54/100

Avery Wagner

ASTR 1040 Midterm Exam 1 (100 points)

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1 Constants you may need...

$$1\text{ AU} \approx 1.496 \times 10^{11}\text{ m}$$
$$1\text{ pc} \approx 3.26\text{ ly} \approx 3.086 \times 10^{16}\text{ m}$$
$$1\text{ ly} \approx 9.461 \times 10^{15}\text{ m}$$
$$1\text{ eV} \approx 1.602 \times 10^{-19}\text{ J}$$
$$\sigma \approx 5.67 \times 10^{-8}\frac{\text{W}}{\text{m}^2\text{K}^4}$$
$$c \approx 2.998 \times 10^{8}\frac{\text{m}}{\text{s}}$$
$$m_p \approx 1.67 \times 10^{-27}\text{ kg}$$
$$m_e \approx 9.109 \times 10^{-31}\text{ kg}$$
$$k_B \approx 1.37 \times 10^{-23}\frac{\text{J}}{\text{K}}$$
$$G \approx 6.674 \times 10^{-11}\frac{\text{m}^3}{\text{kgs}^2}$$
$$H_0 \approx 70\frac{\text{km}}{\text{sMpc}} \approx 2.2 \times 10^{-18}\frac{1}{\text{s}}$$
$$h \approx 6.626 \times 10^{-34}\text{ J} \cdot s$$
$$M_\odot \approx 1.989 \times 10^{30}\text{ kg}$$
$$L_\odot \approx 3.827 \times 10^{26}\text{ W}$$
$$R_\odot \approx 6.96 \times 10^{8}\text{ m}$$
$$F_\odot \approx 1,380\frac{\text{W}}{\text{m}^2}\text{ (at Earth's surface)}$$
$$M_\oplus \approx 5.97 \times 10^{24}\text{ kg}$$
$$R_\oplus \approx 6.4 \times 10^{6}\text{ m}$$
$$g \approx 9.81\text{m/s}^2$$
$$q_p = -q_e = e \approx 1.602 \times 10^{-19}\text{ C}$$

Spectral types: O, B, A, F, G, K, M

2 Multiple Choice (40 points, 2 points each)

2.1 Which forces balance each other in stars that are in hydrostatic equilibrium?

high T
high P_{pres}

a) pressure gradient and electromagnetism
b) pressure gradient and gravity
c) strong nuclear force and electromagnetism
d) strong nuclear force and gravity
e) strong and weak nuclear forces

2.2 What is the source of neutrinos we observe coming from the Sun?

a) solar flares releasing highly energetic particles
b) the magnetic field heating of the solar corona
c) decay of helium atoms due to weak force interactions
d) nuclear fusion reactions obeying particle physics conservation laws
e) The breaking and recombining of magnetic field lines in the solar cycle

* **2.3 When we use Einstein's famous $E = mc^2$ to calculate the amount of energy released by 1 nuclear fusion reaction following the proton-proton chain, what does the mass m (approximately) refer to?**

$E \Rightarrow$ from tiny diff in mass

$4\,{}^1H + 2e \rightarrow 4\,{}^4He$

a) the mass of a proton
b) the total mass of 4 protons
c) ~~the mass of the star~~
d) the difference in mass between 4 protons and a Helium nucleus
e) the mass of a Hydrogen atom

2.4 How are thermal (blackbody) radiation's wavelength of peak intensity and effective temperature related to each other?

$T = \frac{b}{\lambda_{max}}$ $\quad T \propto \frac{1}{\lambda_{max}}$

a) proportional
b) exponential
c) inversely proportional
d) they're not
e) constant multiples of each other

2.5 What is the spectral classification of the star closest to Earth?

SUN

a) O
b) A
c) G
d) M

-2

2.6 W

2.6 Which property is most responsible for determining where a main sequence star falls on the HR diagram?

a) metallicity
b) mass
c) age
d) radius
e) intensity

The next 3 questions refer to the following data table for a selection of stars. Assume that there is zero extinction from the interstellar medium for each star.

