ASTRONOMY

2025 Southeastern NM Regional

Information

- Please write all answers on the answer sheet. Nothing written in this test book will be scored.
- All images are on the attached image sheet.
- If you have a laptop, please disconnect it from the internet. Also note that AI tools are prohibited.
- For mathematical questions,
    - Don't stress about significant figures, but make sure your answers are in the correct unit
    - You will be eligible for partial credit if you show your work.
- Point values are specified next to each question. Ties will be broken by the last question answered correctly.
- This exam has three sections. Divide and conquer as you will.
- If you have any questions, please feel free to raise your hand and ask!

Above all, try to have fun! Good luck!

Cover Image: Jason Major, NASA Hubble

Section A
TOPIC-SPECIFIC

This section of the exam contains 20 questions for 30 points.

1. [1] What stage of stellar evolution will a star spend most of its lifetime in?
    A. Red Giant
    B. T Tauri
    C. Planetary Nebula
    D. Main Sequence
2. [1] What stage of stellar evolution comes after the red giant phase for a 2 $M_\odot$ star?
    A. Red Dwarf
    B. Planetary Nebula
    C. Type II Supernova
    D. Main Sequence
3. [1] What initial property of a star primarily determines its evolutionary pathway?
    A. Metallicity
    B. Mass
    C. Recessional Velocity
    D. Molecular Cloud Composition
4. [1] What stellar remnant will our sun likely become?
    A. Black Hole
    B. Brown Dwarf
    C. Neutron Star
    D. White Dwarf
5. [1] Which element is the heaviest that can be produced by stellar core fusion?
    A. He B. C
    C. Fe D. Ni
6. [1] A star that fails to initiate hydrogen nuclear fusion is known as what?
    A. Neptune-like Planet
    B. Black Hole
    C. Red Giant
    D. Brown Dwarf
7. [2] What causes a star to leave the main sequence?
8. [1] By definition, a star's apparent and absolute magnitudes are the same when…
    A. …the star is 10 pc away.
    B. …the star is 5000 K.
    C. …the star is our sun.
    D. …the star appears stationary.
9. [2] List the stellar spectral classes from hottest to coolest.
10. [3] For each of the following regions, circle the form of hydrogen (H, H^+, H^-, or H_2) that the region primarily contains.
    (a) H I Region
    (b) H II Region
    (c) Molecular Cloud
11. [1] What range of wavelengths are H I regions typically mapped in?
    A. Radio B. Infrared
    C. Visible D. Ultraviolet
12. [2] What objects typically cause hydrogen to ionize in an H II region?

Consider the star formation diagram in Image A.

13. [1] Which of these stages would cause the formation of a Herbig-Haro object?
14. [2] What is happening in Stage I?
15. [2] What is the process by which the star gains mass in Stage II called?
16. [2] What is the structure around the star in Stage III called?
17. [2] What is one mechanism that causes the massive variability in a T Tauri star?
18. [1] Do Herbig Ae/Be variables or T Tauri variables form more massive stars?
19. [1] In the artist's impression of a Herbig Ae star in **Image B**, which location is a planet most likely forming?
20. [2] As a protoplanet gains mass, it also heats up. What is one source of this heat?

Section B
OBJECTS/SYSTEMS

This section of the exam contains 20 questions for 35 points.

Identification

21. [2] Identify the object pictured in **Image C**.
22. [2] Identify the object pictured in **Image D**.

For each of the following statements, circle the object numeral (i-v) that corresponds to it.

Objects:	
i. WD1856+534	***iv. LTT 9779b***
ii. Kepler-62	***v. HD 80606b***
iii. PSR B1257+12	

23. [1] System with 5 planets, and 2 in the habitable zone.
24. [1] Extremely hot neptune planet, with a high albedo.
25. [1] Possible "survivor" planet around a white dwarf.
26. [1] Hot Jupiter with a highly eccentric orbit and intense weather systems.
27. [1] Planetary system around a neutron star discovered by timing pulsar pulses.

