Midterm Results
Average: 26/38

Grades:
A: 32-38
B: 26-31
C: 20-25
D: 14-19

Average: 26.1
σ = 6.3
Midterm Results
Average: 27/38

Grades:
A: 32-38
B: 26-31
C: 20-25
D: 14-19
If a star with mass of 5 MSUN uses 300 kg of Hydrogen, roughly 3 kg of mass will be lost. Use $E = M c^2$ to compute the energy released (in Joules, $J=\text{kg} \ \text{m}^2/\text{s}^2$). The speed of light is: $3 \times 10^8 \text{ m/s}$.

A.) $1.5 \times 10^{19}$ Joules
B.) $2.7 \times 10^{19}$ Joules
C.) $4.5 \times 10^{17}$ Joules
D.) $2.7 \times 10^{17}$ Joules
Binary Stars in Astronomy

Most of our knowledge of stars’ **Masses** comes from **binary stars**

In a **binary star** system two stars orbit each other.

*Alberio, a double star in Cygnus*

*Alpha Centauri A & B, The nearest star system to the Sun*
Motion Measures Mass

In a binary star system, both stars orbit around the Center of Mass, or balance point.

By measuring the motions of the stars, (ie their orbits) we can determine their mass.
Kepler’s 3rd Law & Mass

Isaac Newton used Gravity to derive Kepler’s Laws of planetary motion. He improved Kepler’s 3rd law to read:

\[ P^2 = \frac{a^3}{(M_1 + M_2)} \]

- \( P \) = orbital period (in years)
- \( a \) = semi-major axis (AU)
- \( M_1 \) & \( M_2 \) = Masses of the two orbiting bodies
  - \( M \) is measured using the Sun’s Mass: \( M_{\text{Sun}} \)

So, if we measure the size of the orbit (semimajor axis, \( a \)) and the period (\( P \)), we can find the \textbf{masses} of stars in a binary system.
If a binary star has a period of 4 years, and a semi-major axis of 2 AU, what is the combined mass of the two stars?

\[ P^2 = \frac{a^3}{(M_1 + M_2)} \]

\[ (M_1 + M_2) = \frac{a^3}{P^2} \]

\[ (M_1 + M_2) = \frac{a^3}{P^2} = \frac{2^3}{4^2} \]

\[ = \frac{8}{16} = 0.5 \, M_{\text{sun}} \]

The combined mass is 1/2 the mass of the Sun.
Mass and Luminosity are Related

We have measured the mass of many main sequence stars using binary stars.

We find that:

More massive stars are also more luminous...

...much more luminous...
The Mass-Luminosity Relation on the Main Sequence

\[ L \sim M^{3.5} \]
Chapter 11 Summary

- Distances to stars: Parallax method
- Luminosity of stars \((L_{\text{sun}})\)
- Absolute \((M)\) and Apparent \((m)\) magnitudes.
- Organizing stars: HR Diagrams
- Measuring stellar masses: Binary Stars
HR Diagram

...Is a graph of a star’s Luminosity vs. its Temperature

Most stars fall on a single line, The Main Sequence

Other stars:

Giants

Supergiants

White Dwarfs
CHAPTER 12

The Lives of the Stars

Optional:
Sec. 12:1-12:6
Where do Stars Come From?

Some stars are old, but others are very young; they must have just formed.

What could these stars form out of? Empty Space?

The space between the stars is not empty; it contains gas and dust.
Material between the stars is called the Interstellar Medium (ISM)
It is very diffuse and thin…. In most places it is almost a vacuum.
But other places have dense concentrations of gas called Nebulae
The ISM is Visible as Clouds Called **Nebulae**

(Inter-Stellar Medium)

The Eagle Nebula

(ground based photo)

Eagle Nebula Closeup

(Hubble Space Telescope)
Stars form in Giant Clouds

Star-forming Cloud in Ophiuchus
Triggered Star Formation

A nebula’s **density** must increase dramatically to form a star.

This could happen if a nearby star **explodes** & creates a shock wave that compresses the nebula.

If parts of the nebula become dense enough, they will be pulled together by gravity.

Parts of a nebula may collapse into dense knots of gas called **“protostars”**