2.5

	STAR	APPARENT MAGNITUDE (m)		ABSOLUTE MAGNITUDE (M)	SPECTRAL TYPE	LUMINOSITY CLASS
(a)	Antares	+0.9	Δ=5.4	-4.5	M1 (7)	I
(b)	Arcturus	-0.05	Δ=1.5	-0.2	K2	III
(c)	Rigel	+0.1	Δ=7.2	-7.1	B8	I
(9) (d)	Alpha Cen A	0.0 bright	Δ 4.4	+4.4 dim	G2	V (8)
(e)	Altair	+0.8	Δ=1.3	+2.2	A7	IV

2.7 Which star has the lowest effective surface temperature?

a) Antares
b) Arcturus
c) Rigel
d) Alpha Centauri A
e) Altair

O B A F G K M

2.8 Which star is most similar to our Sun?

a) Antares
b) Arcturus
c) Rigel
d) Alpha Centauri A
e) Altair

✗ **2.9 Which star is farthest away from Earth?**

a) Antares
b) Arcturus
c) Rigel
d) Alpha Centauri A
e) Altair

Apparent magnitude

-2

2.10 Why is there an upper limit on all the masses of stars?

a) stars over the upper mass limit tend to interfere with each other's stellar winds and magnetic fields too much
b) extremely massive stars would instantly go supernova
c) there isn't, the upper limit only applies to roughly our Local Group
d) if stars got more massive they would be too energetic and blows themselves apart
e) heavier stars end up in supermassive black holes

2.11 The HR diagram in its typical form plots luminosity vs. temperature. Which of the following can be used to infer temperature?

a) spectral type and redshift
b) color and spectral type
c) rotation rate and redshift
d) color and rotation rate
e) spectral type and mass

2.12 The star Betelgeuse—which we all hope goes supernova soon—has an effective surface temperature of a few thousand K, significantly cooler than the Sun, but its luminosity is on the order of $10^5 L_\odot$. What gives??

a) Betelgeuse is cooler and redder but is many light years away from us, so the inferred luminosity is large
b) someone said Betelgeuse 3 times
c) Betelgeuse is cooler and redder but is a red supergiant with a far larger radius
d) peak wavelength is inversely proportional to temperature so the cooler star gives off more energy
e) Betelgeuse is believed to be currently in an expanding flare phase and is temporarily more luminous

2.13 Compared to how long the Sun will be on the main sequence, stars which are more massive than the Sun have main sequence lifetimes which are...

a) longer
b) shorter
c) about the same
d) it depends on the luminosity
e) longer than the age of the universe

2.14 What is/are the key ingredient/s for the prequel to *A Star Is Born*?

a) consistent radiation pressure from nearby stellar winds
b) gravitational instability to begin cloud collapse
c) turbulence in the interstellar medium
d) cold, dense cloud with mostly hydrogen
e) b) and d)

2.15 Suppose that all O spectral type stars have the same intrinsic luminosity. If we observe two O type stars in essentially the same direction in the sky but find that one of them is 16 times dimmer than the other, how much farther away is the dimmer star relative to the nearer one?

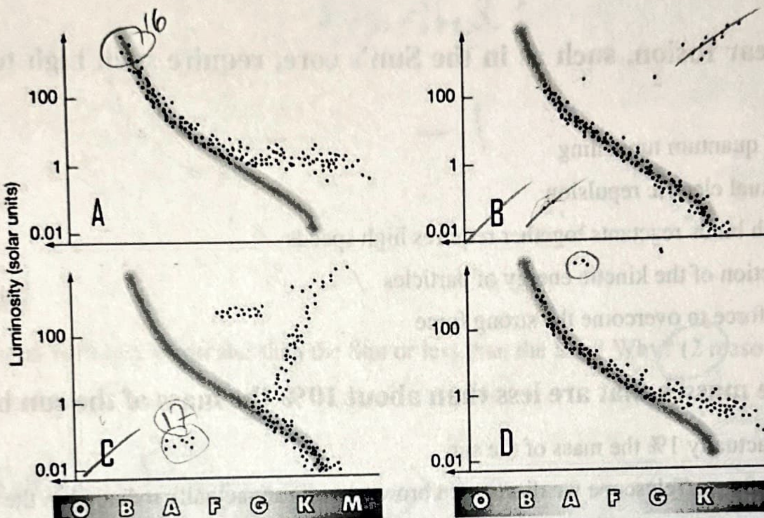
2^{4} 2^{2}

$d = \sqrt{\frac{L}{4\pi I}}$

$I = \frac{L}{4\pi d^2}$

$I \propto \frac{1}{d^2}$

a) 32 times farther
b) 16 times farther
c) 8 times farther
d) 4 times farther
e) 2 times farther



2.16 The figure above shows HR diagrams for 4 different star clusters, with identical axes and main sequence on each plot. Which star cluster is youngest?

