate any faster than this, the box will not be able to keep up and will be seen to slide backwards relative to the truck. (Note that relative to a person standing on the ground, the box is still accelerating forward.)

c/. $a_{max} = \mu_s g$ (doesn't depend on m, at all!)

$a_{max} = (0.30)(9.8\,m/s^2) \cong \frac{1}{3} g$
$= 2.94\,m/s^2$ - [How is that compared to your car's acceleration?]

d/. As seen above, a_{max} is INDEPEDENT of mass.

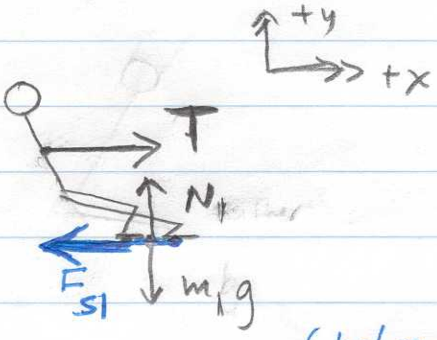
P5/.

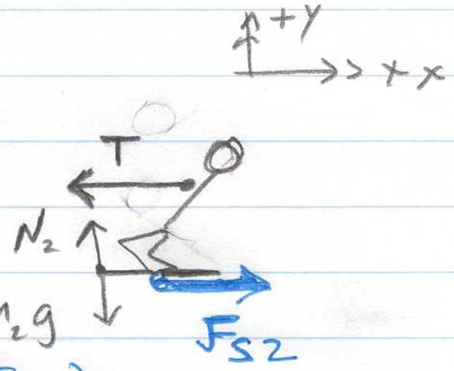
a/. Both the father and the son are at rest. The rope doesn't accelerate. The tension at each end of the rope then MUST be the same

(i)

But T is the force with which the rope is being pulled at both ends. So the son and the father are both pulling on the rope with force = T.

(ii) From Newton's 3rd law, if the rope is pulled by a force T by the father, it pulls the father back by a force with magnitude T, but just in the opposite direction. Same thing for the son. So the rope is pulling on both of them with a force of magnitude T.





(below find $F_{s2} = F_{s1}$)

(3) & (4) Since neither the father nor the son accelerate in the x-direction, from N2:

Father

$$\Sigma F_x = m_1 a_{1x}^{\nearrow 0}$$

$$T - F_s^{(1)} = 0$$

$$\Rightarrow \boxed{T = F_s^{(1)}}$$

Son:

$$\Sigma F_x = m_2 a_{2x}^{\nearrow 0}$$

$$-T + F_{s2} = 0$$

$$\Rightarrow \boxed{T = F_{s2}}$$

$$\Downarrow$$

$$\boxed{F_{s1} = F_{s2}}$$

[note to graders: this last bit not asked for in the problem]

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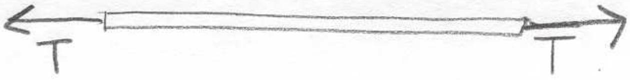
(6). Now, $a_{1x} = 0$ (i.e. accel. of the father) but $a_{2x} \neq 0$ (accel. of the son). In fact a_{2x} is to the left.

(1). If we assume the rope to be of negligible mass, then the tension at the two ends will <u>still</u> be the same (i.e Tension at the left end same as tension at the right end.)



(2) Ans. to part 2 then is same as before.

3 & 4 Now, $\Sigma F_x = m_2 a_{2x}$ and $a_{2x} \neq 0$ but is to the left.

$$-T + F_{s2} = -m_2 a_2$$

(− sign because a is to the left – check coordinate system.)

$$\Rightarrow \quad F_{s2} = T - m_2 a_2$$

$\Rightarrow$ $F_{s2} < T$ and not $F_{s2} = T$ as in part (a).

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