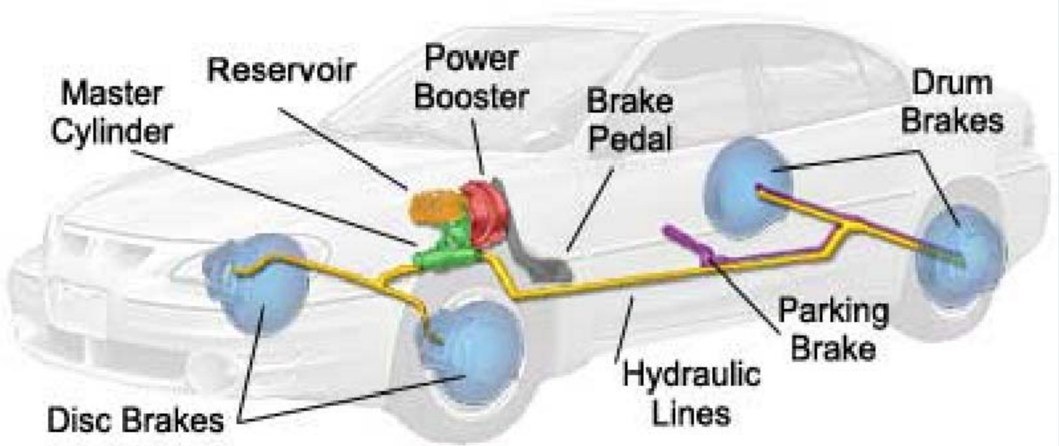
13-01

Rollercoaster Physics

Work, power, simple machines & braking notes

Brakes

- The jobs of brakes: Remove KE of a car
- Brakes do enough negative work, to turn car's KE into internal energy (by friction)
- The amount of work they do is: W = Fd, F is the frictional force
- Know the relationship between speed and braking distance! This could save your life! (it's NOT linear)



Braking – example/self-learning

- How much work do brakes do to stop a 1200 kg car going 30 mph (13.5 m/s)?(109,350 J)
- What is the car were going 60 mph (27 m/s)?

(437,400 J)

- If your brakes apply a total force of 5,000 N, what's the stopping distance in each case? How does speed affect stopping distance? (this is the physics knowledge you need to know to drive safely!) (22 m, 88 m)

Braking Work

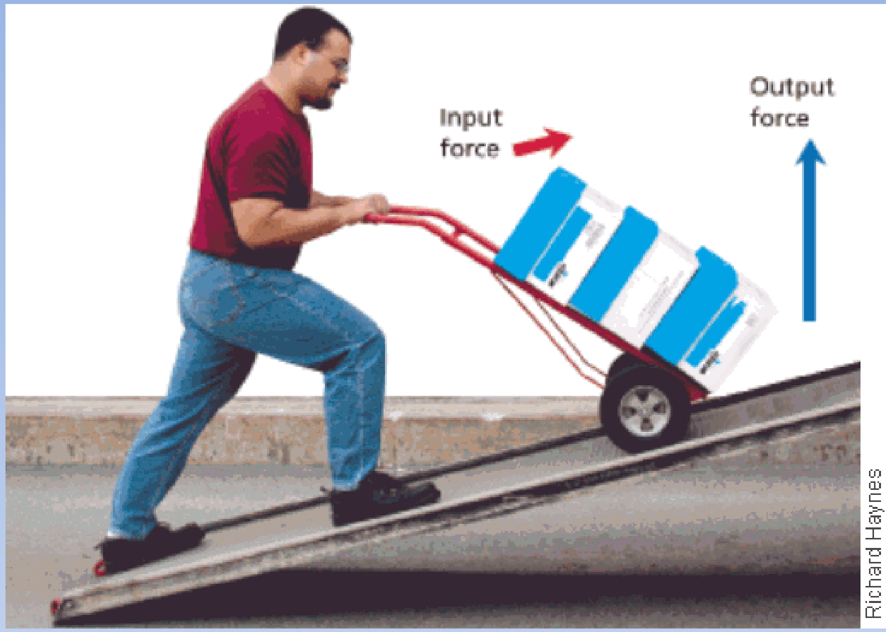
- Work increases the KE or PE of an object, negative work decreases it
- Example: Brakes
- Brakes apply enough force over a distance (do work) to exactly equal the KE the car had
- KE goes into the brakes and into skidding tires
- Example of how to figures braking force:
  – *You need to stop your 1200 kg car going 30 mph in 20 m. How much force must be exerted by your brakes to do this? (30 mph = 13.5 m/s)*
- *Braking distance increases by what amount as car mass doubles? As car speed doubles? What does this mean about tailgating a car on the expressway?*

