AP Physics C: Mechanics Lab: Review Sheet

Chapter 5: The Laws of Motion

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<u>Background:</u>	<u>Major Topics:</u>
This unit focuses on Newton's Three Laws of Motion and how forces affect an object's motion. This unit is the groundwork for most of Mechanics and teaches us the basics of analyzing forces on an object.	• Newton's Laws of Motion • How To Do Free Body Diagrams • Dealing with inclined planes

<u>Unit Vocabulary</u>

- *Force:* a push or pull on an object
- *Inertia:* the tendency to maintain one's state of motion
- *Mass:* a measure of the amount of inertia that a body has or of how hard it is to change an object's motion
- *Weight:* a measure of how strongly Earth's gravity pulls on a mass
- *Free-body diagram:* a sketch or drawing that identifies all of the vector forces acting on a single object of interest
- *Normal force* - a responsive opposing force from an object or surface pushing back up on another object, with a gravitational force acting upon it
- *Pulley* - a wheel mounted on an axle that allows tension in a string, rope, or cord to change direction

Important Formulae:

$F_{net} = ma$	$F_g = W = mg$

<u>Newton's Three Laws</u>

1. Inertia

- "Every body continues its state of rest or uniform speed in a straight line, unless it is compelled to change that state by a net force acting on it."

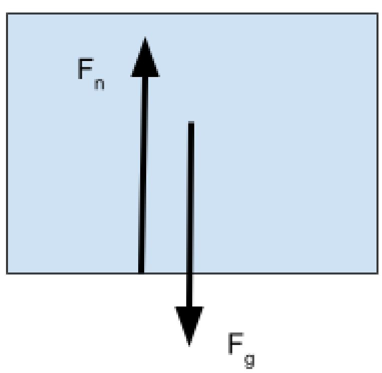
- Basically, an object moving stays in motion, and an object at rest stays at rest, unless some outside force acts upon it.

2. F = ma

- "Force is equal to the rate of change of momentum. For a constant mass, force equals mass times acceleration."
- Basically, the net force acting on an object is equivalent to the mass of the object times its acceleration.

3. Every action has an equal and opposite reaction

- "Whenever one object exerts a force on a second object, the second objects exerts a force (equal in magnitude, in the opposite direction) back on the first."
- Basically, every force has a counterforce equal to the force acting on an object at rest. A force also has a counterforce when interacting with another object.
    - Ex: The opposite of gravity's force is the normal force. When an object is resting on a table, gravity's force pushes the object into the table, and therefore, the table pushes back up.



How to make a free-body diagram:

1. Analyze the forces acting on an object
2. Draw an arrow for a force that points in the direction of the force applied.
3. Draw the arrow so that its base is located where the force is applied.
4. Draw the arrow with a length that represents the relative magnitude of the force.

Inclined Planes

Important: An inclined plane has gravity pulling down on an object, while the normal force is acting at an angle different than that of gravity because the surface the object is on is at an angle. Therefore, we have to take extra steps to analyze the forces on the object.

1. Draw a Free-Body Diagram:
    a. Use forces like:
        - Gravity, which points down
        - Normal Force, which is perpendicular to the surface
        - Friction, which opposes the motion and is parallel to the surface.
        - Applied force, which is the direction an object is pushed or pulled
2. Rotate your axes to be flat with the incline:

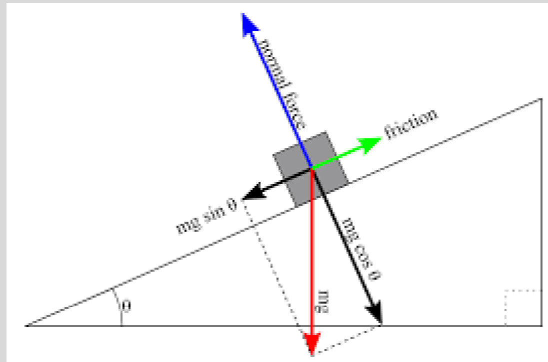
a. This is to make the math easier, since the motion is on the incline

3. Split the gravitational force into two parts:

   a. This is to ensure that the force of gravity is parallel and perpendicular to the now rotated axes.

