Physics 211 Group Exam 1, Form 2

Problem 1	Problem 2	Total
/25	/25	/50

Name: Solutions

Partner #1: ____________________

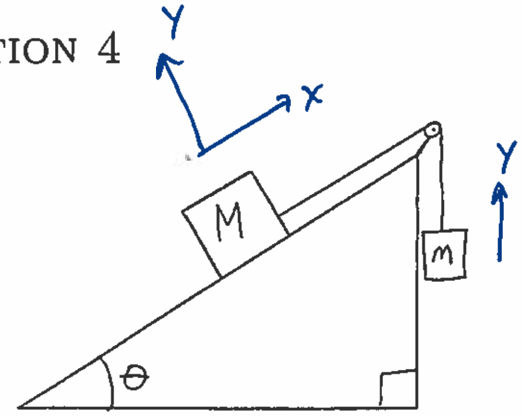
Partner #2: ____________________

Recitation section number: __________

- There are two questions, each worth twenty-five points.
- **You must show your reasoning to receive credit.** A numerical answer with no logic shown will be treated as no answer.
- You are highly encouraged to use both pictures and words to show your reasoning, not just algebra.
- If you run out of room, ask for an extra sheet of paper, or get one from your notebook.
- Show your reasoning as thoroughly as possible for partial credit.
- You may use $g = 10\,\mathrm{m/s^2}$ throughout, except where indicated, to minimize arithmetic.

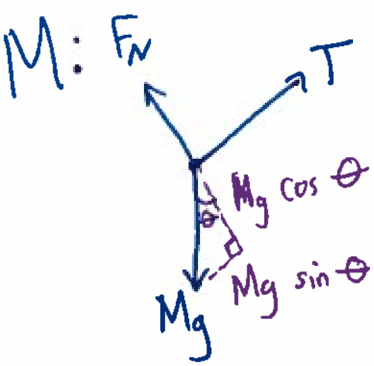
Question 4

A block of mass M sits on an inclined plane angled at an angle θ above the horizontal;
it is connected by a string to a block of mass m hanging over the top. (See picture.)



$a = 0$

a) In terms of M and m, what must the angle θ be such that the two blocks do not move? Assume for this part that there is no friction. (7 points)



M, x: $T - Mg\sin\theta = 0$

M, y: $F_N - Mg\cos\theta = 0$

m : $T - mg = 0 \Rightarrow T = mg$

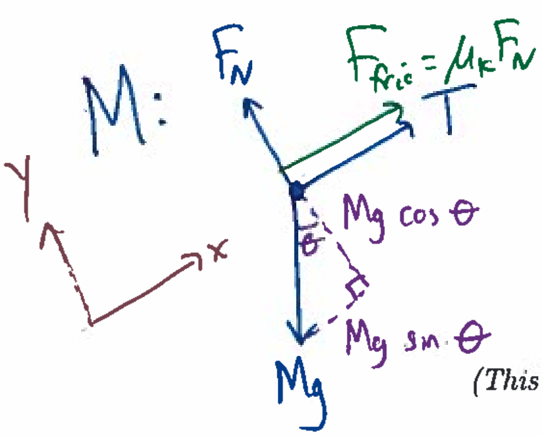
$\Rightarrow mg - Mg\sin\theta = 0$

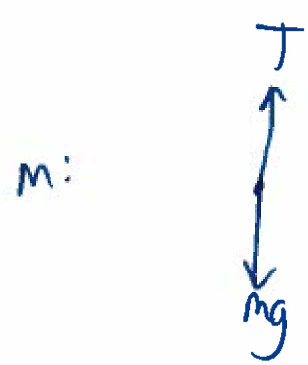
$\sin\theta = \frac{mg}{Mg} \rightarrow \theta = \sin^{-1}\frac{m}{M}$.

Now, assume that M is large enough that it slides down the ramp. There is kinetic friction between that block and the ramp; the coefficient of kinetic friction is μ_K.

friction is up the ramp

b) Draw force diagrams for both blocks. Indicate your choice of coordinate system for both of them (they do not have to be the same, and in fact shouldn't be!) (3 points)





(This problem continues on the next page.)

c) Calculate the acceleration of both blocks in terms of M, m, g, θ, and μ_k. (15 points)

$\sum \vec{F} = m\vec{a}$ for both!

(1) M, X: $T + \mu_k F_N - Mg \sin\theta = Ma_{x_1}$

(2) M, Y: $F_N - Mg\cos\theta = Ma_{y_1} = 0$ $a_{y_1} = 0$ since it stays on the slope

(3) m, Y: $T - mg = ma_{y_2}$

Note $a_{x_1} = -a_{y_2}$.

From (2): $F_N = Mg\cos\theta$.

From (3): $T = ma_{y_2} + mg = mg - ma_{x_1}$.

Substitute into (1):

$$mg - ma_{x_1} + \mu_k Mg\cos\theta - Mg\sin\theta = Ma_{x_1}$$

Solve:

$$a_{x_1} = \frac{mg + \mu_k Mg\cos\theta - Mg\sin\theta}{m + M}.$$

Question 3

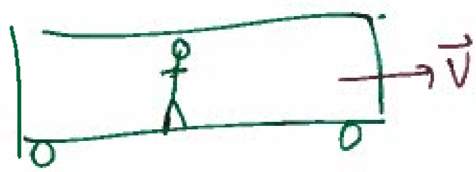
A person is standing in a subway car, looking forward. She is not holding onto anything, trusting the friction between her shoes and the ground to keep her balance.

