Astro 350
Lecture 5
Jan 28, 2022

Announcements:

- **Homework 1** due **today**
- **Discussion Question** 2 posted on Canvas
  due next Wednesday

Last time: Kepler's mighty Laws

Q: what are they?

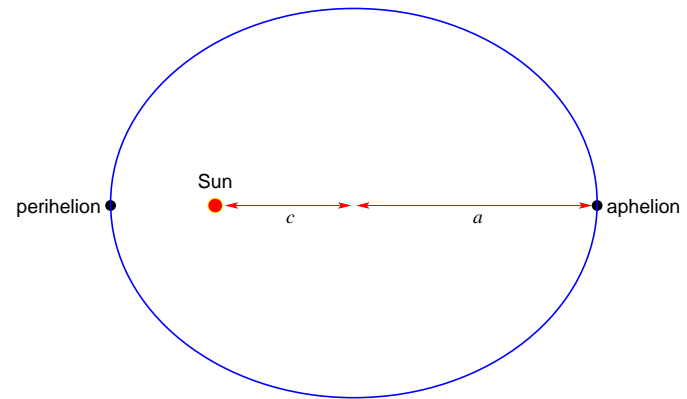*Q: how do planet speeds vary with orbit?*

Q: how does speed vary in a circular orbit?

Q: which planet has the shortest period? the longest?

Kepler I:

solar system orbits are ellipses
with the Sun at one focus

- Sun is off-center
- planet-Sun distances change
  except for circular orbits

Kepler II: orbits sweep equal areas in equal times

- orbits fastest when closest to Sun
  and slowest when farthest away
- circular orbits: constant distance $\rightarrow$ constant speed

Kepler III: $P_{\text{yr}}^2 = a_{\text{au}}^3$

- larger a means larger P
- so P for Mercury is smallest, for Pluto is largest

Galileo Galilei: Astronomer

First to use telescope in Astronomy

`www:  Galileo shows scope to Duke`

contributions:
- mountains on the Moon
- moons of Jupiter
- sunspots

These are bad for Ptolemy (but maybe not deadly) *Q: how?*

Experimentum Crucis

Crucial, decisive experiment: *phases of Venus*

geocentric and heliocentric model both predict
that Venus should show phases just as the Moon does
depending on how much of the sunlit side we can see

but geo and helio models make *different predictions*
for *which phases* are visible

`www:  Venus phase animations`

also note: Venus phases not visible with naked eye
$\Rightarrow$ telescope *required* to test these prediction

Observation: `www:  modern image`
Follow geocentric prediction!
contradicted Ptolemy, supported Copernicus!

Copernican Revolution I

"paradigm shift" (Kuhn)
radical change in outlook/conceptual framework

Earth no longer the the center of the cosmos
one planet among many orbiting the Sun
and implicitly: the stars are far away − perhaps like the Sun?
• can view as "the great demotion"
• but also a democratizing idea − the cosmos contains other worlds

We will encounter further Copernican-style revolutions
where our view of the Universe broadens

Q: was Galileo rewarded for these discoveries?

Changing Worldviews is Hard

Galileo published his findings
Dialogue Concerning the Two Chief World Systems (1632)
character defending Aristotle: Simplicio. Not a bright guy.
offended the Pope

Galileo put on trial, forced to recant heliocentrism
• Church banned his work & that of Copernicus until 1832
• official semi-apology ("mistakes were made") 1992

complex: crackdown as much political as theological
shows view of the world people had
1. really not at all obvious that sun at center
2. the paradigm shift difficult, challenged outlook

The Science of Motion

Description of Motion

want precise language not just for planets but all objects

Speed: rate of motion
$$\text{speed} = \frac{\text{change in distance}}{\text{change in time}}$$
mathematically: $v = d/t$ (more technically $v = dx/dt$)
so: $\boxed{d = vt}$ distance traveled = speed $\times$ travel time
    Fine Print: $d = vt$ valid when speed constant = not changing

Velocity: both speed and direction of travel
ex: if 10 mi East in 1/2 hour,
    velocity = 10/(1/2)= 20 mph East

Q: can two objects have same speed, different velocity?
Q: does car speedometer really measure speed or velocity?
Q: turn corner in car, speedometer pegged at 20mph–so?

∞

Acceleration: *change* in speed *or* direction of motion

speed up rate or slow down rate

ex: slam on gas, brakes in car

Q: what kind(s) of motion(s) have zero *acceleration?*

intuitively: acceleration is rate of speeding up
  or slowing down

sometimes useful to distinguish:
- **ac**celeration = speeding up
- **de**celeration = slowing down

Poll: Acceleration

young James T. Kirk (remake version) drives from point X to Y
his motorcycle speedometer readings are unknown
  maybe constant, maybe not

In which case(s) is it **certain** he accelerated?

Path A   Path B   Path C

X X X

Y Y Y
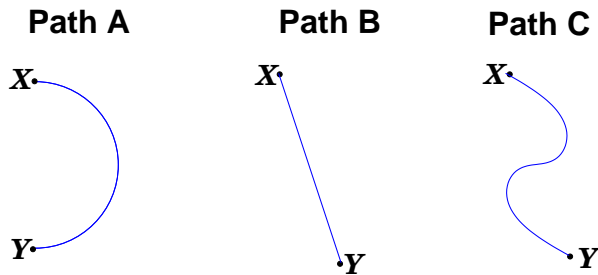
A Path C only

B Paths A and C

C Paths A, B, and C

D if speed kept constant, all paths can be unaccelerated

Galileo: Physicist

studied motion of objects on earth two important cases:

Special Motion I: **"Free Body"**
moving with *no* external influences
(including friction, gravity)
$\rightarrow$ moves in straight line, constant speed $\rightarrow$ **constant velocity**

Galileo finds this is the "**natural motion**"
of an object − keeps constant speed & direction
unless something happens to change this

Contrary to Aristotle: natural motion is to come to rest
Q: Why did Aristotle think this?

Special Motion II: **"Free Fall"**
motion due to **gravity only**

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www:   Tower of Pisa
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Demo: Pisa: heavy, light objects
Demo: Pisa: ball, paper sheet

Q: in free fall, is velocity constant?

even if fall in straight line, speed changes
$\rightarrow$ gravity causes **acceleration**
$\rightarrow$ *same* acceleration for all objects
   independent of size, mass

Einstein called this independence the "equivalence principle"
crucial in his invention of General Relativity

Note: Galileo *describes* motion (mathematically)
but to *explain* with a theory fell to...

Isaac Newton 1643-1727

Why Kepler's laws for planets?

Are they special?

Can we understand using general rules for all motion?

New concepts

⋆ **mass**: "amount of stuff"

measure in kg → 1 kg of anything has the same mass

• **force**: push or pull on object

can have more that one acting, in different directions

• **net force**: *total* of all forces acting.

if forces unbalanced, net force is present

Newton's Laws of Motion

motion & forces linked

Newton I. "Inertia"

- an object at rest stays at rest if no net force acts on it
- an moving object goes in straight line w/ const speed
  if no forces act on it

i.e., "free body" as per Galileo

so we say: objects have "*inertia*" or "*momentum*"

$\Rightarrow$ will keep their state of motion (i.e., velocity)
  unless and until a net force acts