Guide to NII.2: Dynamics & Statics

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I. WARM UP IN 1 DIMENSION

An ice-skater with a mass of 60 kg pushes off from the wall of the ice rink and glides out across the ice with an initial velocity of 3m/s. The ice exerts a slight but non-negligible frictional force on the skater of 2N. How far will the ice skater travel before coming to a complete stop? ***If and only if*** you are ***stuck***, try the hints below:

Hint #1: What is the acceleration of the ice-skater? (Try an FBD.)
Hint #2: How much time will it take the ice-skater to come to a stop?

- Draw a picture of the problem.
- Define a coordinate system for the problem and indicate positive & negative directions in your picture.
- What are you looking for?
- What are you given?
- What information are you missing?
- The problem asks how far the skater will go before coming to rest: WHY will the skater eventually come to rest? What force will make this happen? What direction will her acceleration be in.
- Make a system schema.
- Make an FBD of the skater. There should be three arrows on this FBD.
- You are looking for how far the ice-skater traveled. What AXIS is the ice-skater traveling on? This is the axis you ultimately need to examine.
- Set up an Newton's Second Law (NII) equation for the axis you care about.
- Solve this equation to find the ice-skater's acceleration.
- Use kinematics to find time.
- Use kinematics to find your final answer.

II. Friction Warm Up

A child sleds down a hill. When she reaches the bottom, she is going 11 m/s. She then sleds ***across level ground*** until she slows down and comes to rest. The coefficient of kinetic friction between the sled and the snow is given as $\mu_k = 0.1$. The sled weighs 4kg and the child weighs 25 kg.

A) Draw a picture of this situation as you understand it.

- Define a coordinate system for the problem and indicate positive & negative directions in your picture.

B) Draw a System Schema for the situation.

C) Draw an FBD of the sled-child system during the time they are sledding ***on level ground***.

D) What is the force of kinetic friction on the sled-child system?

Hint #1: What is the normal force on the sled.

Hint #2: Treat the sled and the kid as a single system.

- Remember that $f_k = \mu_k N$
- Remember that the equation above is all about MAGNITUDES, so there are no DIRECTIONS or SIGNS involved.
- You are looking for the force of friction between the SLED and the SNOW, so the normal force you need is the normal force between the sled and the snow.
- You're not given the magnitude of this normal force, so you have to find it.
- What direction does this normal force point in? What AXIS is it on?
- Set up an NII equation for this axis. There will be two forces on this axis.
- Solve the NII equation to find the normal force.
- Plug into the equation above to find the force of kinetic friction.

E) How far will they go before coming to rest?

Hint #1: first find the acceleration of the sled, using Newton's laws.

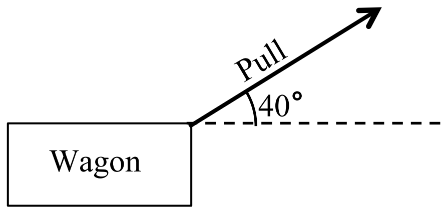
Hint #2: to find a, first draw an SS and an FBD.

Hint #3: once you've found a, use kinematics to find d_{final}.

- What AXIS do you care about in this part of the problem?
- This is now very similar to Warm Up I above. Go back & look at that if you're not sure what to do.

III. Wagon Pull

A child is pulling a ***wagon*** along a ***road*** at an angle 40 above the horizontal, as shown:



The wagon has a mass of 2kg, and the child pulls with a force of 4N.
All frictional forces are negligible.

A) Create a drawing of this situation and a system schema.

- Again, define a coordinate system for the problem and indicate positive & negative directions in your picture.
- In ALL problems in this unit, you want the X-axis of your coordinate system to line up with the direction of acceleration. Which way is the wagon accelerating?
- HINT: it's the same direction it's MOVING in.

B) Create an ***pure*** FBD of the wagon. (Your FBD will have three arrows.)
C) Create a ***component*** FBD of the wagon using a vertical-horizontal coordinate system. (Your FBD will have four arrows.)

Hint: the component FBD looks just like the pure FBD, except that the tension force is split into vertical & horizontal components

- To split a diagonal vector into components, you will need to form a RIGHT TRIANGLE and then use TRIG.

D) Show that the wagon will remain on the ground despite the upward pull from the child.

Hint 1: staying on the ground means vertical acceleration is zero.
Hint 2: if wagon leaves ground, normal force from road drops to zero.

