Announcements: Pre-Midterm

- **Stargazing night!** Wednesday, Feb 13th (backup date: 02/19)
  See our class webpage for details [www.ucolick.org/~mfduran/AY2]

- **Next Tuesday is the Midterm!**
  Bring calculator (although you can survive without one), Scantron form (red, big), pencil, eraser...
  No cellphones, books or notes allowed.

- **Review Sessions**
  Friday (Jieun) and Monday (Katie), regular section times, regular room.
  Do not wait until the Monday session, if it fills you might just not get in!
  (seriously, the fire department will shut it down)
  More of a Q&A than a lecture.

- **Sample problems**
  I am finishing up those and the midterm itself. They will be uploaded tonight or tomorrow morning at the latest.

- **Office hours:** Monday afternoon (all afternoon).
  ISB 2nd floor lobby. Check sign at ISB 201 door for directions.
  2:00-3:30 Katie  3:30-4:30 Jieun  4:30-6:00 Me.
Topics for the midterm

• **Well... everything so far.**
  Do not take this lecture as ‘this is all I have to study’ It is impossible to cover everything we have talked about in the past 9 lectures in just 1.

• **Naked eye astronomy**
  Phases of the Moon, motions of the planets, the Sun, eclipses, tides, the celestial sphere, local coordinates, seasons, ... etc.

• **Light and Matter**
  Light as a wave and a particle
  Energy levels of atoms
  Types of spectra: absorption, thermal, emission
  Wien’s law
Distance and Angular Size

- You can ALWAYS measure the angular size $\alpha$
- Sometimes, you know the distance to the object
- We can use these to calculate the physical size of the object.

\[
\frac{\alpha}{360^\circ} = \frac{s}{2\pi d}
\]

Solving for $s$

\[
s = \frac{\alpha \times 2\pi d}{360^\circ}
\]
Jupiter has an angular diameter of 31.2 arcseconds. The distance between Jupiter and the Earth is measured to be $9.43 \times 10^8$ km. What is the diameter of Jupiter in kilometers?

a) $1.43 \times 10^5$ km  
b) $2.03 \times 10^5$ km  
c) $1.05 \times 10^4$ km  
d) $3.18 \times 10^5$ km
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Draw this first!
Distance and Angular Size : Example

Jupiter has an angular diameter of 31.2 arcseconds. The distance between Jupiter and the Earth is measured to be $9.43 \times 10^8$ km.

What is the diameter of Jupiter in kilometers?

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b) $2.03 \times 10^5$ km  

c) $1.05 \times 10^4$ km  

d) $3.18 \times 10^5$ km
Stellar Parallax

• This is how we know that it is the Earth that orbits the Sun (and not the other way around)

• Parallax is the effect that nearby stars appear to move back and forth on 1 year timescales. If the Earth orbits the sun, you get this effect. If the Sun orbits the Earth, you don’t get it.

• We can use the distance-angular size relation to find the distance to stars using parallax.
Phases of the Moon
Phases of the Moon

- Ex. When does the first quarter moon rise?

Earth (viewed from the North pole down) rotates counter clockwise.
Phases of the Moon

• Ex. When does the first quarter moon rise?
  At noon!

Earth (viewed from the North pole down) rotates counter clockwise.
Tides

- **Spring tide**: Sun and Moon reinforce each other (highest tides)
- **Neap tide**: Sun and Moon fighting each other (lowest tides)

**total change = a few feet**
Eclipses

• What is a Solar eclipse? total? partial? annular?

• What is a lunar eclipse? total? partial? penumbral?

• Why don’t we have eclipses every month?
Planetary motion

- Retrograde motion: a key observation that models had to be able to explain and predict.
Planetary motion: Ellipses!

- Ellipses
  “A circle with two centers”

- Kepler’s first law:
  Planets orbit the Sun in ellipses with the Sun in one of the focus

\[ c = \text{distance from center to focus} \]
\[ a = \text{semimajor axis} \]

\[ e = \frac{c}{a} \]

\[ \text{aphelion distance} = a(1+e) \]
\[ \text{perihelion distance} = a(1-e) \]
Planetary motion

• **Kepler’s second law:**
  “Equal areas in equal times”

(i.e. moves fastest at perihelion and slowest at aphelion)
Planetary motion

- **Kepler’s third law:**
  Relation between semi-major axis (or average distance to the star) and the orbital period (how long it takes to complete one lap)

\[
\frac{a^3}{p^2} = \text{constant}
\]

- In the case of our Solar system the constant is 1
Problem 3.55

A newly discovered planet orbits a distant star with the same mass as the Sun at an average distance of 112 million kilometers. Its orbital eccentricity is 0.2.

a) Find the planet’s orbital period (in months)
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a) Find the planet’s orbital period (in months)

Step 0: identify the info we got and the question

Step 1: Identify the formula to use: \( \frac{a^3}{p^2} = \frac{1\text{AU}}{1\text{year}} \)

Step 2: check the units and convert if necessary
Problem 3.55

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\[
\frac{a^3}{p^2} = \frac{1\text{AU}}{1\text{year}}
\]

Step 2: check the units and convert if necessary

Step 3: work it out

Step 4: check the units the answer should be in.
A newly discovered planet orbits a distant star with the same mass as the Sun at an average distance of 112 million kilometers. Its orbital eccentricity is 0.2.

