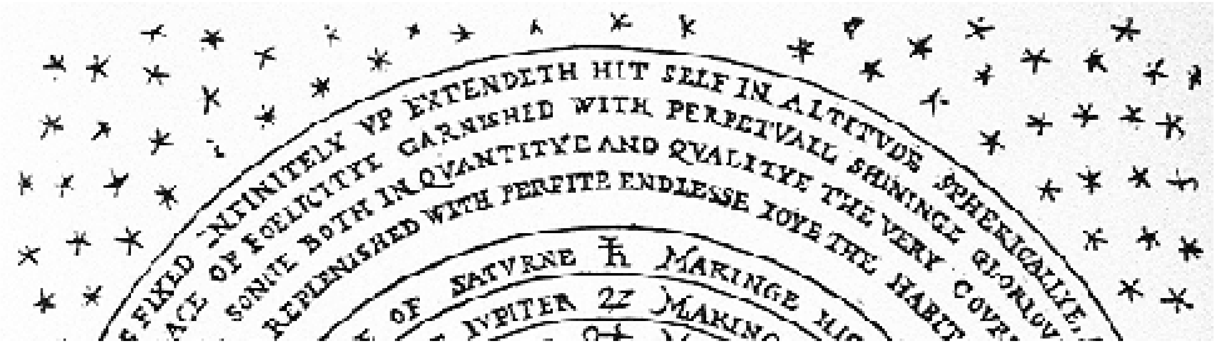


PHY1033C/HIS3931/IDH 3931 : Discovering Physics:

The Universe and Humanity's Place in It

Fall 2016

Prof. Peter Hirschfeld, Physics

Announcements

- HW 3 due Tuesday, Sept. 27
- Reading: Copernicus On the Revolution of the Heavenly Orbs
- Gregory, Chapter 4, pp. 80-89
- Note: film on Thursday, *The Starry Messenger*

Last time

- Ptolemaic astronomy in crisis: star charts increasingly inaccurate, calendar 10 days off!
- Pressure from church, maritime industry to improve
- Copernicus: his heliocentric system and motivations
- Copernican system: advantages and disadvantages

Clicker question:
Copernicus's *de Revolutionibus*

a. was a call to revolution against King Sigismud I in Poland

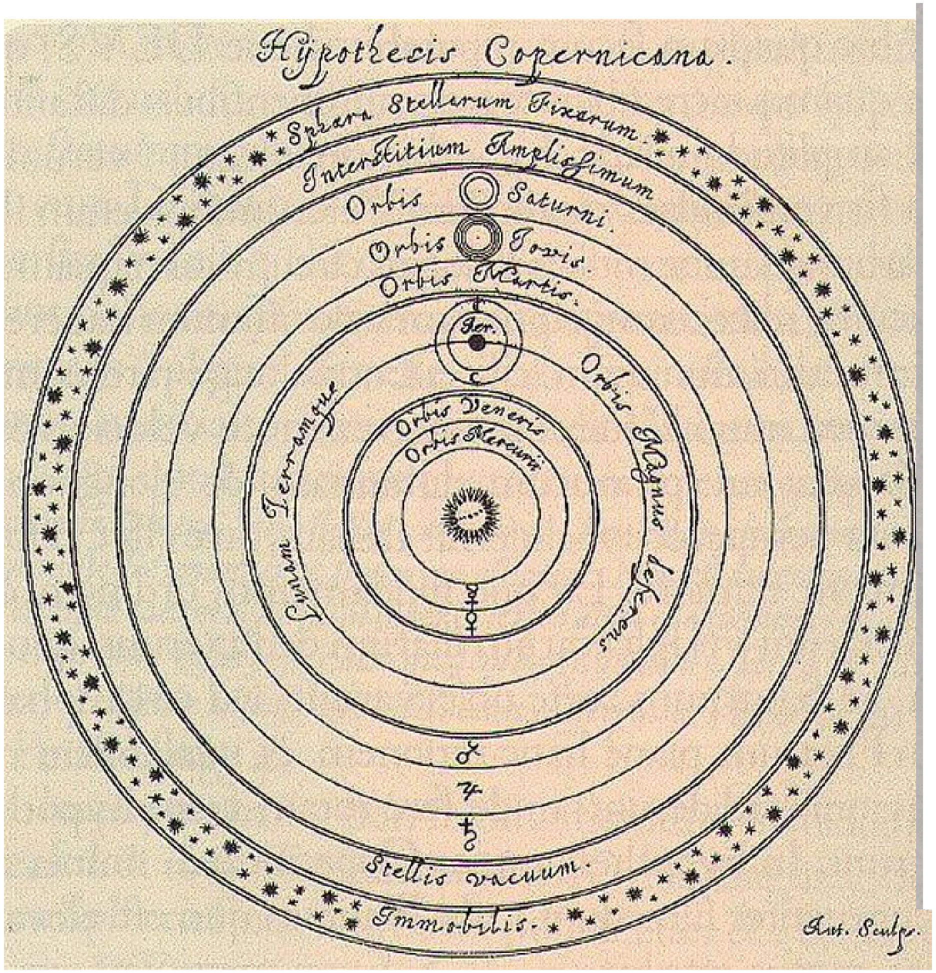
b. was published when he was a young man, to irk church authorities