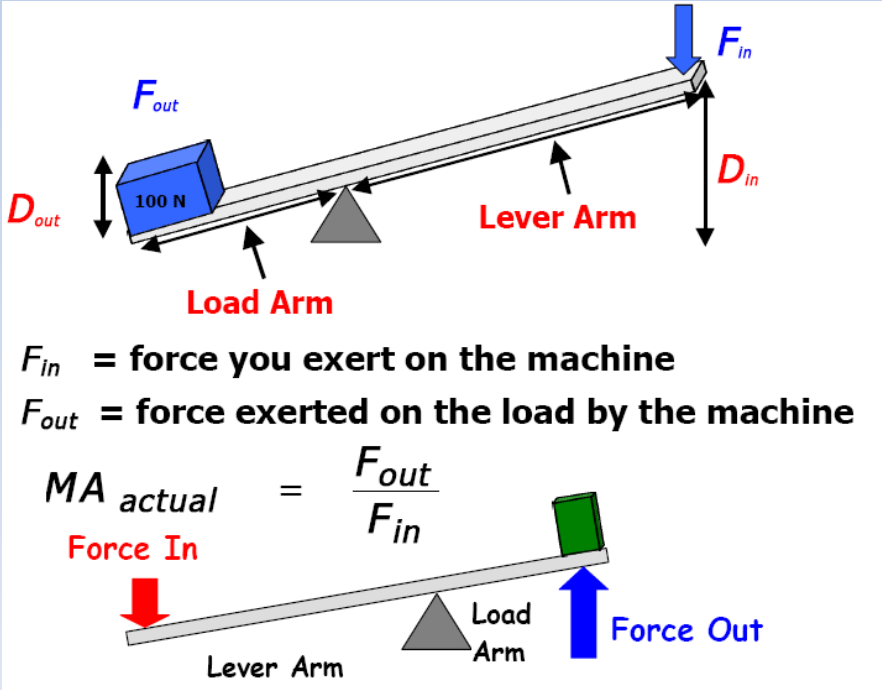
Work, power, simple machine definitions

- **Efficiency** – Rating for machine that does work: Efficiency = W_o/W_i
- **Simple machine** – Mechanical system that trades force for distance (usually gets big forces over small distances)
- **Lever** – Simple machine using a pivot point (fulcrum): “teeter totter”
- **Ramp/Inclined plane** – Simple machine that ***gradually lifts*** an object
- **Pulley** – Simple machine using low friction wheels to allow long lengths of rope to life heavy object up short distances

Simple machines

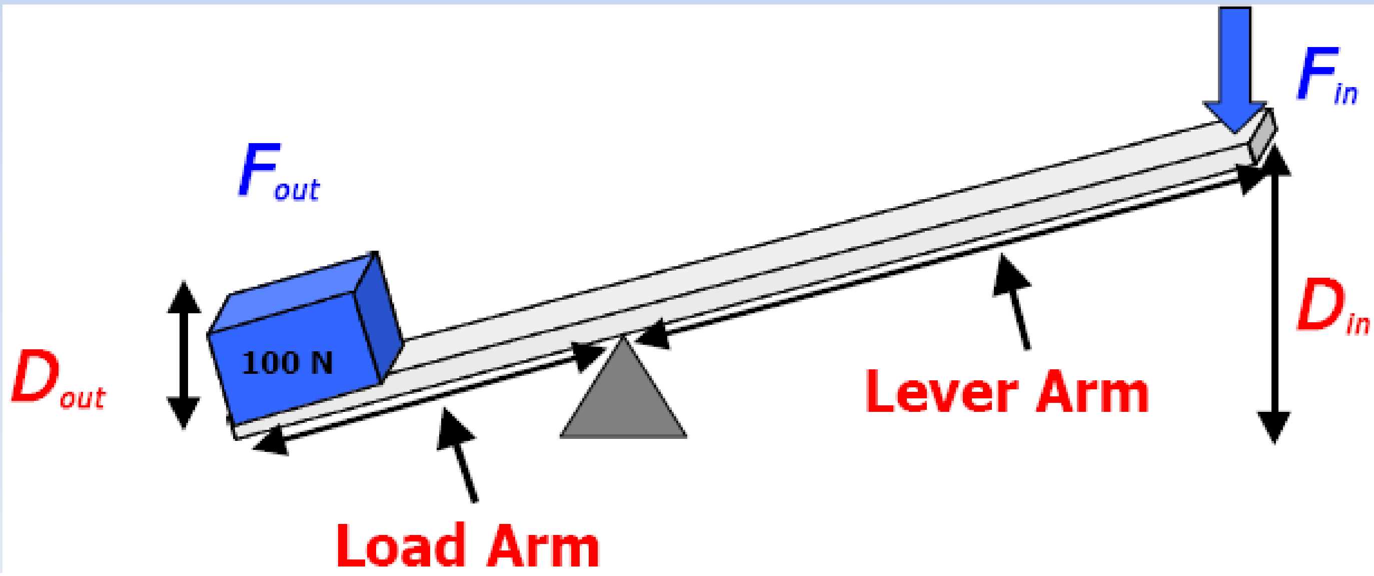
- Simple machines trade force for distance
- $F\,d = f\,D$
- $W_{out} = W_{in}$ (if 100% efficient)
- Inclined plane (ramp)
  - Hypotenuse is distance in
  - Height lifted is distance out
  - F_{out} is weight of object
  - F_{in} is small applied force
- Lever is a teeter tauter
  - Your little brother can lift you up if you sit close to the pivot





