Ay 1 – Midterm

Due by 5pm on Wednesday, May 4, to your head TA’s mailbox (249 Cahill), or hand it directly to your section TA.

You have THREE HOURS to complete the exam, but it is about two hours long.

The exam is closed notes (anything from the class, including the lecture slides and your own notes) and NO internet. You should either know, or be able to derive any formulas that may be needed. You may use a standard calculator. The exam has a no collaboration policy. The usual honor code rules apply.

The exam includes a table of all the constants you will need (and more).

There are NINE PAGES in the exam (including this cover sheet and the table of constants). Make sure you have all the pages before starting.

Breakdown of the exam:
12 multiple choice questions
5 short answer questions
4 computational questions

For the computational questions, please show all work. If you use any additional paper, turn it in with your exam. If you get stuck on a problem, write down what you can, and you will receive partial credit.
Ay 1 – Midterm

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Your name: ___________________________ Your section: _______

Section I.

Multiple choice questions have only one correct answer, worth 1 point; circle only one.

1. The Sun will spend about 10 billion years burning hydrogen on the Main Sequence. You look at an open cluster and construct an HR diagram which shows a Main Sequence turnoff at about 6500 K. How old is this cluster?
   A. More than 10 billion years.
   B. Less than 10 billion years.
   C. You can’t tell the age of the cluster from its Main Sequence turnoff point.
   D. The same age as the Sun.

2. Which type of stars die as supernovae?
   A. Very massive stars (8 solar masses or more).
   B. Moderately massive stars (between 4 and 8 solar masses).
   C. Sun-like stars (roughly 1 solar mass).
   D. M-dwarfs and other stars smaller than the Sun.

3. Which event marks the time that a star departs from the Main Sequence and becomes a red giant?
   A. When it is more than 10 billion years old.
   B. When gravitational interactions with nearby star systems lead it to begin accreting more mass.
   C. When it has converted all of the available hydrogen in its core to helium.
   D. When it has a significant fraction of the heavy metal iron.

4. What is the correct order for the following stages in the birth of a star?
   i. Gravitational instability causes a cloud of gas and dust to undergo freefall.
   ii. Nuclear fusion begins.
   iii. Rise in interior temperature and pressure while radiating away gravitational energy.
   A. i, ii, iii
   B. ii, iii, i
   C. i, iii, ii
   D. iii, i, ii
5. What is the best technique of those below to determine the size of an exoplanet?
   A. Gravitational microlensing
   B. Pulsar timing variations
   C. Eclipsing transits
   D. Radial velocity

6. If the measured parallax of Sirius is 0.38", what is its distance from Earth in parsecs?
   A. 0.26 pc
   B. 2.6 pc
   C. 26 pc
   D. 550 kpc

7. Which radiation type has the highest energy?
   A. Gamma ray
   B. Radio
   C. Optical
   D. X-ray

8. What is the most essential physical property to know for a Main Sequence star if you want to determine its other properties?
   A. Radius
   B. Temperature
   C. Mass
   D. Proper motion

9. Which of the following does NOT affect the shape of a spectral line?
   A. Density
   B. Thermal velocities
   C. Magnetic field strength
   D. Proper motion

10. An ideal blackbody...
    A. Emits all wavelengths of radiation.
    B. Absorbs all wavelengths of radiation.
    C. Obeys Wien’s law.
    D. All of the above.

11. The spectrum of Star A peaks at 700 nm. The spectrum of Star B peaks at 470 nm. We know nothing about what stage of stellar evolution either of these stars are in. Which of the following are true?
    A. Star A has a higher luminosity than Star B.
    B. Star B has a higher luminosity than Star A.
    C. Star A is cooler than Star B.
    D. Not enough information to comment on their luminosities.
    E. B and C
    F. C and D
12. Consider the angular momentum $L$ of the Earth when it is closest to the Sun in its orbit ("perihelion") and farthest from the Sun ("aphelion"). Which of the following is true?

A. $L_{\text{aphelion}} > L_{\text{perihelion}}$
B. $L_{\text{aphelion}} = L_{\text{perihelion}}$
C. $L_{\text{aphelion}} < L_{\text{perihelion}}$
D. Not enough information

Section II.