c. continued to place the earth in the center, although it rotated

d. described planets, including Earth, revolving around the sun in perfect concentric circles, with no epicycles

e. described planets, including Earth, revolving around the sun on nonconcentric circles and epicycles

Copernican system



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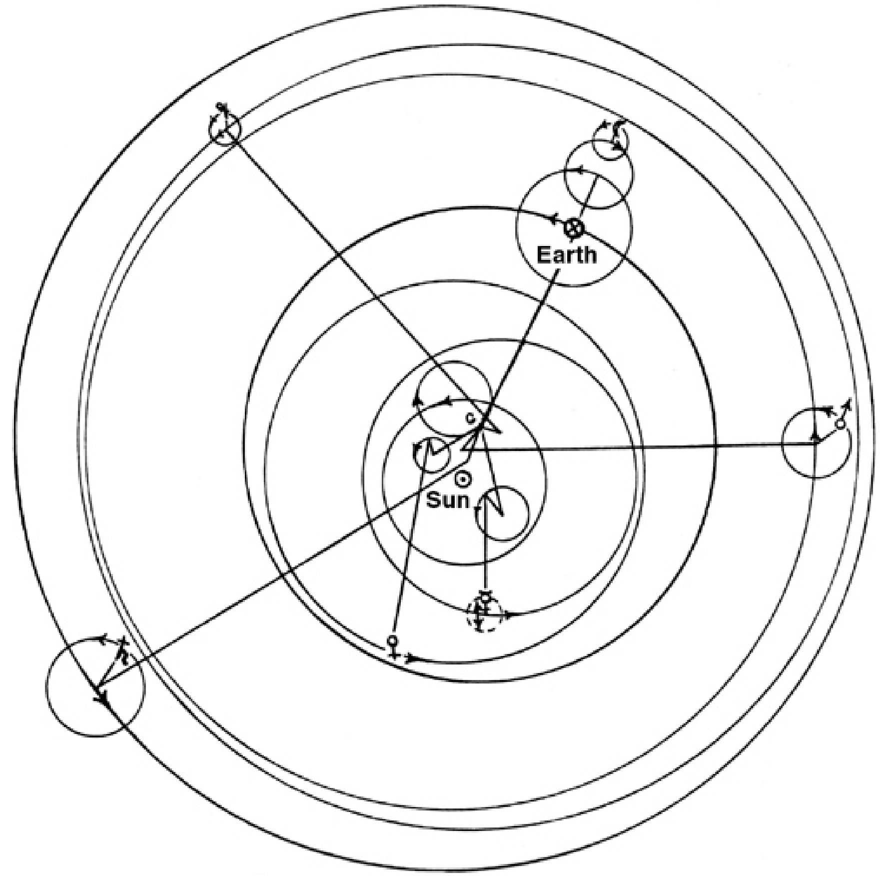


for calculations

Advantages of Copernican system

- No equant

- Slightly better fit (was not hugely better)

