Lab: AP Review Sheets **AP Physics**
Chapter 5: The Laws of Motion by Patrick Seo

Important Vocab:

- **Force**: "push or pull on an object"
  - Vector Quantities: *magnitude* and *direction*
  - Units = kg · m/s^2 OR N [Newton]
- **Mass**: the amount of *inertia* a body has (how hard it is to change an object's motion)
  - More mass => More Inertia => Harder to move / stop movement
  - Consistent (ie. doesn't change with changes in gravity)
  - Units = kg (typically)
- **Weight**: how strongly earth's gravity pulls on a mass
  - Measure of Force
  - Written as F_g or W
  - Units = kg · m/s^2 OR N [Newton]
  - Weight of an object at the earth's surface: $F_g = mg = W$
- **Speed**: "how fast an object's moving"
  - Scalar Quantity
  - Rate at which an object covers a distance
- **Velocity**:
  - Vector Quantity
  - Rate and direction of an object's movement
- **Acceleration**:
  - Vector Quantity
  - Rate at which the object's velocity changes and at what direction

Newton's Three Laws:

First Law of Motion - "The Law of 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 upon it."
- **Inertia**: tendency to maintain one's state of motion (whether moving or at rest)
- Describes that an object will remain at a constant motion unless acted upon by an external force

Second Law of Motion - $F_{net} = ma$

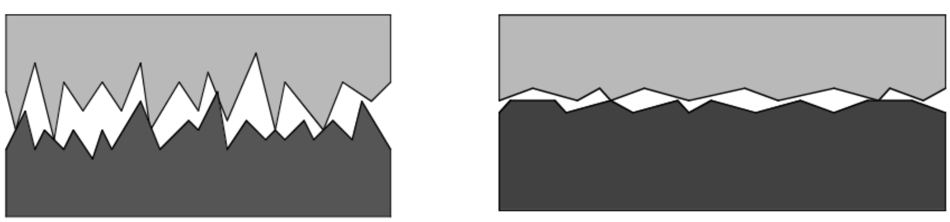
- The acceleration of an object is dependent upon two variables:
  - Net force acting upon the object
  - Mass of the object
- [Directly related to the net force; Inversely related to the mass]
- "Describes what happens if a net (resultant) force is applied to a mass"

Third Law of Motion - "Action-Reaction Law" / "Force Pairs"

- "Whenever one object exerts a force on a second object, the second object exerts a force (equal in magnitude, opposite in direction), back on the first"
- "Every action has an equal and opposite reaction"
- Describes the relationship between two bodies that are interacting with each other

Friction:

- A force that opposes the motion of an object
- Different Types:
    - Rolling Friction: a force that opposes the rolling motion of an object over a surface
    - Fluid Friction (liquid or gas): molecules of fluids in constant motion -> collisions with each other -> force that opposes motion in between / within fluid
    - Sliding Friction: when a small force / torque is applied to an object, sliding friction prevents the body from sliding (body starts rolling)
        - Static: object acted upon by external force(s) with a component parallel to the surface (object at rest)
        - Kinetic: objects are in motion
- Magnitude is dependent on:
    - How hard two surfaces are being pushed together, indicated by normal force F_N
    - Nature of two surfaces in contact with each other, indicated by "coefficient of friction" μ
- μ [Coefficient of Friction]
    - Experimentally determined number
    - Describes how "sticky" two surfaces are when placed next to each other
    - Higher μ = More "sticky" = More friction force when two surfaces try to slide against each other



Close-up of high μ   Close-up of low μ

- Ratio between $F_{friction}$ and F_{Normal}:

$$\mu = F_{friction}/F_{Normal}$$

FRQ's

[easy] How much force is required to accelerate a 60.0-kg object from rest to 4.00 m/s in 3 seconds?

[medium] At the instant a race began, a 50-kg sprinter exerted a force of 750 N on the starting block at a 20º angle with respect to the ground.

a) What was the horizontal acceleration of the sprinter?
b) If the force was exerted for 0.46 s, with what horizontal speed did the sprinter leave the starting block?

[hard] A young skier has lost control and is now traveling straight down a mountain. The skier is halfway down a run that is 100 m long (horizontally) with a slope of 30º and traveling at a rate of 10 m/s. If the skier is traveling at a rate of 30 m/s at the end of the run, what is the coefficient of kinetic friction between the skis and snow?

Solutions

[easy]
Solving for: a, F
$a = (v_f - v_i)/t$
$\Rightarrow (4\ m/s^2 - 0\ m/s^2)/3\ s = 4/3\ m/s^2$
$F = ma$
$\Rightarrow 60\ kg\ (4/3\ m/s^2) = 80\ kg \cdot m/s^2 = 80\ N$

[medium]
a)
$F_x = ma_x$
$\Rightarrow 750\ N\ (\cos(20^o)) = (50\ kg)a_x$
$\Rightarrow a_x = 14.1\ m/s^2$
b)
$v_{f,\,x} = v_{i,\,x} + at$
$\Rightarrow v_{f,\,x} = 0\ m/s + (14.1\ m/s^2)(0.46\ s) = 6.49\ m/s$

[hard]
We can use the equation for conservation of energy to solve this problem.
$E = U_i + K_i + W_{ext} = U_f + K_f$

Substituting expressions for each term, we get:
$mgh_i + ½mv_i^2 + \mu_k F_N d = ½mv_f^2$

Determine initial height and the normal force of the skier before solving for the coefficient of friction.
$h_i = d\sin(30^o)$
$F_N = mg\cos(30^o)$

Substitute these into the original equation:
$mgd\sin(30^o) + ½mv_i^2 + \mu_k mgd\cos(30^o) = ½mv_f^2$

Canceling out mass and rearranging for the coefficient of friction, we get:
$\mu_k = -[gd\sin(30^o) - ½v_i^2 + ½v_f^2] / [gd\cos(30^o)]$

Plug in our given values to solve:
$\mu_k = -[(9.8\ m/s^2)(100\ m)(\sin(30^o)) - ½(10\ m/s)^2 + ½(30\ m/s)^2] / [(9.8\ m/s^2)(100\ m)(\cos(30^o))]$

Finally:
$\mu_k = -1.05$