WASP-17b *(a.k.a. Ditsǒ)*

28. [1] Ditsǒ has a mass of around ____ Jupiter's, and a volume of around ____ Jupiter's.
    A. Mass: 7 times, Volume: 0.5 times
    B. Mass: 0.5 times, Volume: 7 times
    C. Mass: 4 times, Volume: 1.2 times
    D. Mass: 1.2 times, Volume: 4 times
29. [2] On Earth, ice clouds are made of tiny frozen water crystals. On Ditsǒ, these clouds are made of what instead?
30. [2] Ditsǒ is a *puffy planet*. What is thought to cause the inflated nature of puffy planets?
    A. Low rotational velocity
    B. Tidal heating
    C. Intense stellar winds
    D. Meteor impacts

GJ 1214b

31. [1] Roughly how far from this planet's star does it orbit?
    A. 0.015 AU B. 0.15 AU
    C. 1.5 AU D. 15 AU
32. [1] This close orbit means the planet has a temperature...
    A. Much hotter than habitable.
    B. Near the habitable zone.
    C. Much colder than habitable.
33. [2] What property of this planet's atmosphere makes studying it difficult?
34. [3] Despite this, researchers managed to estimate the temperature of the planet, and it is far less than expected. What property of this planet do we think causes this?

30 Doradus

35. [2] What is the primary source of x-rays in this object?
36. [3] How does this influence star formation in 30 Doradus?

WASP-121b

37. [3] We observe iron and magnesium gas from WASP-121b far enough away that it is not gravitationally bound. How does this indicate an *extremely* high temperature of the planet?
38. [2] What is thought to rain down on the nightside of this planet?

AU Microscopii

Image E gives the light curve for this system.

39. [2] Estimate the period (in days) of the high-amplitude oscillations of this object.
40. [2] In addition to this periodic oscillation, this object also exhibits flaring activity. How does this flaring activity likely affect the atmospheres of any surrounding planets?

Section C
ANALYSIS

This section of the exam contains 20 questions for 45 points.

Look at the H-R Diagram in Image F.

41. [1] Which of these stars is the brightest?
42. [1] Which of these stars is the hottest?
43. [1] A stellar remnant is located at which of these points?
44. [2] An object at which of these points will eventually explode as a core-collapse supernova?
45. [2] When our faithful sun leaves the main sequence, it will transition from Point IV to Point II. At Point II, what will our sun's new luminosity and radius be?
46. [2] What effect will the transition in the previous question have on Earth's temperature?

Suppose we measure a star with a parallax angle of 0.0031 arcseconds.

47. [2] What is the distance to this star in parsecs?
48. [3] If this star has an apparent magnitude of 11.5, estimate the absolute magnitude.
49. [3] This star has a temperature of 5000 K. Is it a main-sequence star? How do you know? *Hint: there may be a diagram on the image sheet that will help.*

Consider the 3 blackbody spectra in Image G.

50. [3] For each spectrum, determine the visible color of the star that produced it (from blue, white, or red).
51. [2] Order these blackbody spectra from hottest to coldest.

Consider the 2 transmission spectra in Image H.

52. [3] What is one way we can obtain the transmission spectrum of a planet?
53. [3] Suppose we measure these spectra from two planets orbiting nearly exactly the same distance from the same star. Which spectrum corresponds to the planet we would expect to be hotter? Why?

Consider the 2 radial velocity curves in Image I. The planets that generated these curves orbit stars of the same mass.

54. [2] If these planets orbit at the same distance, which system has the more massive planet?
55. [2] Now, suppose these planets have the same mass and orbital distance, which system has a larger inclination angle, as measured from the horizontal?

Look at the transit light curve in Image J. This is for a planet orbiting a star with a stellar radius of 25 solar radii (1.75×10^7 km).