- Internal harmony (one geometry of heavens, not 7 individual accounts of planets)

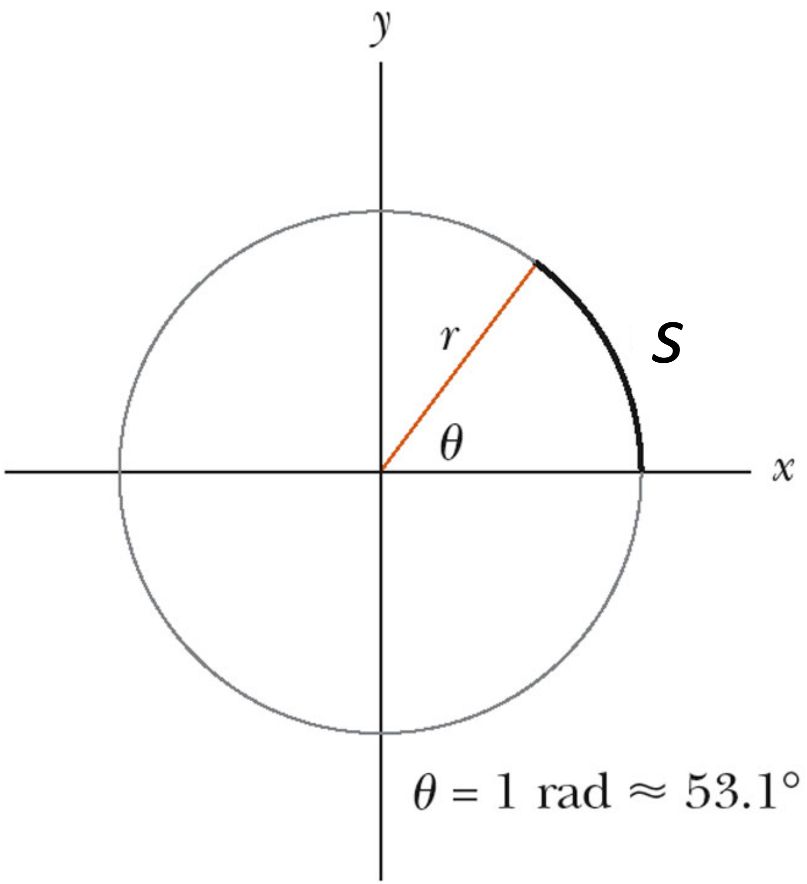
- Order of planets certain

Disadvantages of Copernican system

- Not appreciably less complex (still plenty of epicycles, etc.)
- Sun the center of stars, not planets (nonconcentric circles)
- Physics of motion inconsistent with predicted experience (if earth in motion)
- Challenge to understanding of scripture (Joshua @ Jericho)
- Lack of parallax

The Radian

- The radian is a unit of angular measure
- The radian can be defined as the arc length s along a circle divided by the radius r
- $$\theta = \frac{s}{r}$$