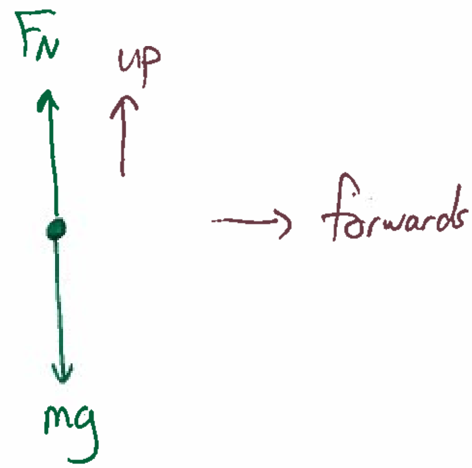
Draw force diagrams for the following situations. Make sure you indicate which direction is which (i.e. tell me whether I am looking at the person from above, from the side, etc., and which direction is toward the front of the subway car.) Indicate the relative sizes of the forces by the lengths of the arrows in your force diagram. Forces that have the same magnitude should have the same size arrows; if you think it's not clear, you can write a little text telling me which forces are larger, smaller, or equal.

a) The subway car is moving forward at a constant velocity $\vec{v}$. (5 points)

means $\vec{a} = 0$.

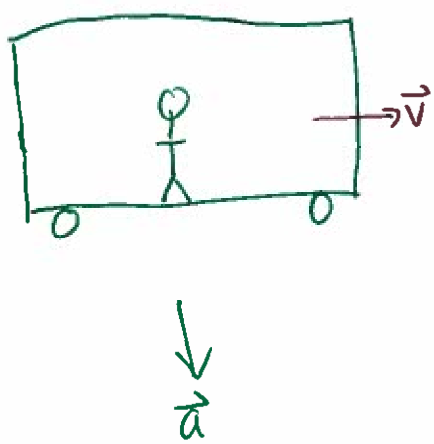
Side view:

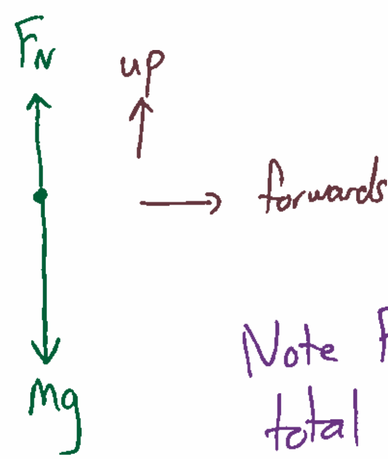




b) The subway car is going over the top of a hill, and is accelerating straight downward at 3 m/s^2. *(5 points)*

net (sum) force must be down

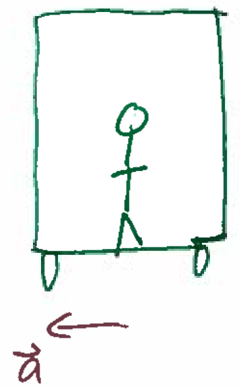




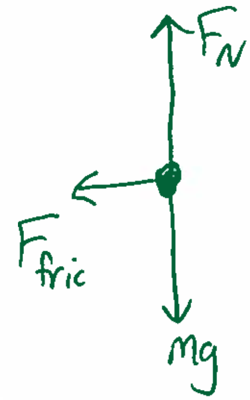
Note $F_N < mg$ since total force is down.

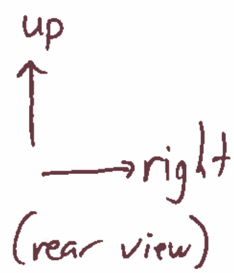
c) The subway car is moving at a constant speed v; it is turning left, gently enough that the passengers do not slip and fall. (5 points)

Rear view



- Only available force to make her accelerate left is friction. Since $\mu_s < 1$, $F_{fric} < F_N$.

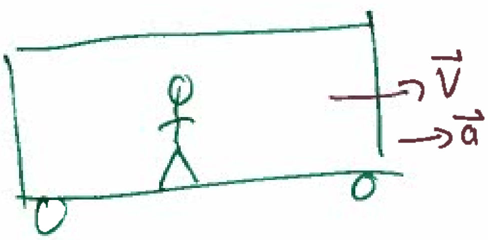


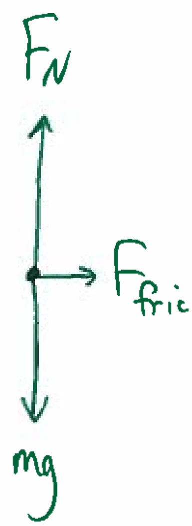


Note $F_N = mg$, $F_{fric} < mg$.

d) The subway car is accelerating forward at $3\,\mathrm{m/s^2}$. *(5 points)*

Side view





Again, the only force available to accelerate her is friction.

$$F_{fric} = ma = (3\ \mathrm{m/s^2})\,m$$
$$= 30\% \text{ of gravity/weight.}$$

e) Anyone who has ridden a subway car feels themselves "thrown backwards" when it accelerates forward. What force is pushing them backwards? (If there is no such force, then explain why they feel themselves thrown backwards when the car accelerates.) (5 points)

There is no such force.

When the car accelerates forward, the rider won't accelerate forward themselves unless some other force (friction, holding onto the car, a seat belt, normal force from a seat-back) pushes them forward.

Absent ~~[illegible]~~ this, the car will accelerate forward without them, so they will move backwards relative to the car.