56. [2] What causes the dip in brightness that we observe in this light curve?
57. [2] Estimate the orbital period of this planet, in years.
58. [3] If this planet orbits 0.4 AU away from the star, what is the mass of the star, in solar masses?
59. [3] Is this star a main-sequence star? How do you know?
60. [3] Describe how we can estimate the radius of a planet using a transit light curve, and the radius of the star.
    Don't actually carry out the calculation; you weren't given all the necessary information.

IMAGE SHEET

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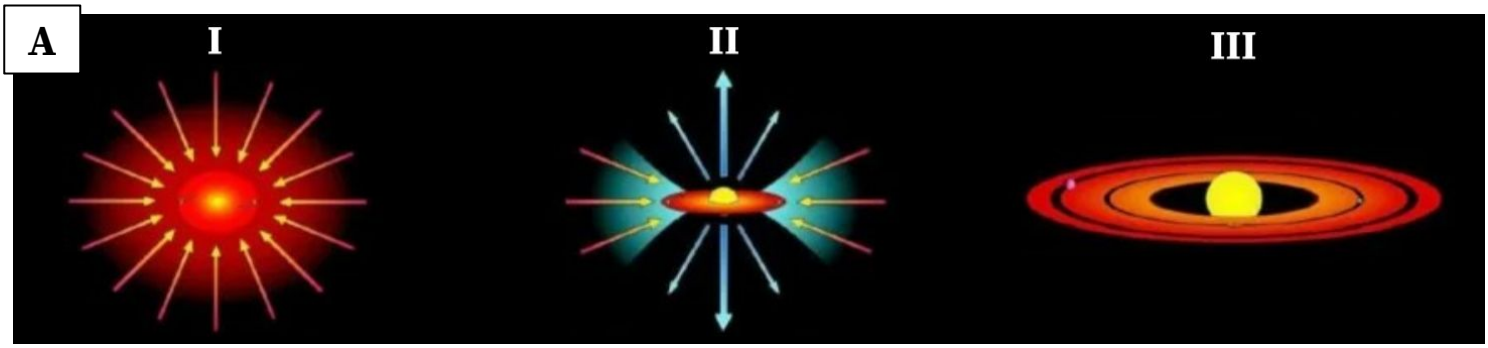
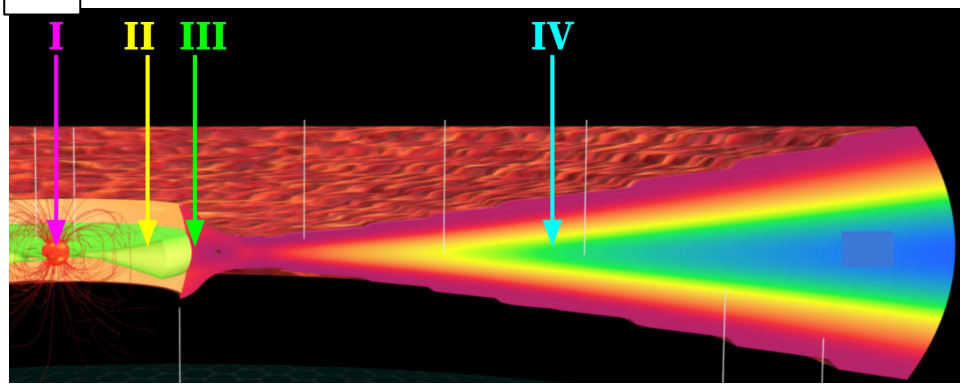
A