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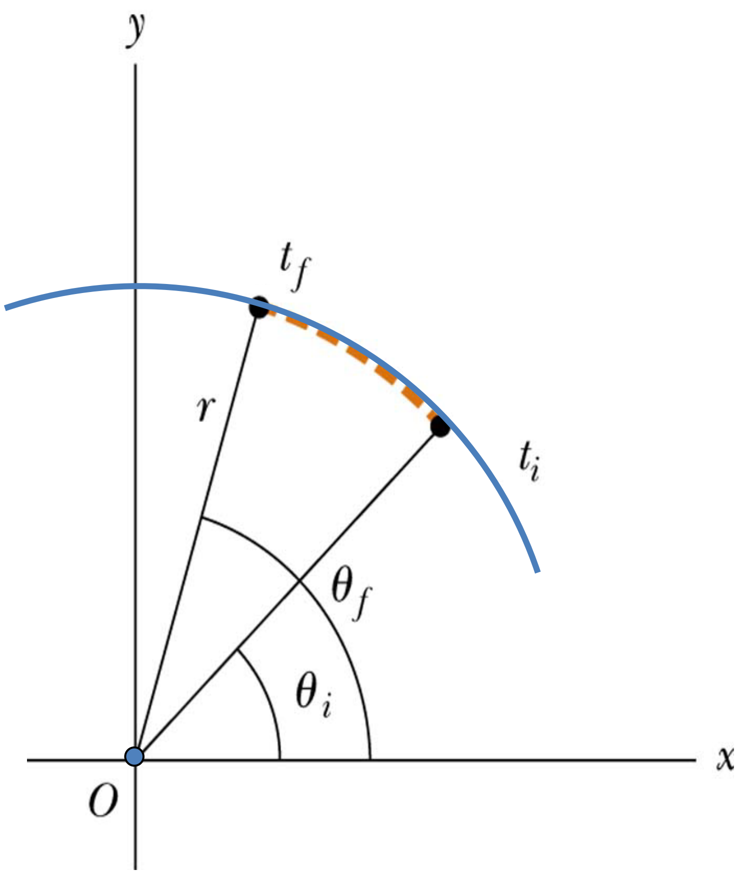
Average Angular Speed

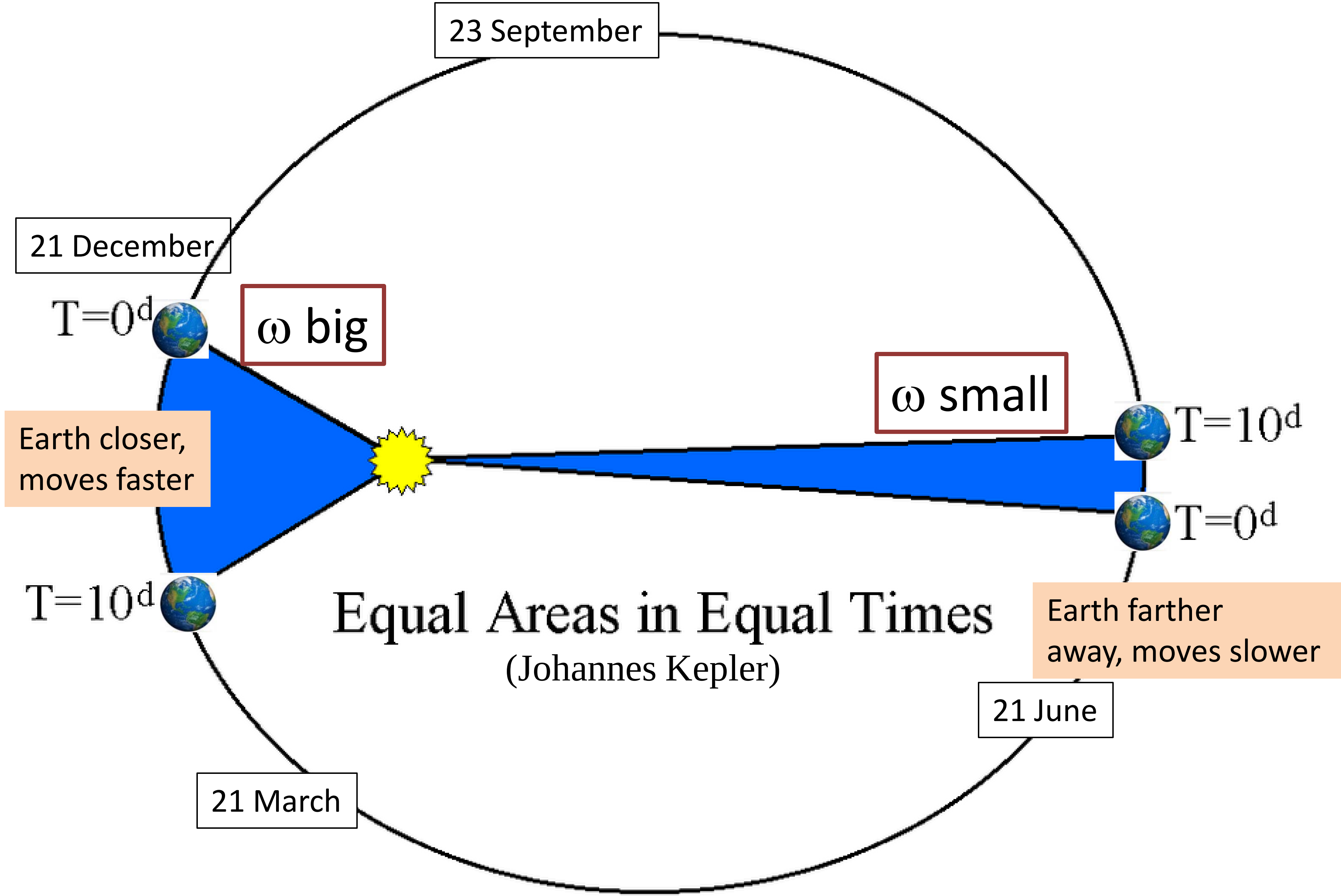
- The average angular speed, ω, of a rotating object (or an object going in a circle) is the ratio of the angular displacement to the time interval

