Paradigms we will use

- Block on Inclined Plane (Energy Conservation)
- Porsche (Power)
- Braking Car (Kinematics)
- Lifting a box (Equilibrium)
- Circuit (Resistance, Current, Capacitance and Voltage)
- Charge in Capacitor (Electric Forces)
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Block on Inclined Plane Paradigm

- This is a paradigm for conservation of energy. This is the easiest way to work a problem – if it works.

- Energy and work:

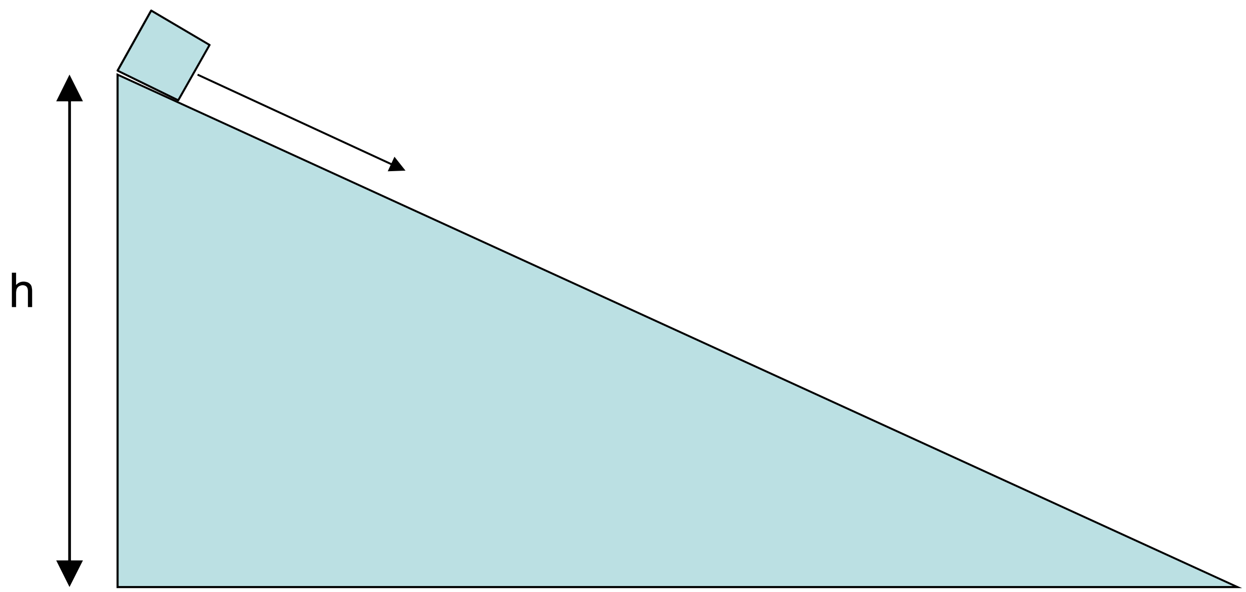
$$E_{initial} = E_{final}$$

$$E = KE + PE$$

$$PE = mgh$$

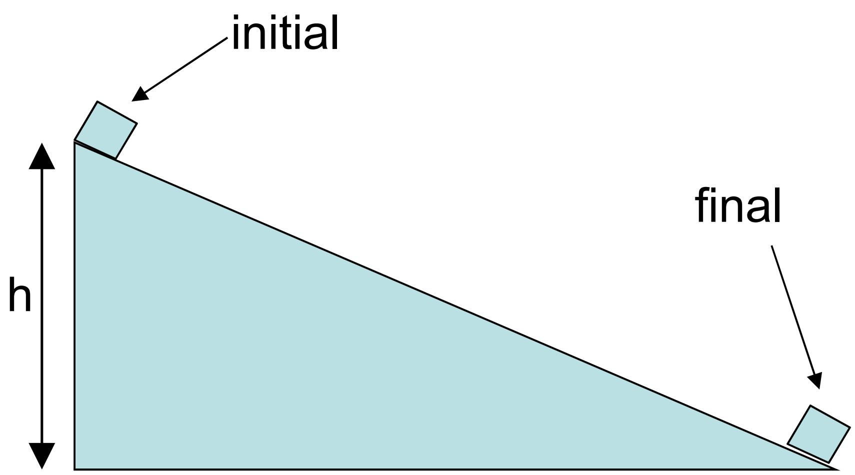
$$KE = \frac{1}{2}mv^2$$

Block on Inclined Plane Paradigm



- There is no friction.