Short answer questions, limit answer to a few sentences, no more than a paragraph.

13. (3 points) For a while, most exoplanets were found using the radial velocity technique and tended to be very massive, close-in planets ("Hot Jupiters"). Explain how the nature of this detection technique leads to a bias for finding massive, short-period planets.

14. (3 points) What is the difference between Type Ia and Type II supernovae, in terms of 1) the kinds of stars that explode and 2) their explosion mechanisms?
15. (3 points) Outline and briefly describe the basic stages of stellar evolution for a 1 solar mass star, starting with its time on the Main Sequence and ending with its final state.

16. (3 points) Draw a simple diagram that shows how a cloud in the ISM can appear as 1) a blue reflection nebula and 2) a red transmission nebula, depending on your line of sight. Explain what is happening and how dust in the ISM plays a role.
17. (3 points) Explain why the bright (dark) spectral lines emitted from (absorbed by) the atoms of an element are unique to the element.

Section III.

Computational questions:

18. (4 points) Mars has an albedo of 15%. Given that it doesn’t have much of an atmosphere, estimate the mean surface temperature on Mars. Note: the semimajor axis of the orbit of Mars is 1.52 AU.

Show your calculations (intermediate steps) here:

Write your answer here:
19. (4 points) The red supergiant Betelgeuse has a surface temperature of 3600 K.

   a) Using the fact that the Sun's surface temperature is about 5800 K and that its continuous spectrum peaks at a wavelength of 500 nm, find the peak wavelength of Betelgeuse's continuous spectrum. What region of the electromagnetic spectrum is this?

   b) Betelgeuse has a luminosity that is 120,000 times that of the Sun. Find Betelgeuse's radius.

   Show your calculations (intermediate steps) here:

   Write your answers here:

   a)______________________________

   b)______________________________

20. (4 points) A geosynchronous satellite is a satellite whose orbital period matches the rotation of the Earth. Calculate the height above the surface of the Earth which a satellite must have in order to be in a geosynchronous orbit.

   Show your calculations (intermediate steps) here:

   Write your answer here:

______________________________
21. (4 points)

a) Compare the angular resolutions of the following two telescopes: 1) the Hubble Space Telescope (2.4-meter aperture) at optical wavelengths and 2) the Very Long Baseline Array (VLBA), a radio interferometer with a maximum baseline of 8600 km observing at 1-mm wavelengths.

b) The Event Horizon Telescope is attempting to image the supermassive black hole at the center of the Milky Way using Very Long Baseline Interferometry. Using the angular resolution you found above, how big of an object at the center of the Milky Way can the Event Horizon Telescope resolve? Put your answer in units of solar radii.

Show your calculations (intermediate steps) here:

Write your answers here:

a)______________________________

b)______________________________
## Appendix C
### Physical and Astronomical Constants and Unit Conversions