$$\omega_{av} = \frac{\theta_f - \theta_i}{t_f - t_i} = \frac{\Delta\theta}{\Delta t}$$

Unit: rad/s



Angular speed changes on Earth's orbit!



Average Angular Acceleration

- The average angular acceleration α of an object is defined as the ratio of the change in the angular speed to the time it takes for the object to undergo the change:

$$\alpha_{av} = \frac{\omega_f - \omega_i}{t_f - t_i} = \frac{\Delta\omega}{\Delta t}$$

Unit: rad/s^2

Relationship between angular and linear quantities in circular motion

- Displacement

$$\Delta s = r\,\Delta\theta$$

- Speed

$$v_t = \omega r$$

- Acceleration

$$a_t = \alpha r$$

- Every point on the rotating object has the same angular motion
- Not every point on the rotating object has the same linear motion

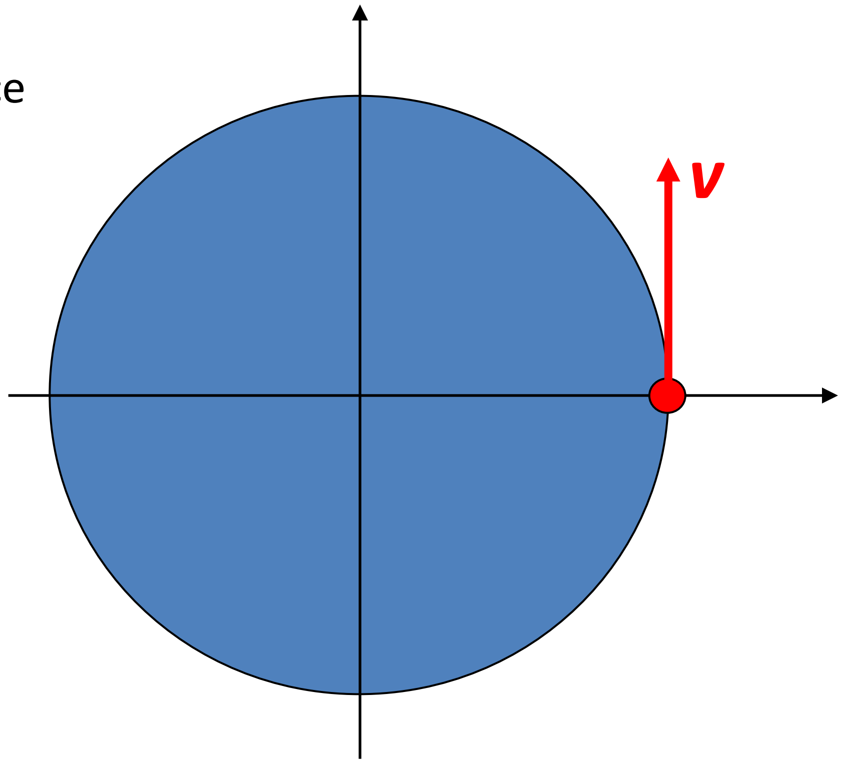
Subscript "t" means "tangential"