Open
↳ "bluer"

a) A
b) B
c) C
d) D
e) cannot be determined with the given information

2.17 The figure above shows HR diagrams for 4 different star clusters, with identical axes and main sequence on each plot. Which star cluster is oldest?

a) A
b) B
c) C
d) D
e) cannot be determined with the given information

2.18 Astronomers are planning to spectroscopically observe a K type star with effective surface temperature $T_\star = 3600\ K$. If it's known that there's a gas cloud with temperature $T_{cloud} = 100\ K$ directly between Earth and the K type star, what should the astronomers expect to see in the star's spectrum at wavelengths where the gas cloud has spectral lines? *Hint: think about the Sun*

a) absorption features
b) emission features
c) blackbody/thermal continuum
d) all of the above
e) the future

2.19 Why does nuclear fusion, such as in the Sun's core, require such high temperatures and pressures?

a) it does not because of quantum tunnelling
b) to overcome their mutual electric repulsion
c) the strong force, which binds reactants together requires high speeds ✓
d) temperature is a reflection of the kinetic energy of particles ✓
e) in order for the weak force to overcome the strong force

2.20 Stars can't have masses that are less than about 10% the mass of the sun because

a) they can, this limit is actually 1% the mass of the sun
b) they can, with Hubble Space Telescope we discovered brown dwarfs are actually radiating in the infrared
c) below this limit their masses are insufficient for gravity to overcome the thermal pressure of the cloud and fusion to commence ✓
d) degeneracy pressure prevents the cloud from condensing enough for the core to get hot enough for fusion
e) below this limit, the mass of low mass stars is insufficient to overcome turbulence generated by winds from high mass stars

-2

3 Short Answer Questions (24 points)

Answer the following questions in *a few* sentences.

3.1 [4 points]

Explain what's meant by the concept of the "solar thermostat." On a related note, if it's in equilibrium, why is the Sun gradually getting brighter?

how does it do the things you described?

−1

3.2 [4 points]

Are there more stars with masses greater than the Sun or less than the Sun? Why? (2 reasons)

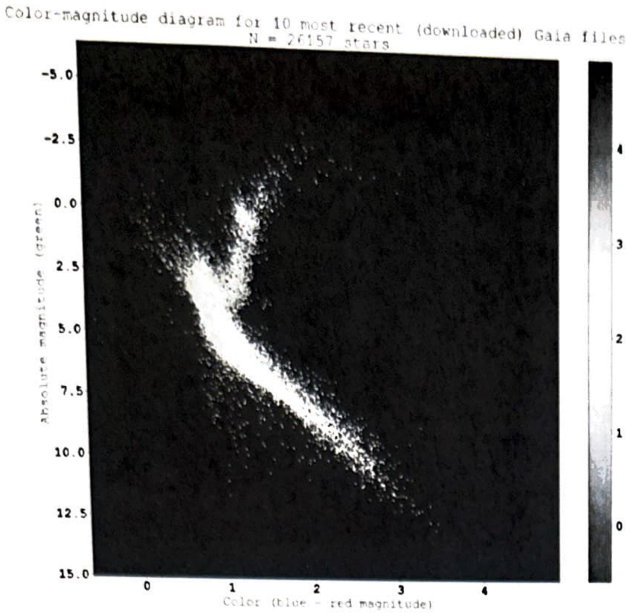
only 1 reason given −2

3.3 [4 points]

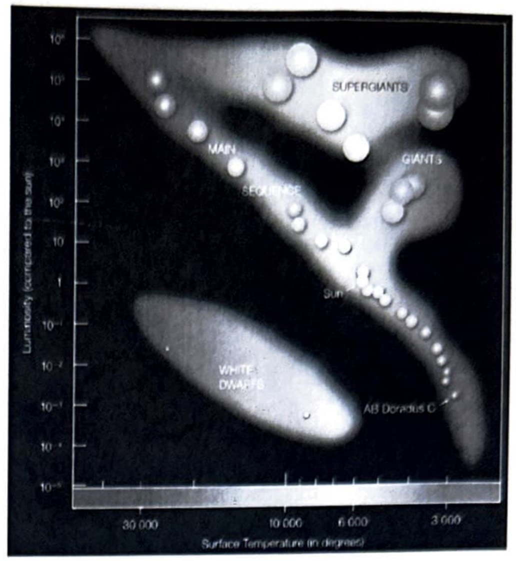
How long was the lifespan of the first generation of stars, why did they live this long, and why were they important?