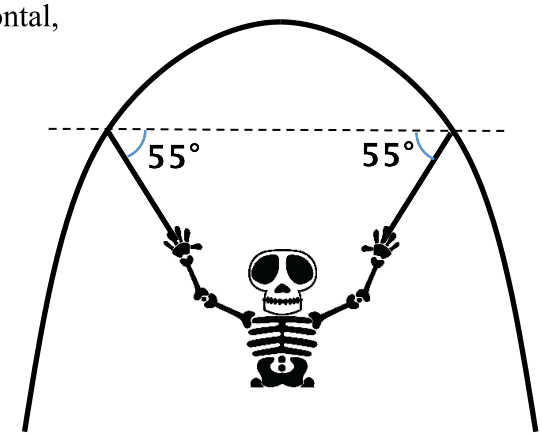
- There are a couple ways to think about this. Here's one:
- How hard would you have to yank UPWARDS on the wagon to make the normal force go to zero? You can answer this intuitively, or you can do it with a hypothetical ("what if?") NII equation.
- If the wagon is getting yanked up LESS than this amount, then it must be staying on the ground.

E) Find the horizontal acceleration of the wagon.

- You want horizontal acceleration, so set up an NII equation on the horizontal axis.
- Look back at your COMPONENT FBD to see what forces are on this axis. There will only be one.

IV. Halloween Hang

A **20kg** skeleton is suspended by diagonal chains in an archway, as shown below: Each chain forms a **55 degree** angle with the horizontal, and the weight of the skeleton is evenly distributed across the chains—that is, the force of tension on one chain is the same as the force of tension on the other. The skeleton is ***not moving.***



A) Draw a system schema of the situation.
B) Draw a ***pure*** FBD for the skeleton.
C) Draw a ***component*** FBD for the skeleton.
D) Calculate the magnitude of the force of tension on each chain.

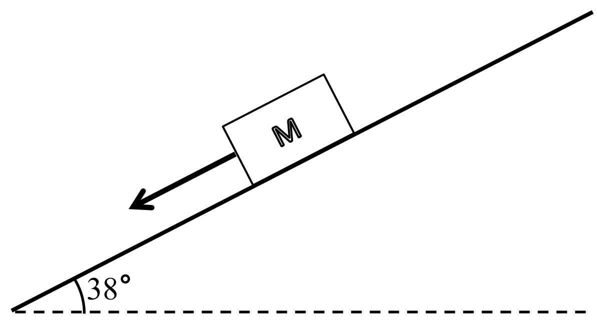
Use the hints if you get stuck.

Hint #1: The shape of the arch makes no difference.
Hint #2: To draw the component FBD, split all diagonal forces into components
Hint #3: What is the vertical acceleration? What is the horizontal acceleration?
Hint #4: Since you know the force of gravity, you know something about the vertical direction. Therefore, use the vertical direction to figure out magnitude of F_T

- When you are making your component FBD, you may notice that you don't know the magnitude of the forces you are trying to split into components. In other words, you can make a right triangle, but you don't know the length of the hypotenuse. So how do you find the components—i.e. how do you find the length of the legs??
- Well, it's easy. Just leave the magnitude (the hypotenuse) as a VARIABLE. You could call it T. (Since you know it's the same for both wires, you don't have to call use T_1 and T_2, since $T_1 = T_2 = T$.)
- You'll still have to use trig, but you won't multiply your sines & cosines by a NUMBER, because you don't (yet) know the number. You'll just multiply them by your variable.
- Next, set up an NII equation for the Y-AXIS.
- If you solve this equation, you will find out that cos(55)T = _______. Then you can divide by cos(55) to find T.

V. Frictional Galileo Track

Mass M is sliding down a ***rough*** track. The track forms a 38 degree angle with the horizontal. The mass has a coefficient of kinetic friction with the track of 0.3.



Your goal: find an expression for the ***a***, acceleration of the mass

A) Create a system schema for this situation.

B) Create a ***pure*** FBD of the mass.

C) Create a coordinate system ***in which the x-axis lines up with the direction of acceleration***. In other words, the x-axis will be parallel to the track. As always, the y-axis will be perpendicular to the track. In other words, neither axis will be vertical, and neither axis will be horizontal.

D) Create a ***component*** FBD of the mass.

E) Set up a Newton's 2^{nd} Law equation for the y-components.

F) What is the acceleration of the mass in the y-direction?

G) Solve for the magnitude of the normal force between the track and the mass.

H) Set up a Newton's 2^{nd} Law equation for the x-components.

I) Solve for ***a***.

- This one's really HARD… but it's also veeeeeery similar to something happening in Lab…
- The one difference is that, in this case, mass is not given. BUT you can still find a, even without knowing M! Just ***leave M as a variable***, and (if you do everything right), it will cancel out at the end.

VI. Written Responses & Reflections

- No guide provided for these problems, but please THINK honestly about them and answer in COMPLETE SENTENCES.
- You can even use pictures & other diagrams, if you think that will make your point clearer.
- This might even be a place you could earn bonus points…