Period T and frequency f

$$T = \frac{2\pi}{\omega} = \frac{2\pi r}{v}$$

$$f = \frac{1}{T} = \frac{\omega}{2\pi}$$

Time to go around once



What is the *angular velocity* ω of the Earth's *rotation* on its axis?

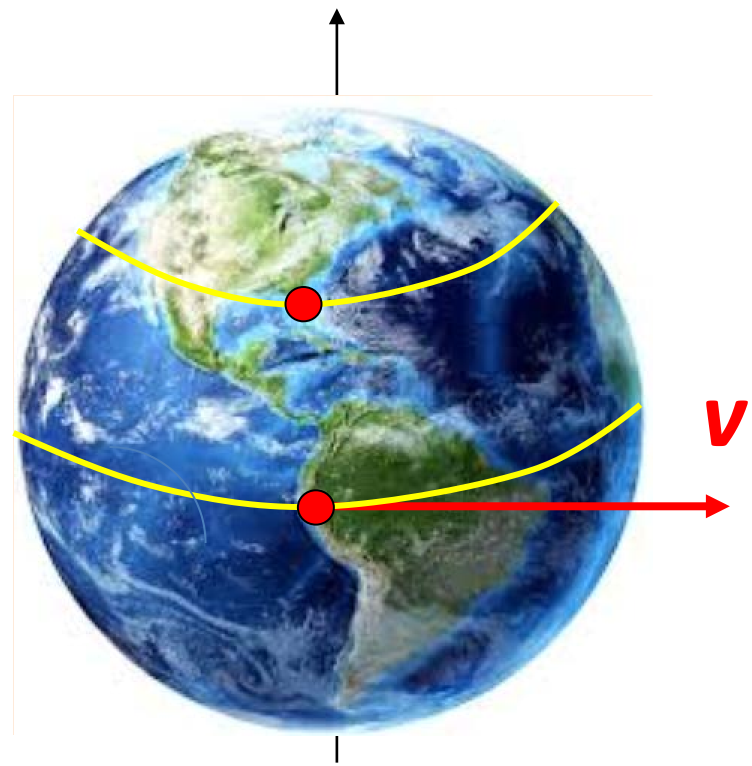
A. 2π/1 day
B. 2π/1 year
C. 1/1 day
D. 1/1 year
E. 24,000 mi/1 day

What is your linear speed sitting on the Earth's surface at the equator due only to its rotation? (Hint: $R_E \approx 4000$mi)

A. 8000 miles/28 days
B. 4000 miles/1 day
C. 24,000 miles/1 day
D. 4000 miles/28 days
E. 24,000 miles/28 days

Let's put in the numbers

$$v = 2\pi R_E / T$$
$$\approx 24000 \text{ miles}/1 \text{ day}$$
$$= 24000 \text{ miles}/24 \text{ hours}$$
$$= 1000 \text{ mi/hr}$$