−4

−7



(a) Gaia color-magnitude diagram



(b) Standard HR diagram as seen in class

3.4 [12 points]

Above are two versions of the HR diagram. At left is a color-magnitude diagram constructed from real Gaia data (a satellite that measures many stars in the Milky Way). You can assume the stars observed represent a roughly random statistical sample of stars in the Milky Way (so they are **not all from a single cluster**, but from many many clusters across the entire galaxy). At right is the idealized version of the HR diagram as seen in class.

a) (4 pts) Explain why the color-magnitude diagram is a suitable proxy for the HR diagram at right. In particular, how are the axes of both plots transferable?

✓

b) (8 pts) Identify two key differences between the Gaia and textbook HR diagrams and offer a possible explanation for *why* those differences exist. *Hint: think about observational / statistical constraints.*

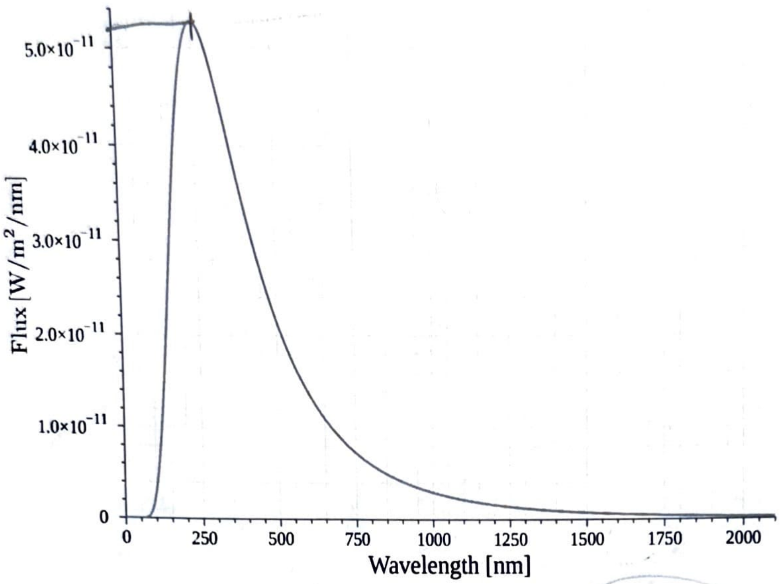
WD reason ✓ other reason X

-3

4 Quantitative (36 points)

4.1 Properties of stars 1 (18 points)

Say you observe a mystery star to have the (somewhat unrealistic) spectrum below. You also find that it has a parallax angle of 0.130" and an integrated flux of $\approx 2 \times 10^{-8}$ W/m^2.



(a) [12 points] Calculate the surface temperature (in K), the luminosity (in terms of $L_\odot$), and radius (in terms of $R_\odot$) of the mystery star.

$T = \frac{b}{\lambda_{max}}$ ✓

$d = \frac{1 AU}{\alpha [rad]}$

$L = 4\pi d^2 \cdot I$

$R = \sqrt{\frac{A}{4\pi}}$ ✗ $\frac{L}{I}$

−6

(b) [6 points] Comment briefly on what your answers to part (a) imply about the spectral designation and rough expected lifetime of the mystery star.

answer cut off on PDF, come talk to me for more points...

−6

−12

4.2 Properties of stars 2 (18 points)

Two stars are orbiting each other in a binary system. We take spectra of them over several years and find they have an orbital period of 1 year. We additionally find that star 1 has an orbital velocity of 0.22 km/s and star 2 has an orbital velocity of 110 km/s. Parallax measurements indicate a parallax of 0.1", allowing us to infer their intrinsic luminosities to be 8×10^5 $L_\odot$ and 3×10^{-3} $L_\odot$.

(a) [12 points] Estimate the mass of each star, assuming the orbits are circular.

−12

(b) [6 points] The stars were born at the same time 1 million years ago, and the brighter star just turned off the main sequence. Approximately when will the fainter star turn off the main sequence? (Assume the bright star does not affect the faint star's main sequence lifetime).

−6

−18