AP Forces

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1 Introduction

Kinematics is a useful tool in describing the motion of objects. However, a key limitation is the object must be of constant acceleration. When acceleration is changing, the kinematic equations break down and we must find another method to describe the motion. This is where the idea of forces comes in.

2 Newton's Laws

The idea of forces can be best represented in Isaac Newton's three laws of motion.

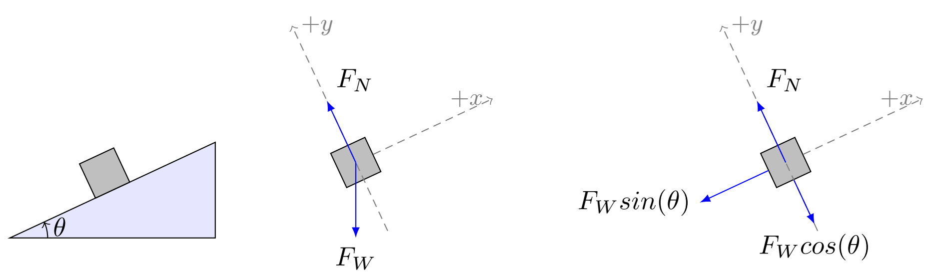
1. If an object is at rest, it will stay at rest unless acted upon by an outside force. If an object is in motion, it will stay in motion unless acted upon by an outside force.
2. $\vec{F_{net}} = m\vec{a}$
3. Every action has an equal and opposite reaction.

3 Important Forces

Force due to gravity (Weight) : $F_W = mg$
Normal (Support) Force such as from a table that a book is on : F_N
Friction force that acts against motion : $F_f = \mu F_N$
Centripetal force that acts toward the center of rotation during circular motion : $F_c = m\frac{v^2}{R}$
Spring force that opposes motion which is proportional to displacement from equilibrium : $F_s = -kx$

4 Free Body Diagrams (FBD's)

When trying to solve a problem involving forces, it is important to write out all of the forces that are acting on the object. A common way to do this is a free body diagram. NOTE: It is crucial to define a coordinate system when drawing an FBD.



5 Method to Solve Problems

1. Determine all forces in the system
2. Draw a free body diagram (with a coordinate system) for each object that includes all the forces (Newton's 3rd law will come in handy here)
3. For each object, write out Newton's 2nd law in each of the coordinate axes
4. Solve for wanted quantity

6 Simple Harmonic Motion (SHM)

Sometimes when dealing with mechanical systems, we get repetitive or *harmonic* behavior. For example, if we were to attach a mass to a spring on a horizontal surface, moved the mass, and let go, the mass would osciallate back and forth across the surface. We can use Newton's second law to see what is going on:

$$F_{net} = ma$$

$$-kx = ma$$

$$-kx = m\frac{d^2x}{dt^2}$$

$$\frac{d^2x}{dt^2} + \frac{k}{m}x = 0$$

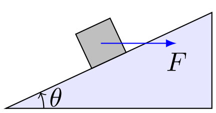
$$\frac{d^2x}{dt^2} + Cx = 0$$

This is the generic form of a system exhibiting SHM. We could go ahead and solve for x in terms of t, but it turns out that all the relevant information we would want is sitting in this equation, such as the period, T, of the motion.

$$T = \frac{2\pi}{\sqrt{C}}$$

7 Problems

1. Consider a mass moving up the incline shown below under the influence of an applied force F. If the block's mass is m and the magnitude of its acceleration is a, what is the magnitude of the friction force? What is the coefficient of kinetic friction in this situation?



2. A ball attached to a string of length r rotates in a vertical circle. When the string is parallel to the ground and the ball is moving upward, the ball's velocity is v. What is the magnitude of the rate of change of the ball's velocity at this point?

3. A block of mass m slides across a frictionless floor and then up a frictionless ramp. The angle of the ramp is θ and the speed of the block before it starts up the ramp is v_0. The block will slide up to some maximum height h above the floor before stopping. Derive an expression for h.

4. Determine the force applied to a mass m if its position as a function of time is represented by $x(t) = \sin t^2 + t$.

5. The setup below is called an *atwood machine*. It is composed of two masses attached by a string over a frictionless pulley. Determine the acceleration of each mass. Assume masses m_1 and m_2.