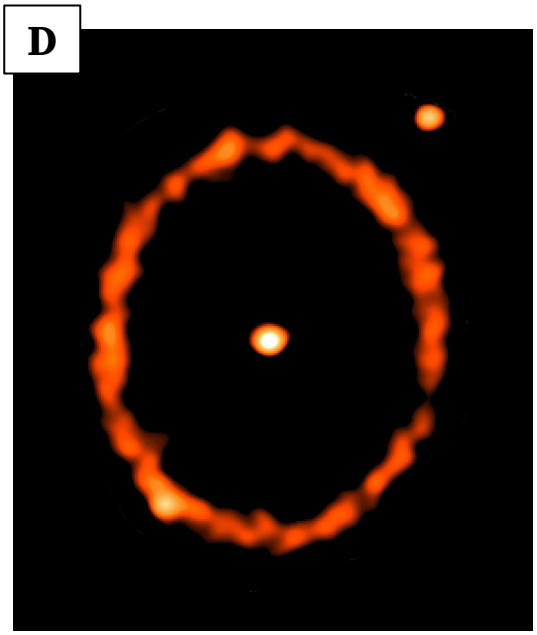


B

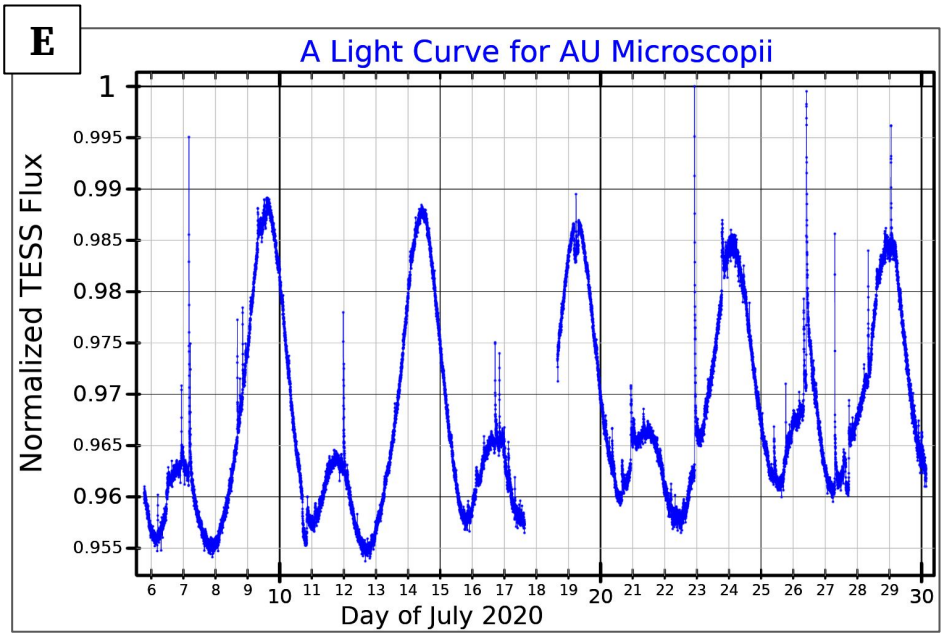


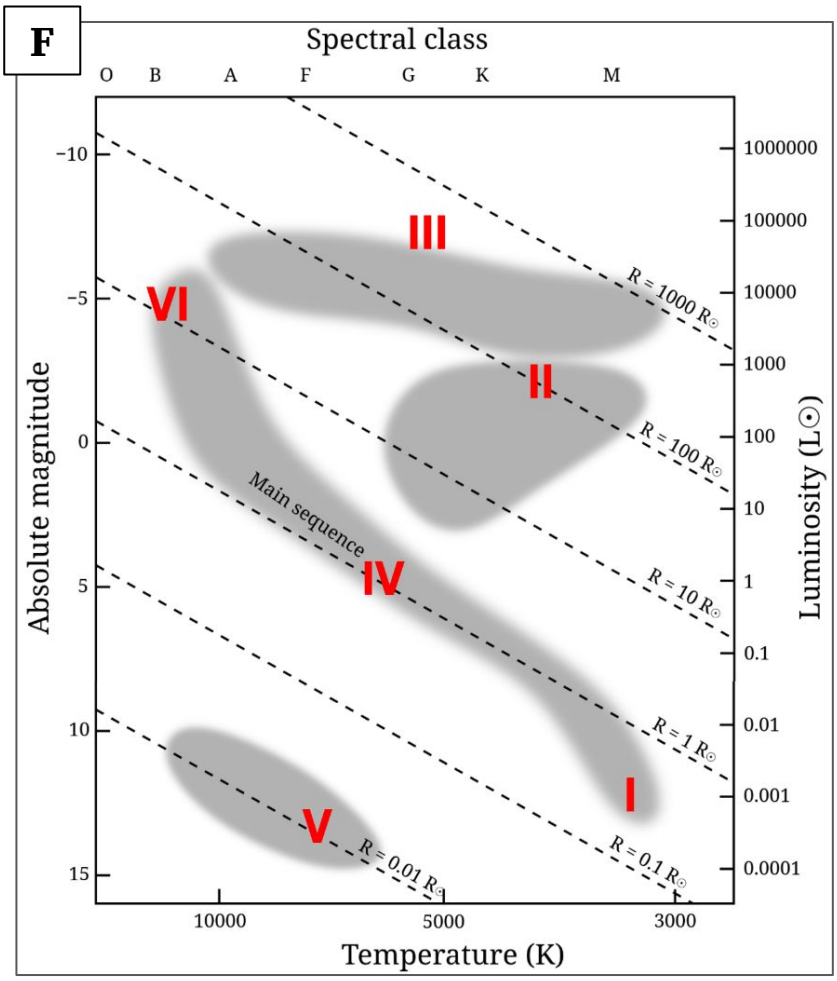
C

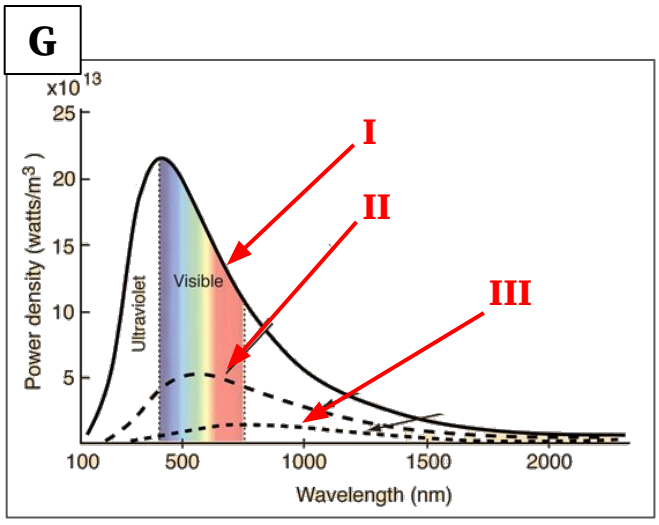
D