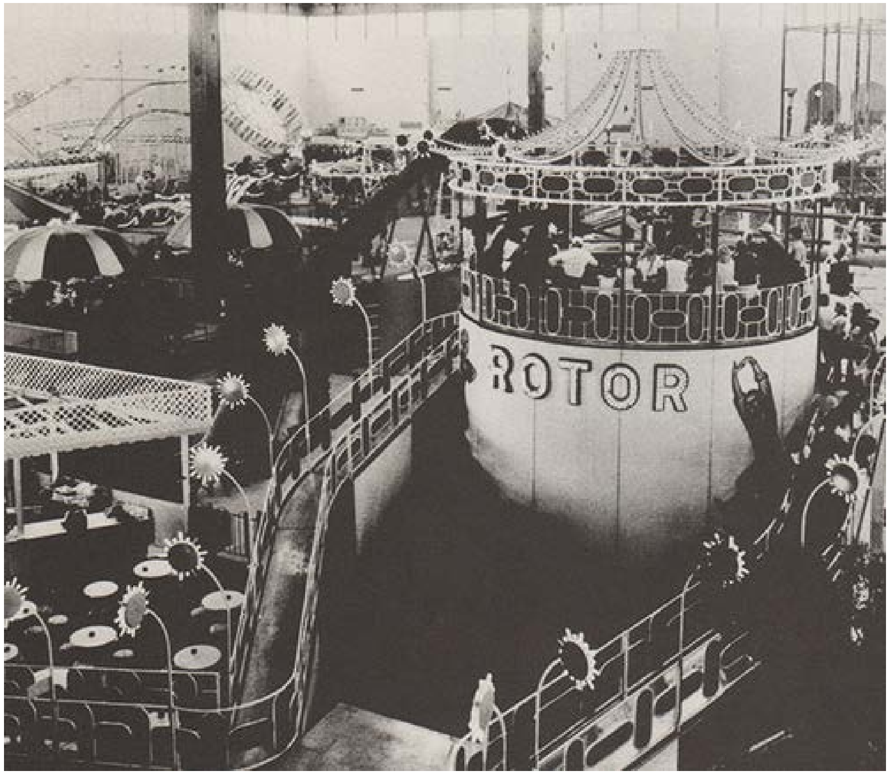
a little slower in Florida, because the circle you follow is smaller away from the equator!

What's your centripetal acceleration at the equator?

$$a = v^2/R_E \approx (1000\ \mathrm{mi/hr})^2/(4000\ \mathrm{mi})$$
$$= 250\ \mathrm{mi/hr}^2$$
$$= \frac{250\ \cancel{\mathrm{mi}} \times (1609\ \mathrm{m}/\cancel{\mathrm{mi}})}{(1\ \cancel{\mathrm{hr}} \times 3600\ \mathrm{sec}/\cancel{\mathrm{hr}})^2} = \boxed{0.03\ \mathrm{m/s}^2}$$

Recall acceleration of falling bodies at Earth's surface $g=9.8\ \mathrm{m/s}^2$:
$0.03\ \mathrm{m/s}^2$ is 0.3% $\Rightarrow$ you weigh 0.3% because the Earth is rotating