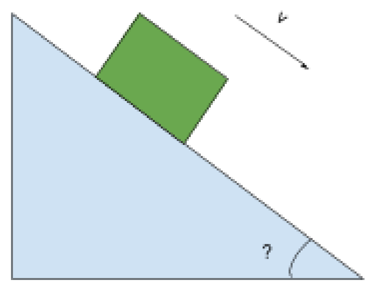
   b. $F_{//}$: This is the force that is parallel to the surface

   c. F_{perp} : This is the force that pushes the object into the surface, and is therefore the force that is the same magnitude and opposite of the normal force.

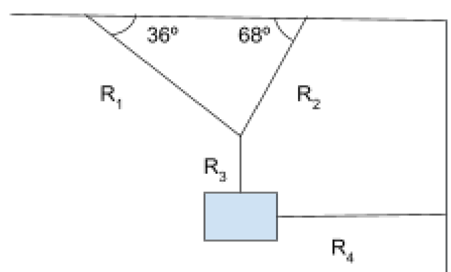


Questions:

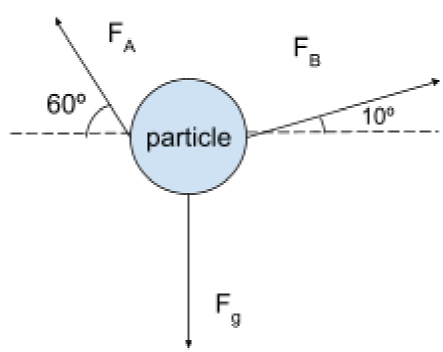
1. In the figure to the right, a block slides on a frictionless, angled surface. The F_{app} is 30 N down the surface, the normal force is 15 N, and the mass of the block is 15 kg.
   a. Draw a FBD.
   b. What is the magnitude and direction of the acceleration of the block?



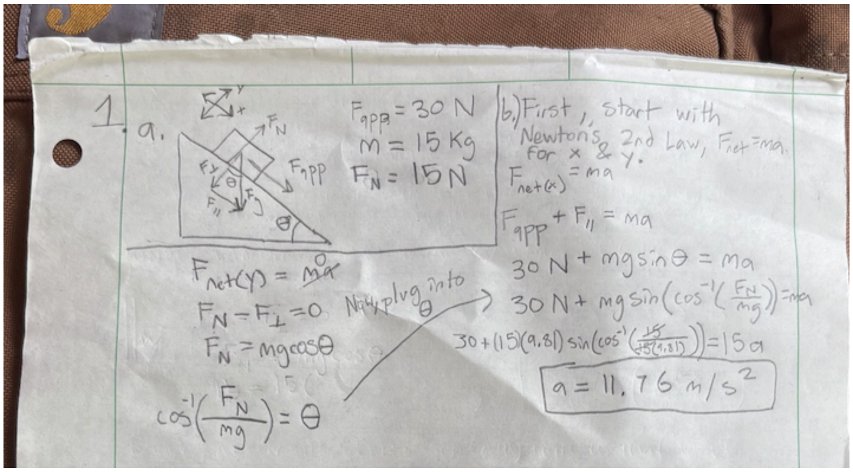
2. An object hangs from the figure below.
   a. Draw a FBD of the object.
   b. Suddenly, R_4 snaps. After a bit of time, the angles turn from 36º and 68º to 42º and 62º, 65respectively. Does the force downwards change?



3. A particle shown below has a mass of 1.0 kg with three forces pulling it in different directions. If the particle is accelerating at 5 m/s to the right, what is the magnitude of the forces acting upon the object?



Answers:



1. a.

$F_{app} = 30\ N$

$m = 15\ Kg$

$F_N = 15\ N$

$F_{net(y)} = ma$ (a = 0)

$F_N - F_\perp = 0$ Now plug into θ

$F_N = mg\cos\theta$

$\cos^{-1}\left(\frac{F_N}{mg}\right) = \theta$

b.) First, start with Newton's 2nd Law, $F_{net} = ma$ for x & y.

