Topic 3A: Newton's Laws, Force Vectors and Equilibrium Equations

Skill 22: Part Two-Applying equations to Horizontal, Vertical and Inclined Planes Scenarios

- Forces are vector quantities, meaning direction is important. Specifically you must understand how each force in a problem aligns with each axis and keep in mind the sign (+ or −) for each force. Only forces from the same axis can be combined by simple addition.

For object on a level surface (horizontal motion)

- Axes are defined as "x" & "y"
- For forces applied at an angle use equations

$F_{AX} = F_A \cos\theta$
$F_{AY} = F_A \sin\theta$
$\theta = \tan^{-1}\left(\frac{F_{AY}}{F_{AX}}\right)$

When force is horizontal (or parallel to level ground) $\theta = 0$
So $F_{AX} = F_A$ as θ increases F_{AX} decreases

For objects on vertical axis

- F_g is always downward
- F_N is upward from a surface
- F_T & F_A represent force from a rope, chain, etc
- At rest or constant speed $F_N = F_g$ (elevator)
$F_A = F_g$ (rope)

For objects on an inclined plane

Axes are defined parallel to plane "∥" or perpendicular to plane "⊥"

"⊥" − F_N & $F_{g\perp}$ are equal but opposite

"∥" − F_A, F_f, $F_{g\parallel}$ are on axis of motion

- For any axis of motion you must determine
  - If forces are balanced; ie equilibrium $F_{net} = 0$, $a = 0$
    ie; constant speed or rest
  - If forces are unbalanced; ie accelerating, $F_{Net} = ma$, $F_{net} = m\frac{\Delta V}{t}$
    ie; speeding up; slowing down changing direction
- To solve for unknowns you combine the above into a single equation where "The sum of forces on any axis" is set equal to "zero or ma"

Examples

Objects moving or at rest on a level surface

$\Sigma F_x = F_{AX} + F_F$ At equilibrium $F_{AX} + F_f = 0$ With net force present $F_{AX} + F_f = ma$

If force is applied horizontal than $F_{AX} = F_A$ $\left(\frac{F_{AX} =}{F_A \cos\theta}\right)$ $\theta = 0$

If multiple forces are applied than add 1st

$F_{AX} = F_f$ constant speed or rest
$F_{AX} > F_f$ speeding up due to applied force
$F_{AX} < F_f$ slowing down due to Friction

Objects on a vertical axis

$\Sigma F_y = F_A + F_g$ where $F_g = mg$ always downward

If $F_A = F_g$ object is at rest or constant velocity
If $F_A > F_g$ object is accelerating upward
If $F_A < F_g$ object is accelerating downward

F_A is the upward force. It can be represented as F_T for a rope or chain or as F_N for an elevator

☆ The net force is the imbalance (difference) between F_A & F_g

Objects on an inclined plane

- For frictless incline
$F_{net\parallel} = F_{g\parallel} = F_g \sin\theta = mg\sin\theta$
or $ma = mg\sin\theta$
so $a = g\sin\theta$

With Friction or other applied force
$\Sigma F_{\parallel} = F_{g\parallel} + F_A + F_f$

$\Sigma F_{\perp} = F_{g\perp} + F_N$ since ⊥ is at equilibrium

$F_N = -F_{g\perp} = F_g \cos\theta = mg\cos\theta$