Centripetal vs. centrifugal

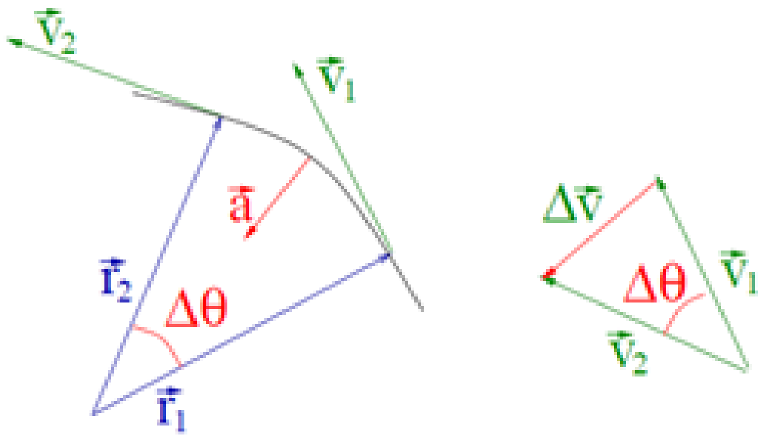


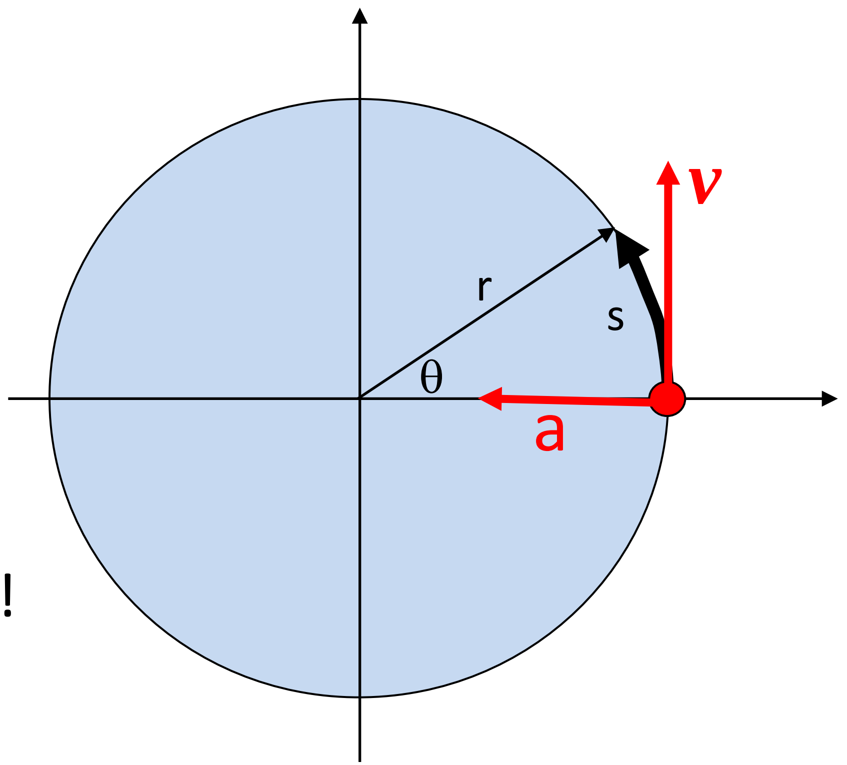
You "feel" a force pressing you outwards, not inwards – why?

Demos: centripetal force

- bucket/water
- hanger/coin
- ball/string

Centripetal vs. centrifugal





$$\boxed{a = \frac{v^2}{r}}$$ towards center!

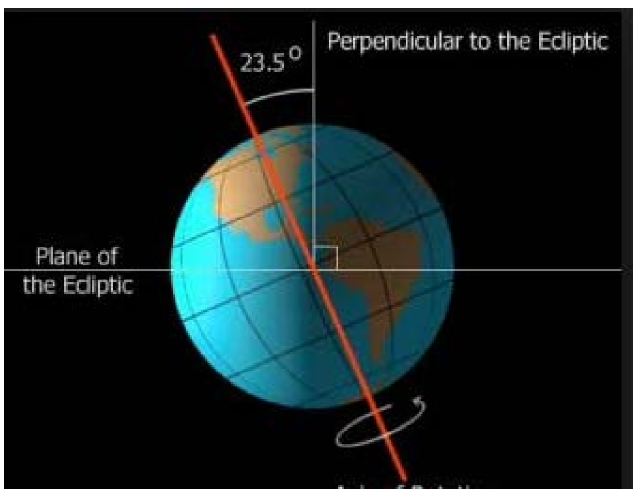
v=speed

r=radius of circle

At rotating surface you "feel" an "outward" tendency because of your inertial tendency to go in a straight line

Why does Earth's axis stay pointing in the same direction (more or less)?

A: for same reason a bicycle is very stable when it is moving fast, or a top doesn't want to change its direction



Top in space:
https://www.youtube.com/watch?v=vedP40v0eDY

and just for fun:

https://www.youtube.com/watch?v=KaOC9danxNo