a) Find the planet's orbital period (in months)

b) Find the planet's nearest orbital distance from its star. \( e = \frac{c}{a} \)
Problem 3.55

A newly discovered planet orbits a distant star with the same mass as the Sun at an average distance of 112 million kilometers. Its orbital eccentricity is 0.2.

a) Find the planet's orbital period (in months)

b) Find the planet's nearest orbital distance from its star.

c) Find the planet's farthest orbital distance from its star.
Problem 3.55

A newly discovered planet orbits a distant star with the same mass as the Sun at an average distance of 112 million kilometers. Its orbital eccentricity is 0.2.

a) Find the planet’s orbital period (in months) : 7.7 months

b) Find the planet's nearest orbital distance from its star: 0.60 AU

c) Find the planet's farthest orbital distance from its star: 0.90 AU
Newton’s version of Kepler’s 3rd law

- Kepler’s version: \( \frac{a^3}{p^2} = \text{constant} \)

- Newton’s version: \( \frac{a^3}{p^2} = \frac{GM}{4\pi^2} \)
  
  Constant for any planet orbiting a star of mass M

- a: average distance planet-star
p: orbital period for planet
G: gravitational constant
M: mass of the star

- This is how we can calculate the mass of any star if we know the orbital parameters of a planet that orbits it!

Disclaimer: When using this expression we are neglecting the mass of the planet.
Problem 4.57

\[ \frac{a^3}{p^2} = \frac{GM}{4\pi^2} \]

The Moon orbits Earth in an average time of 27.3 days at an average distance of 384,000 kilometers. Use these facts to determine the mass of Earth (in kg).

Step 0: identify the info we got and the question

Step 1: Identify the formula to use

Step 2: check the units and convert if necessary

Step 3: work it out

Step 4: check the units the answer should be in.
Motion basics

- **Velocity:**
  Change in position over time
  Speed (number) + direction

  \[ v = \frac{\text{distance}}{\text{time}} = \left[ \frac{\text{m}}{\text{s}} \right] \]

- **Acceleration:**
  Change in velocity over time
  Change in speed or direction

  \[ a = \frac{\text{speed}}{\text{time}} = \left[ \frac{\text{m}}{\text{s}^2} \right] \]
Newton’s laws

- **First law: Inertia**
  
  An object at motion stays at motion, an object at rest stays at rest, unless some force acts upon the object.

- **Second law:**
  To change the velocity of an object (to cause an acceleration) requires a force.
  \[ F = ma \]

- **Third law:**
  Action and reaction
  \[ F_1 = F_2 \]
Gravity

• If an object has mass, then it can feel gravity. Maybe is not very strong because the mass is small, or because is far away, but gravity is always there,

\[ F_{\text{gravity}} = \frac{GmM}{r^2} \]

\[ G = 6.67 \times 10^{-11} \frac{\text{m}^3}{\text{s}^2\text{kg}} \]
Problem 4.36

- If Earth were twice as far from the Sun, the force of gravity attracting Earth to the Sun would be:
  
a) twice as strong  
b) half as strong  
c) one-quarter as strong

\[ F_{\text{gravity}} = \frac{GmM}{r^2} \]

\[ G = 6.67 \times 10^{-11} \frac{\text{m}^3}{\text{s}^2\text{kg}} \]
Acceleration due to gravity

- Force due to gravity:
  \[ F_{\text{gravity}} = \frac{GmM}{r^2} \]

- Newton’s second law:
  \[ F = ma \]

- Setting \( F = F \)
  \[ \frac{GmM}{r^2} = ma \]

- Simplifying ‘m’
  \[ a_G = \frac{GM}{r^2} \]
Acceleration due to gravity

• The planet Neptune has a mass of $1 \times 10^{26}$ kg and a radius of 24,500 km. If you stand on the surface of Neptune and drop a ball, what is its acceleration?

a) 9.8 m/s$^2$
b) 11 m/s$^2$
c) 1.1 m/s$^2$
d) 98 m/s$^2$
e) 110 m/s$^2$

\[ a_G = \frac{GM}{r^2} \]
Conservation of Energy and Orbits

- Kepler’s second law: Planets sweep equal areas in equal times

- At perihelion (smallest distance)
  P.E. is smallest: closest to the Sun
  K.E. is largest: fastest speed

- At aphelion (largest distance)
  P.E. is largest
  K.E. is smallest

Total energy = K.E. + P.E. = constant
Toolkit so far (not everything is here)

\[ \frac{\alpha}{360^\circ} = \frac{s}{2\pi d} \]  
Angular size-distance relation

\[ \frac{a^3}{p^2} = constant \]  
Kepler’s third law: for the solar system and others

\[ \frac{a^3}{p^2} = \frac{GM}{4\pi^2} \]

\[ v = \frac{\text{distance}}{\text{time}} \]  
Motion basics

\[ a = \frac{\text{speed}}{\text{time}} \]

\[ F = ma \]  
Newton’s second law

\[ e = \frac{c}{a} \]  
eccentricity

\[ F_{\text{gravity}} = \frac{GmM}{r^2} \]  
Gravity and acceleration

\[ a_G = \frac{GM}{r^2} \]  
due to gravity