Newton's Correction to Kepler's First Law

The orbit of a planet around the Sun has the common center of mass (instead of the Sun) at one focus.

Clicker Question:

A flaw in Copernicus’s model for the solar system was:

A: It didn’t explain retrograde motion.
B: He used circular orbits.
C: The Earth was still at the center.
D: He used the same mass for all the planets.
E: All of the above

Clicker Question:

How long does it take the space shuttle to orbit the Earth once?

A: 10 minutes
B: 90 minutes
C: 1 day
D: 1 week

Clicker Question:

Suppose Matt weighs 120 lbs on his bathroom scale on Earth, how much will his scale read if he standing on a platform 6400 km high (1 Earth radius above sea-level)?

A: 12 lbs
B: 30 lbs
C: 60 lbs
D: 120 lbs
E: 240 lbs

Phases of Matter and Fluid Mechanics

- What are the different phases of matter and some of the properties of each?

  - Solid: Fixed shape
  - Liquid: Takes shape of container, incompressible
  - Gas: Takes shape of container, easily compressible
    - Gas and liquids both flow => both are “fluids”
  - Plasma: A gas that is electrified or “ionized”
Density

- The density of an object is its mass divided by its volume
  - How is density related to atomic structure?
    - The more closely packed the atoms, the greater the density of an object.
    - What can we say about the atoms in a solid to account for its fixed shape?

The density of an object is a measure of its compactness.

Tension and Compression

- Tension – stretching
  - Atoms pulled apart
- Compression – squeezing
  - Atoms pushed together
- Which part of the beam is under tension? under compression? under no stress at all?
- So, what is the benefit of an I-beam vs. a solid beam?

Examples of Scaling

- Why does an elephant have such big ears?

Scaling

- An ant can lift several times its own body weight
  - Why can’t an elephant do the same thing?
    - Objects grow heavier at a faster rate than they grow stronger
      - Strength related to 2-d cross-sectional area
      - Weight is related to volume
    - What happens to the area to volume ratio of an object as its size increases?
Examples of Scaling

- Why does an elephant have such big ears?
  - Heat radiation governed by surface area
  - Same idea as radiator in your car
- Why don't we see arbitrarily large single-celled organisms?
- Why can a lady bug fall out of a tree unharmed, but a person cannot?
  - Air resistance more effective for larger surface area to volume ratio (crushed vs. uncrushed feather)
  - Bug acts as its own parachute!

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Liquids

- Molecules are not confined to fixed positions
  - Can flow by sliding over one another
- Very difficult to compress
  - What does this imply about the spacing between molecules in a liquid?
  - How do you think this compares to the spacing between molecules in a gas?

Pressure

- Pressure is a force divided by the area over which the force is exerted
  \[ \text{Pressure} = \frac{\text{Force}}{\text{Area}} \]
- Which block feels the greatest gravitational force?
- Which block exerts the greatest pressure on the table?

Pressure in a Liquid

- Pressure in a liquid increases with depth
  - Felt in your ears at the bottom of a swimming pool
  \[ \text{Pressure} = \text{Weight density} \times \text{depth} \]
  - Weight density = weight per unit volume
- Which body of water exerts the greatest pressure on the dam?
- Which fish feels the greatest pressure?
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- Which fish feels the greatest pressure?
  - Pressure only depends on depth

Atmospheric Pressure

- We are at the bottom of the atmosphere
  - At sea level 1 m³ of air weighs 1.2 kg
  - Pressure is 101 kPa (aka 1 atmosphere or 14.7 psi)
  - kPa = kiloPascals
  - psi = pounds per square inch

Clicker Question:
Which material is most resistant (doesn’t break apart) under tension?
A: a concrete block
B: a strand of spaghetti
C: a steel bar
D: a strong man

Clicker Question:
A car has tires at 40 psi measured warm at sea level. Suppose the car is driven up a mountain to 10,000 feet elevation. What will happen to the tire pressure?
A: increase
B: decrease
C: stay the same
D: can’t say

Clicker Question:
To measure the density of an object we need to know what?
A: mass and circumference
B: volume and width
C: mass and volume
D: weight and height

Buoyancy

- The apparent loss of weight of a submerged object
  - Objects under water are much easier to lift
- In what direction does the buoyant force point?
- What is the source of this force?
Buoyancy

- The apparent loss of weight of a submerged object
  - Objects under water are much easier to lift
- In what direction does the buoyant force point?
  - Up (in direction of least pressure)
- What is the source of this force?
  - The pressure difference acting on the top and bottom of the object

Archimedes’ Principle

- An immersed object is buoyed up by a force equal to the weight of the fluid it displaces
  - What property of an object determines how much fluid a completely submerged object will displace?
    - The volume of the object
      - Regardless of shape, mass
    - For partially submerged object, it is the volume of the submerged part
      - Boat

Archimedes’ Principle (Cont.)

- Does Archimedes’ principle depend on depth?
  - No. Volume of fluid displaced by submerged object is the same at any depth.
  - Buoyant force only depends on pressure differences
    - Same at any depth

Sink or Float

- An object more (less) dense than the fluid in which it is immersed will sink (float).
  - What must you do to increase your buoyancy in water?
Sink or Float

- An object more (less) dense than the fluid in which it is immersed will sink (float).
  - What must you do to increase your buoyancy in water?
    - Decrease your density
      - Life jacket increases volume while adding very little weight
  - An object with a density equal to the surrounding fluid will neither sink nor float.
    - Fish (air sac) and submarines (ballast) can vary their densities

DEM O : Cartesian Diver

The Principle of Flotation

- How is it that an iron ship will float in water?
- How much water must be displaced for an object to float?

The Principle of Flotation

- Principle of flotation
  - A floating object displaces a volume of fluid with a weight equal to its own weight.

Pascal's Principle

- A change in pressure at any point in an enclosed fluid at rest is transmitted undiminished to all points in the fluid.
  - Direct consequence of incompressibility
  - How can we use this fact to lift a very heavy load by applying a force that is only a small fraction of the weight of the object?

The Hydraulic Press

- Force = Pressure * Area
  - Area at right is 50 times area at left, and so is the force!
  - Pascal's Principle enables us to multiply forces
  - Why doesn't this violate conservation of Energy?

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  - Pascal's Principle enables us to multiply forces
  - Why doesn't this violate conservation of Energy?
    - Load is raised only 1/50th of the distance that the light load descends!
      - Work = Force * Distance