$F_{net(x)} = ma$

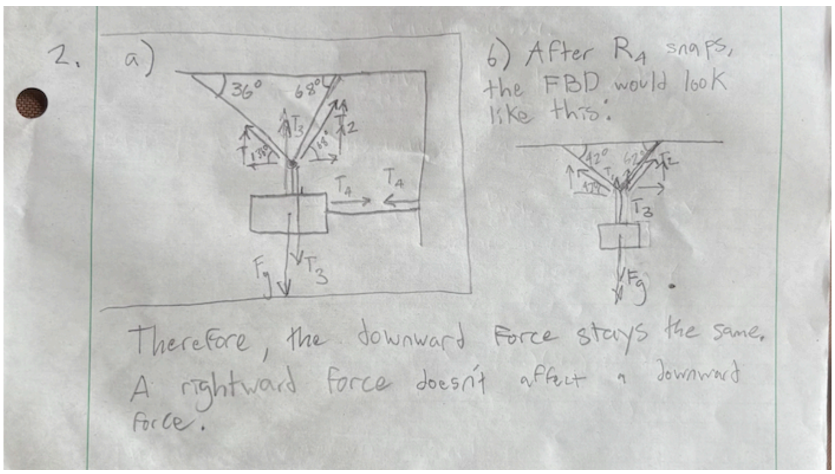
$F_{app} + F_{\parallel} = ma$

$30\ N + mg\sin\theta = ma$

$30\ N + mg\sin\left(\cos^{-1}\left(\frac{F_N}{mg}\right)\right) = ma$

$30 + (15)(9.81)\sin\left(\cos^{-1}\left(\frac{15}{15(9.81)}\right)\right) = 15a$

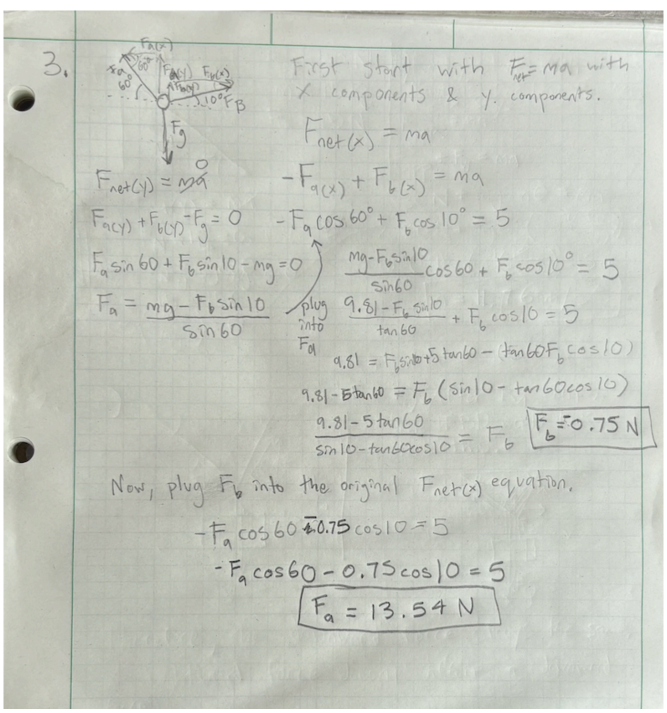
$a = 11.76\ m/s^2$



2. a)

b) After R_A snaps, the FBD would look like this:

Therefore, the downward force stays the same. A rightward force doesn't affect a downward force.



3.

First start with $F_{net} = ma$ with x components & y components.

$F_{net(y)} = ma$ (a = 0)

$F_{a(y)} + F_{b(y)} - F_g = 0$

$F_a \sin 60 + F_b \sin 10 - mg = 0$

$F_a = \frac{mg - F_b \sin 10}{\sin 60}$

plug into F_a

$F_{net(x)} = ma$

$-F_{a(x)} + F_{b(x)} = ma$

$-F_a \cos 60° + F_b \cos 10° = 5$

$\frac{mg - F_b \sin 10}{\sin 60}\cos 60 + F_b \cos 10° = 5$

$\frac{9.81 - F_b \sin 10}{\tan 60} + F_b \cos 10 = 5$

$9.81 = F_b \sin 10 + 5\tan 60 - (\tan 60 F_b \cos 10)$

$9.81 - 5\tan 60 = F_b(\sin 10 - \tan 60 \cos 10)$

$\frac{9.81 - 5\tan 60}{\sin 10 - \tan 60 \cos 10} = F_b$ $F_b = 0.75\ N$

Now, plug F_b into the original $F_{net(x)}$ equation.

$-F_a \cos 60 + 0.75 \cos 10 = 5$

$-F_a \cos 60 - 0.75 \cos 10 = 5$

$F_a = 13.54\ N$