Physics Lecture 4 – Momentum, Machines and Radioactive Decay

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Momentum
- Measure of an object's tendency to continue along its present path
- $p = mv$ (units: kg m/s)
- Is a vector so split it into components
- Always conserved for any collision

Collisions
- *Elastic*: when mechanical energy is conserved (most cases: no U so only K is conserved)
$$\sum U_i + \sum K_i = \sum U_f + \sum K_f, \qquad \sum p_{i,x} = \sum p_{f,x}, \qquad \sum p_{i,y} = \sum p_{f,y}$$
- *Inelastic*: when some energy turns into internal energy/heat i.e. when objects stick together after colliding
$$\sum p_{i,x} = \sum p_{f,x}, \qquad \sum p_{i,y} = \sum p_{f,y}$$
- Always split momentum into x and y components and calculate separately

Impulse
- Relates change in momentum with average force applied:
- $J = \Delta p = F_{avg}\Delta t$
- For an object with a certain momentum, taking more time to slow it down (larger Δt) will require less force. Taking less time to slow it down will require more force
- Object bouncing off a wall has initial momentum mv, final momentum $-mv$ so $\Delta p = -2mv = F_{avg}\Delta t$

Machines
- BASIC GUIDELINE: Force and distance applied are inversely proportional to do the same amount of work
- OTHER BASIC GUIDELINE: Assume minimum applied force to move the object; i.e. dynamic equilibrium

<u>Lifting straight up</u>
- Resisting force: $F = mg$
- Distance: $d = h$
- Total work done: $W = mgh$

<u>Ramp</u>
- Force along the ramp: $F = mg\sin\theta$
- Distance along the ramp: $d = h/\sin\theta$
- Total work done: $W = mgh$
- Decrease F by a factor of $\sin\theta$ → increase d by a factor of $1/\sin\theta$

<u>Lever</u>
- Choose rotation point to be fulcrum, set $\sum\tau_{cw} = \sum\tau_{ccw}$ (don't forget weight of lever if it's not massless)
- If lever is massless, weight is a distance x from fulcrum; force is applied to a distance ax on the other side:
$$\sum\tau_{cw} = (ax)(F) = (x)(mg) = \sum\tau_{ccw}$$
- Force applied: $F = mg/a$
- Distance: angles are the same, so $d = ah$ if object moves up h
- Total work done: $W = mgh$
- Decrease F by a factor of a → increase d by a factor of a

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Concentric pulley

- Count the # of tensions being used to pull the mass upwards, let's call it n
- Force applied: $F = mg/n$
- Distance applied: $d = nh$
- Total work done: $W = mgh$
- Decrease F by a factor of n → increase d by a factor of n

Eccentric pulley

- Actually a lever in disguise, but the force applied changes at every point
- Choose rotation point to be rotation point of pulley, set $\sum\tau_{cw} = \sum\tau_{ccw}$ (don't forget weight of lever)
- If pulley is massless, weight rope is r from rotation point; force rope is ar:

$$\sum\tau_{cw} = (ax)(F) = (x)(mg) = \sum\tau_{ccw}$$

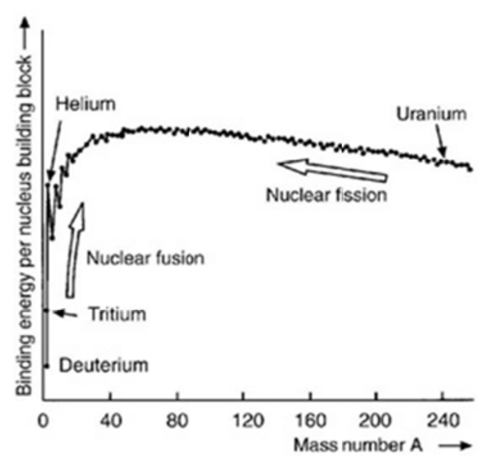
- Force applied: $\mathrm{F} = \mathrm{mg/a}$
- Distance: $d = ah$ if object moves up h
- Total work done: $W = mgh$
- Decrease F by a factor of a → increase d by a factor of a

General rule for levers/eccentric pulleys:

- When weight is closer to rotation point, you need to apply less force over greater distance to lift it

Radioactive Decay

- If an atom has lots of protons, it needs many more neutrons to stabilize the nucleus.
- Half-life: the amount of time it takes for half of a substance to disappear
  - After n half lives, the substance will be left with $\left(\frac{1}{2}\right)^n$ of its original amount
- Types of decay – remember to balance equations
  - *Alpha decay*: atom loses helium nucleus, or $^4_2\alpha$
  - *Beta decay*: atom loses an electron, or $_{-1}^{0}\beta$ (a neutron turns into a proton)
  - *Positron emission*: atom loses a positron, or $^0_1\beta$ (a proton turns into a neutron)
  - *Electron capture*: atom absorbs an electron $_{-1}^{0}\beta$ (a proton turns into a neutron), emits a gamma ray $^0_0\gamma$
  - *Annihilation*: electron and positron combine to form two gamma rays
- Fusion: two nuclei combine to form heavier nucleus
  - Energy is released when *small nuclei* undergo fusion because they form a more stable nucleus or have higher binding energy
- Fission: a nucleus splits to form two lighter nuclei
  - Energy is released when *large nuclei* undergo fission because they form a more stable nucleus or have higher binding energy



Mass Defect

- $E = mc^2$, some mass is used as energy to hold nucleus together
- Sum of masses of all parts of an atom > actual mass of the atom