**Table C.1  Physical constants.**

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Symbol</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed of light</td>
<td>$c$</td>
<td>2.997 924 58 $\times$ 10$^{10}$</td>
<td>cm$^{-1}$</td>
</tr>
<tr>
<td>Gravitational constant</td>
<td>$G$</td>
<td>6.672 59(85) $\times$ 10$^{-8}$</td>
<td>dyn cm$^2$ g$^{-2}$</td>
</tr>
<tr>
<td>Planck constant</td>
<td>$\hbar$</td>
<td>6.626 075 5(40) $\times$ 10$^{-27}$</td>
<td>erg s$^{-1}$</td>
</tr>
<tr>
<td>Boltzmann constant</td>
<td>$k$</td>
<td>1.380 658(12) $\times$ 10$^{-16}$</td>
<td>erg K$^{-1}$</td>
</tr>
<tr>
<td>Stefan–Boltzmann constant</td>
<td>$\sigma$</td>
<td>5.670 51(19) $\times$ 10$^{-5}$</td>
<td>erg cm$^{-2}$ K$^{-4}$ s$^{-1}$</td>
</tr>
<tr>
<td>Thomson cross-section</td>
<td>$\sigma_T$</td>
<td>0.665 246 16 $\times$ 10$^{-24}$</td>
<td>cm$^2$</td>
</tr>
<tr>
<td>Electron charge</td>
<td>$e$</td>
<td>4.803 206 8(15) $\times$ 10$^{-10}$</td>
<td>E.S.U.</td>
</tr>
<tr>
<td>Electron mass</td>
<td>$m_e$</td>
<td>9.109 389 7(54) $\times$ 10$^{-28}$</td>
<td>g</td>
</tr>
<tr>
<td>Proton mass</td>
<td>$m_p$</td>
<td>1.672 623 1(10) $\times$ 10$^{-24}$</td>
<td>g</td>
</tr>
<tr>
<td>Neutron mass</td>
<td>$m_n$</td>
<td>1.674 928 6 $\times$ 10$^{-24}$</td>
<td>g</td>
</tr>
<tr>
<td>Atomic mass unit</td>
<td>$m_u$</td>
<td>1.660 540 2 $\times$ 10$^{-24}$</td>
<td>g</td>
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<tr>
<td>Electron volt</td>
<td>$eV$</td>
<td>1.602 173 3 $\times$ 10$^{-12}$</td>
<td>erg</td>
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### Appendix C Physical and Astronomical Constants and Unit Conversions

#### Table C.2 Astronomical constants.

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Symbol</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Astronomical unit</td>
<td>AU</td>
<td>$1.496 \times 10^{13}$ cm</td>
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</tr>
<tr>
<td>Parsec</td>
<td>pc</td>
<td>$3.086 \times 10^{18}$ cm</td>
<td></td>
</tr>
<tr>
<td>Solar mass</td>
<td>$M_\odot$</td>
<td>$1.989 \times 10^{33}$ g</td>
<td></td>
</tr>
<tr>
<td>Solar radius</td>
<td>$R_\odot$</td>
<td>$6.955 \times 10^{10}$ cm</td>
<td></td>
</tr>
<tr>
<td>Solar luminosity</td>
<td>$L_\odot$</td>
<td>$3.845 \times 10^{33}$ erg s$^{-1}$</td>
<td></td>
</tr>
<tr>
<td>Solar absolute bolometric magnitude</td>
<td>$M_{\text{bol},\odot}$</td>
<td>4.72 mag</td>
<td></td>
</tr>
<tr>
<td>Solar absolute $B$ magnitude</td>
<td>$M_B,\odot$</td>
<td>5.48 mag</td>
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<td>Solar absolute $V$ magnitude</td>
<td>$M_V,\odot$</td>
<td>4.83 mag</td>
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<td>Solar absolute $J$ magnitude</td>
<td>$M_J,\odot$</td>
<td>3.71 mag</td>
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<td>Solar absolute $H$ magnitude</td>
<td>$M_H,\odot$</td>
<td>3.37 mag</td>
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<tr>
<td>Solar absolute $K$ magnitude</td>
<td>$M_K,\odot$</td>
<td>3.35 mag</td>
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</tbody>
</table>

#### Table C.3 Unit conversions.

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Symbol</th>
<th>Conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angström</td>
<td>Å</td>
<td>$1 \text{Å} = 10^{-8}$ cm</td>
</tr>
<tr>
<td>Micron</td>
<td>μm</td>
<td>$1 \text{μm} = 10^{-4}$ cm</td>
</tr>
<tr>
<td>Parsec</td>
<td>pc</td>
<td>$1 \text{pc} = 3.086 \times 10^{18}$ cm</td>
</tr>
<tr>
<td>Light year</td>
<td>ly</td>
<td>$9.46053 \times 10^{17}$ cm</td>
</tr>
<tr>
<td>Kilo-electron volt</td>
<td>keV</td>
<td>$\hbar c/E = 12.39854 \times 10^{-8}$ cm</td>
</tr>
<tr>
<td>Jansky</td>
<td>Jy</td>
<td>$10^{-21}$ erg cm$^{-2}$ s$^{-1}$ Hz$^{-1}$</td>
</tr>
</tbody>
</table>