Simple machines

- AMA: Actual mechanical advantage (Force you get (lift)/Force <u>you</u> push or pull)
  - $AMA = F_{out}/F_{in}$
- IMA: Ideal mechanical advantage
  - Same value as AMA if 100% efficient
  - $IMA = d_{in}/d_{out}$



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Rollercoaster Physics

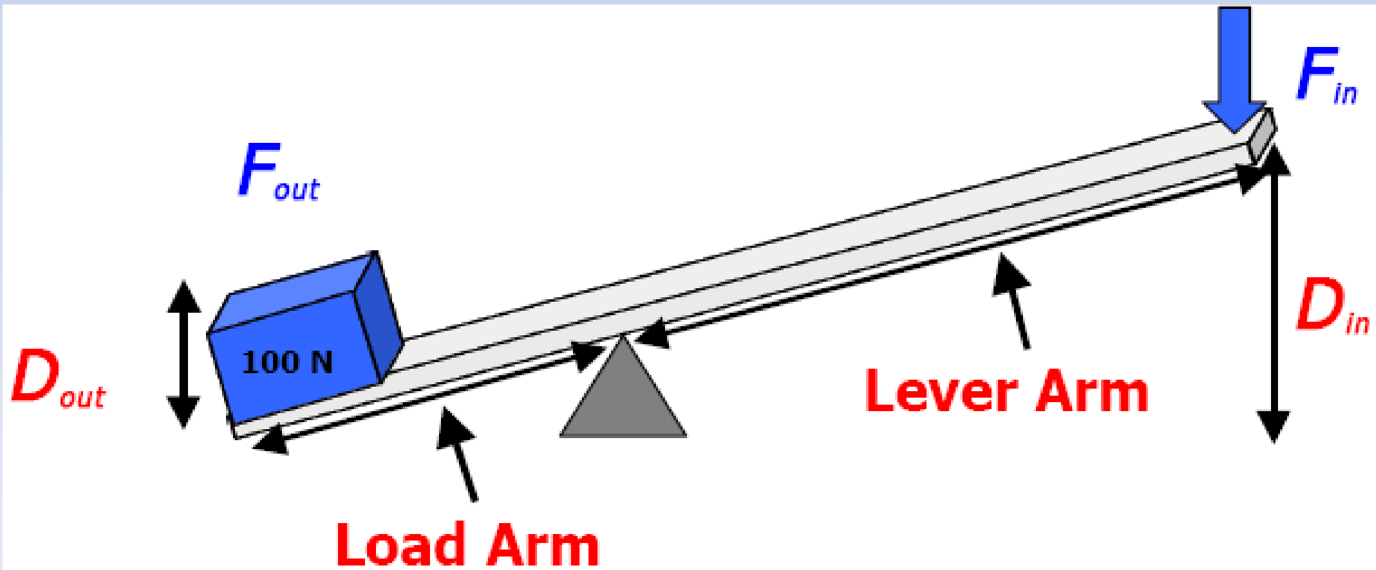
Simple machine calculations

Identifying Forces & Distances

- Simple machines trade force for distance
- Pairing
  - Small distance/BIG force
  - BIG distance/small force
- Force in is the force directly applied to the machine to "get it going"
- Force out is what the machine accomplishes

