Newton 2nd Law : Part II - Solving Problems

I. Introduction:

Although it usually **easy to write** Newton's 2nd Law for a problem, it may be **difficult** **mathematically** to solve the equations. We will study many tricks this semester for solving different specific types of problems. Starting in Chapter 6, we will develop more advanced concepts including energy, linear momentum, torque, etc. for handling problems that are extended bodies, undergoing rotation, or in which the forces acting on the systems are complicated and may be varying quickly in time. This **DOES NOT** mean that **Newton's 2nd Law** is invalid! It means that it is **easier** mathematically to solve it **indirectly** using a **different form** for some types of problems! **You will learn to identify problem types and solution techniques only through lots of practice and by paying careful attention to the details of the theory and concepts that we present**!

In this section, I provide some handy tricks for **reducing** your **math difficulties** when **directly applying Newton's 2nd Law** as well as providing explanations for the **models** of pulleys and strings that we will use in **this course**.

II. Inclined Planes

A. The Trick

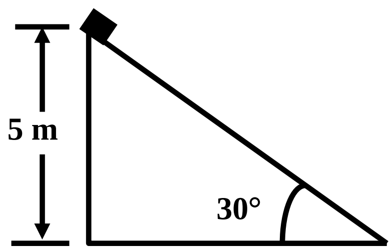
When working an inclined plane problem, you should place your coordinate

axis so that ____________________ of the two axis _______________________

_____________________________ the incline.

Reason: This **REDUCES** a two dimensional problem to a one dimensional problem since the **velocity** and **acceleration** **components** **PERPENDICULAR** to the incline **ZERO**.

EXAMPLE: A block of mass M slides down a frictionless incline plane whose angle of inclination is 30 degrees as shown below:



Assuming that the block starts initially at rest at a height of 5 m, what is its speed when it reaches the bottom of the incline?

Solution:

There is **no plug and chug** formula to directly solve the problem! The problem requires you to **synthesize several different concepts** that we have previously covered this semester and **apply them** to this problem. Thus, you must have a **good knowledge** of the **individual concepts** as well as the **ability to synthesize** the material. This is a **higher** **level reasoning** (more difficult) skill that you are suppose to be developing through out this course!!

Step I : Draw an FBD for the Mass Using Our Axis Trick

Step 2: Write and Solve Newton II for This Problem

Step 3: Check Our Work To See If It Makes Sense (Units, Physical Implications)

Step 4: What Can We Infer From The Acceleration

Step 5: We Use ________________________________

Step 6: Check Your Work To See If It Makes Sense

Although the specific steps in every problem may be different, the procedure for solving problems is the same. You should always have:

1) a good drawing
2) write down all known quantities as well as what you are required to find
3) identify the important physics concepts that are involved
4) write down any physics equations that might be helpful based upon 3)

5) Solve using definitions and the physics identified in 3). If no direct solution procedure presents itself then begin by solving for any unknown physical quantity and repeating steps 3) through 5) until a direct solution path can be found.

III. Physics Strings

A. Unless the problem specifically states otherwise, you will consider any string in a physics problem to be a physics string!

B. Physics strings are ______________________ and

____

C. The properties of a physics string tell us that:

1) The magnitude of the force on a physics string is the **SAME** at

______________________ ___________________ of the string.

2) Two objects are **connected** by a physics string have the **SAME**

_________________________ and _________________________

PROOF:

D. Physics Strings VS Real Strings

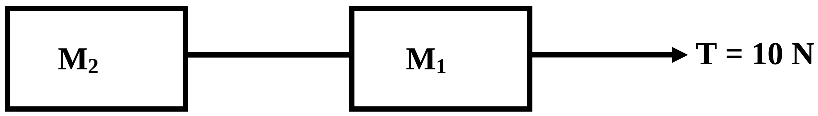
A physics string is an approximation (model) of a real string (cable/wire). Many strings have negligible mass compared to the connected objects. Thus, the strings mass can be neglected. Secondly, many strings are only slightly stretched compared to their length or other important dimensions (distance traveled, etc.) during actual applications. Thus, they can be approximated as unstretchable with small errors. This is like neglecting air friction in projectile motion. We are approximating to simplify the math. However, we should always be on the lookout for the possibility that our approximations are invalid. For example, it is a bad approximation to ignore the mass of a steel bridge cable or the stretching of a rubber band. If the cable's mass can not be neglected then we add another block to represent the cable. This will add another free body diagram to the problem!

E. Important Facts:

STRINGS CAN'T PUSH!!

The only purpose of a string is to connect the motions of two different objects

EXAMPLE: Two mass M_1 and M_2 are connected by a rope. A boy pulls with a force of 10 N on a rope connected to M1 as shown below. Given that the mass of M_1 and M_2 are 5.00 kg and 3.00 kg respectively, what is the acceleration of mass M_2?



Solution:

Since M_1 and M_2 are connected by a physics string, they will have the

____. Furthermore, they can

be considered to be a _________________ body of _________________

______________________. Using this NEW Object as my system, I draw

the following free body diagram:

Now applying Newton's II Law, we have that

IV. Physics Pulleys

A. Unless we are told differently in a problem, we will consider all pulleys to be physics pulleys.

B. Physics pulleys are ___________________________ and

____

C. Purpose of Pulley

> **The Purpose of a Physics Pulley Is To Redirect The Direction of A Force.**

D. A string **ALWAYS enters/leaves** _________________________ to the pulley.

Thus, the ______________________ is ___________________ to the

___________________________ of the pulley.

E. The Trick - "The Rule of The Gun"

When two objects are connected by a string, their motion is linked. If the string passes over a pulley, you will need to link the equations of motion for the two objects. This is most easily done by linking the coordinate axes of the objects' free body diagrams! At West Point, they call this "the rule of the gun."

Step 1: Arbitrarily choose the coordinate axis for one of the two bodies.

Step 2: Place the thumb of your right hand along the +y-axis and your index finger along the +x-axis.

Step 3: Follow the string over the pulley to the next object. Your thumb and index fingers now point in the +y and +x-directions for this object's coordinate axis.

Step 4: Place and label the coordinate axis on the free body diagram of the second object based upon your results in Step 3.

Step 5: Solve the problem like any other Newton II problem.

Note: If you don't use the "rule of the gun" then you will have to connect the Newton II equations of object I and II manually. You will have four acceleration components, velocity components, etc. and will have to write constraint equations. For instance, you might have

$$\mathbf{a_{y1} = a_{x2}}$$

Thus, the acceleration of object #1 in the y-direction is equal to the acceleration of object #2 in the x-direction. The subscripts are important! The "rule of the gun" removes all of this algebra!

EXAMPLE: What is the acceleration of the 3 kg mass shown below assuming that the table is frictionless?