Block on Inclined Plane Paradigm



$$E_{initial} = 0 + mgh$$

$$E_{final} = \frac{1}{2}mv_f^2 + 0$$

$$\frac{1}{2}mv_f^2 = mgh$$

$$v_f = \sqrt{2gh}$$

Block on Inclined Plane Paradigm

- As long as there is no friction, the path between start and finish doesn't matter.
  - Free fall is the same as sliding down something without friction in terms of what the final velocity will be.
- For springs the PE is $\frac{1}{2}kx^2$. You can use this in place of, or in addition to the gravitational PE.

Block on Inclined Plane Paradigm

- Use this technique whenever possible. Key things to look for:
  - Only conservative forces involved (usually gravity, electric forces, and springs.)
  - Time is not involved in the problem, you have just an initial state and a final state.
  - Usually just one object is moving.

Possible biologically related systems

- A spring-loaded lancet is used to pierce a fingertip. How fast is it going when it hits the end of the finger?
- A person is injured by falling off of a wall. How fast where they going when they hit?

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Porsche Paradigm

- Power:

$$P = \frac{\Delta E}{\Delta t} = \frac{\Delta W}{\Delta t}$$

(Porsche speeding up)

Porsche Paradigm

- It can go from 0 to 60 in 3 seconds, what is the power?

$$P = \frac{\Delta E}{\Delta t} = \frac{K_f - K_i}{\Delta t} = \frac{\frac{1}{2} m v^2}{\Delta t}$$

- m ~ 1500 kg, v ~ 25 m/s, so $P = \frac{\frac{1}{2}(1500)(25)^2}{3} \sim 150{,}000\ W$
- $P \sim 210$ HP

- Divide whatever change in energy you have by the time interval. That is the power, the rate at which energy changes. **You don't use this for electrical power in circuits**, although it works at the microscopic level.

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Work done

- Important ideas:
  - Work-Kinetic Energy relation:
    - $\Delta KE = W_{net} = \left(\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2\right) = \Sigma\, W$
  - Definition of Work (units: Joules):
    - $W = Fd\cos\theta$
  - If you have a conservative force, then
    - $|W| = \Delta PE$

Power expended

- Important ideas:
  - Power is the rate of doing work (units: Joules/sec or Watts)
    - Since $P = \frac{W}{\Delta t}$, then the work done is $W = P\Delta t$.
  - If an object is moving at speed v, then the power acting on it instantaneously is
    - $P = \frac{W}{\Delta t} = \frac{F\Delta x}{\Delta t} = F\frac{\Delta x}{\Delta t} = Fv$

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Possible biologically related systems

- How many Calories do you burn climbing to the top of a tall tower?
- How many horsepower can a person exert if they run up a short flight of stairs?
- How deeply will a biopsy needle penetrate, given the compression of the spring shooting it?

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Braking Car Paradigm

- This paradigm is for kinematics – description of motion.

- This is used when the following quantities are involved:

  - Position
  - Velocity
  - Force
  - Time
  - Acceleration

Braking Car Paradigm

- Basic Equations:

$$v = v_0 + a\,t$$

$$x = x_0 + v_0 t + \frac{1}{2} a\,t^2$$

$$v^2 - v_0^2 = 2a\left(x - x_0\right)$$

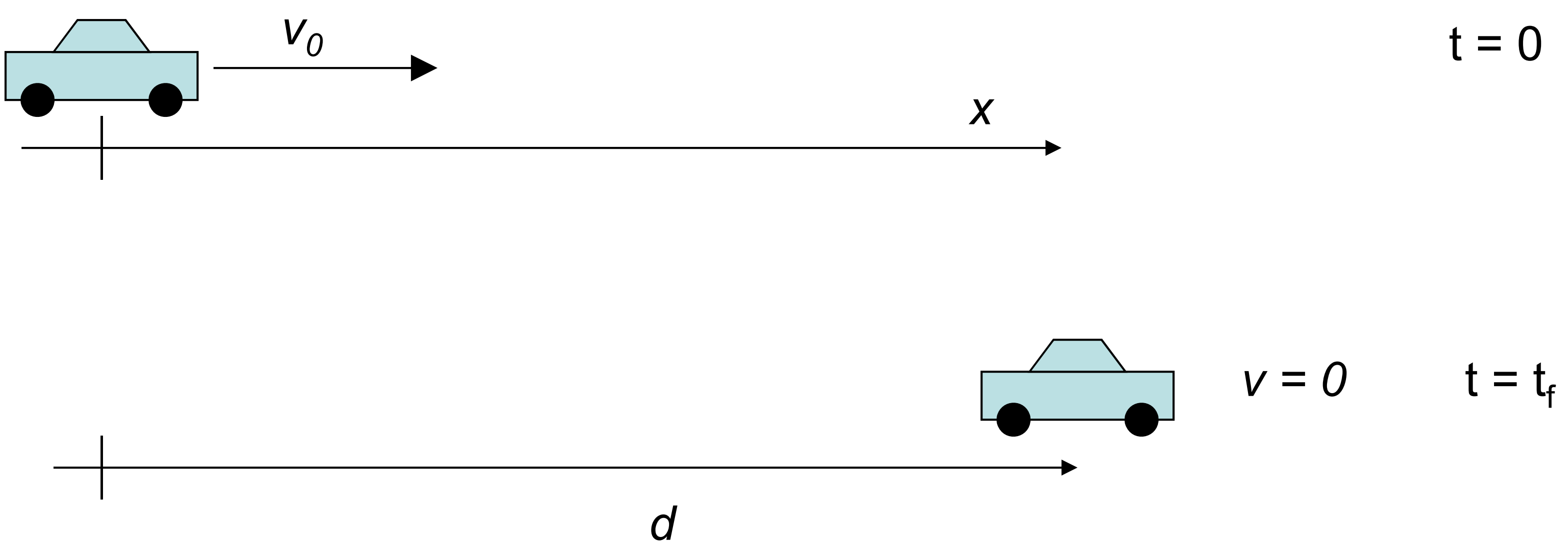
$$\Sigma \vec{\mathbf{F}} = m\vec{\mathbf{a}} \;\Rightarrow\; F = ma$$

$$W = mg$$

$$F_f = \mu N$$

Braking Car Paradigm

- Typical Problem:



Possible questions:

- What is the acceleration?

$$v^2 - v_0^2 = 2a(x - x_0)$$

$$-v_0^2 = 2ad$$

$$a = \frac{-v_0^2}{2d}$$

- What is the coefficient of friction?

$$F_f = ma \qquad (= \Sigma F)$$

$$\mu mg = ma$$

$$\mu = a/g$$

Possible questions:

- How big is the frictional force?

$$a = \frac{(v - v_0)}{(t_f - t_0)} = \frac{-v_0}{t_f}$$

$$F = ma$$

- Given μ and d, what was v_0?

$$\mu mg = ma \Rightarrow \mu g = a$$

$$-v_0^2 = 2ad$$

$$v_0 = \sqrt{2\mu g d}$$

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Braking Car Paradigm

- Remember – this is for anything speeding up or slowing down, whether horizontally or vertically.
- Use whichever equations have the right variables in them.

- Make sure that conservation of energy is not the easier way to do it.

Biologically related problems

- How long does it take a nerve impulse to travel the length of a neuron?
- A person blacks out at an acceleration higher than 7 g. How long would it take a car to go from 0-60 mph with that acceleration? How far would it travel?
  - (0.4 sec, 5 m)
- A person lands after a fall high. Their legs bend when they land. How much force do their legs have to exert when they stop? Will they break their legs?

Aside – Newton's Laws

- A number of conceptual questions address Newton's Laws directly, not in the context of kinematics.

- In many ways Newton's first law is conceptually the hardest.
  - When an object has no net force acting on it, then it moves at a constant speed in a straight line.
  - It does not take a force to keep something moving!

An Example:

- A skydiver jumps out of a plane. His speed increases until he reaches terminal velocity. How big is the force of air resistance on him at first?
  - Greater than *mg.*
  - Equal to *mg*.
  - Less than *mg*.

Another Example:

- A skydiver jumps out of a plane. His speed increases until he reaches terminal velocity. How big is the force of air resistance on him after he reaches terminal velocity?
  - Greater than *mg.*
  - Equal to *mg*.
  - Less than *mg*.

Still Another Example:

- A monkey slides down a vine. At the time he reaches velocity *v*, he starts to tighten his grip on the vine. The frictional force increases with time. At the time that the force of friction equals his weight,
  - He moves with constant speed down the vine.
  - He stops.
  - He starts to move upward.