Simple machines

- AMA: Actual mechanical advantage (Force you get (lift)/Force you lift or push)
  - AMA = F_{out}/F_{in}
- IMA: Ideal mechanical advantage
  - Same value as AMA if 100% efficient
  - IMA = d_{in}/d_{out}

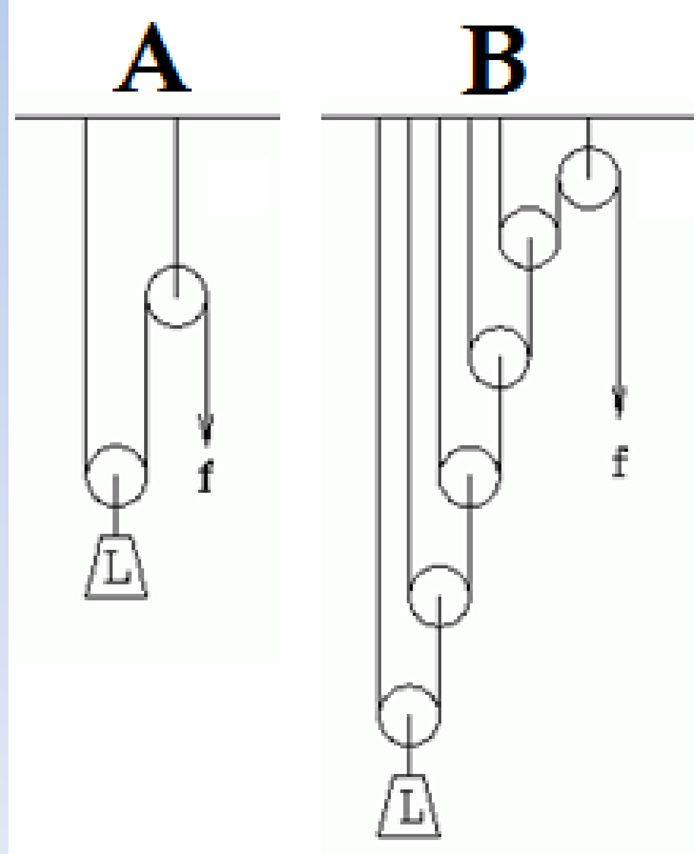


Examples

  - AMA = F_{out}/F_{in}
  - IMA = d_{in}/d_{out}
- Inclined plane: (sketch it)
  - Pushing a barrel up a ramp:
    - What’s the input?
    - What’s the output?
    - (For IMA or AMA) How many variables are there?
    - How many will you be given?
- Lever: (sketch it)
  - Lifting up a car with a tire jack:
    - What’s the input?
    - What’s the output?
    - (For IMA or AMA) How many variables are there?
    - How many will you be given?

Pulleys

- Key idea: Tension in rope same on both sides
- Fig. A: Pull down with 100 lbs on right
  - How hard is it pulling down on left?
  - How heavy is L being lifted?
  - Pull rope down 2 ft:
    - How high is L lifted?
- Fig. B: Pull down with 100 lbs
  - How much weight L can you lift?



13-03

Rollercoaster Physics

Work, Power, Simple machines

Coaster examples & strategies

Power to lift a coaster

- P = w/t
- Make sure time is in seconds
- Work is the wt x height
- Example: 2000 kg coaster lifted 55 m in 10 sec

Work done by friction

- W = F d
- F is in Newtons – we'll break this down further next unit
- d is in meters, a N m is a Joule
- Example: A coaster track is 85 m long and 500,000 J of energy have been converted to heat by the time braking begins,
  - How much KE is there at the bottom?
  - What would you need to know to find the frictional force of the brakes?

Coaster KE with friction

- Conservation of energy says that GPE has turned into KE at the bottom of the coaster ride
- Any frictional loss reduces KE by that amount
- Speed is calculated using KE equation
- Example: A 2000 kg coaster begins at 55 m. At the end of the ride it's lost 500,000 J of energy to friction, how fast is the coaster going?

How long to brake and braking force

- Avg. Speed is half of starting speed
- D = vt
- Work of friction stops coaster, use this to find force
- Example: Previous coaster has 30 m to brake, find the time to brake and the brake force