Astro 350
Lecture 5
Aug 30, 2011

Announcements:

- Discussion Question 1 due tonight!
- HW1 due next time, at start of class
  turn in paper copy, *or* upload on Compass
  online submission gives record that you did it
  Office Hours: Instructor–today, right after class
  TA: Thursday, 2-3pm, Astronomy Building Room 133
- **register** iClicker, link on course page

Last time:

- Kepler: 3 laws describe planetary motion *Q: T-shirt version?*

Today:
theories of motion, of gravity, and of motion due to gravity

Galileo: Astronomer

Crucial, decisive experiment:
- phases of Venus

`www: Venus phase animation`

observations contradicted Aristotle
supported Copernicus
"paradigm shift" (Kuhn)
radical change in outlook/conceptual framework

Note: Galileo put on trial, forced to recant heliocentrism
- his work, Copernicus, Kepler banned 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: 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 measure speed or velocity?

Q: turn corner in car, speedometer pegged at 20mph–whassup?

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

speed up rate or slow down rate

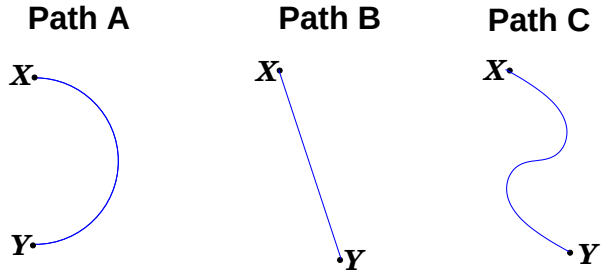
ex: slam on gas, brakes in car

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

iClicker 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?



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**

`www: Tower of Pisa`

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 $\rightarrow$ 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 forces act 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

Newton II: "$F = ma$"

- a net force acting on an object causes it to accelerate
- $a \propto F$ and $a \propto 1/m$ *Q: examples?*
  so $a \propto F/m$, or $\boxed{F = ma}$

Examples:

- ball on table, at rest *Q: how many forces? net force?*
- circular motion: speed const, yet force applied *Q: what's up?*

diagram: circular motion: velocity, force, force-free path

2nd Law a mathematical machine which predicts future!

Q: how? where's the fortunetelling in $F = ma$*?*

Q: what information needed to do this?

Fortunetelling (and Archæology!) with Newton II

input: at initial time, need to know/specify

- object mass m
- all of forces acting on m

$\Rightarrow$ find *net force* F

turn the math crank: $a = F/m$

$\rightarrow$ find *acceleration* = change in velocity

$\rightarrow$ use this to find new position, new velocity
at at moment a little later

$\rightarrow$ at new time and position, find new net force

...lather rinse repeat

Result: find particle path in future!

But also: can mathematically "run the move backwards"
and predict the past history as well!

Newton III: "Action-Rection"

a rule about how forces behave
between two objects

if 2 bodies interact:
the **force** exerted by object 1 on object 2
  is **equal and opposite** to
the **force** exerted by object 2 on object 1

Q: application–you standing still
Q: Jump shot