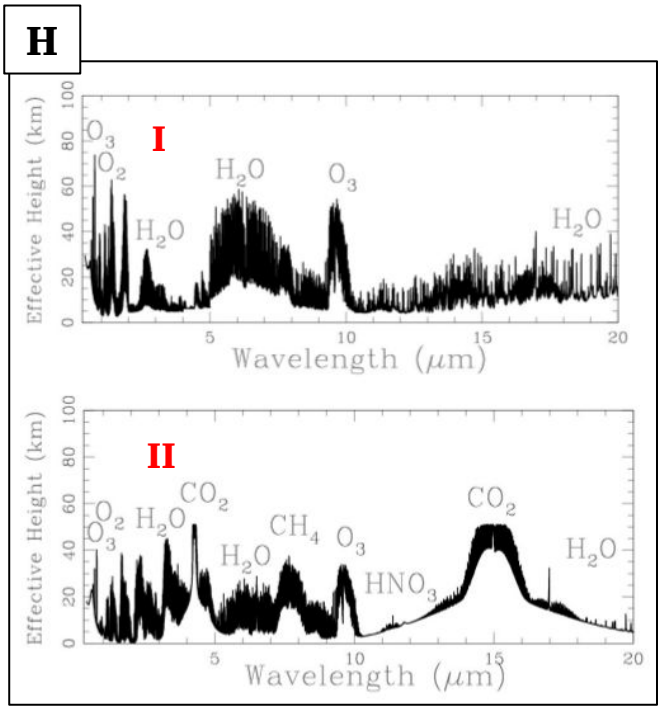


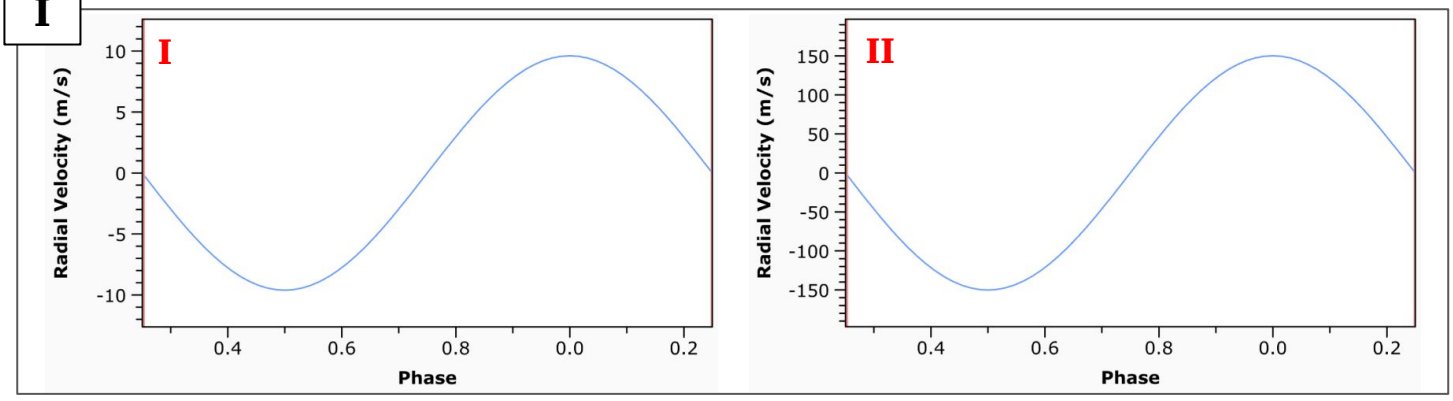
E

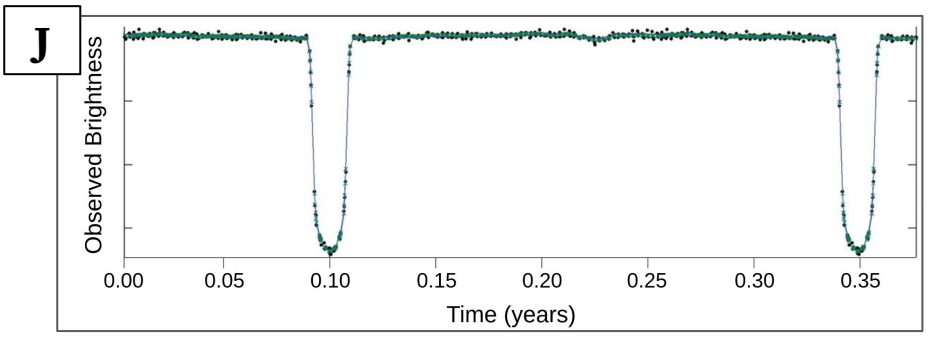



F
Spectral class
O B A F G K M
Absolute magnitude
Luminosity (L⊙)
Temperature (K)
10000
5000
3000
1000000
100000
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
R = 1000 R⊙
R = 100 R⊙
R = 10 R⊙
R = 1 R⊙
R = 0.1 R⊙
R = 0.01 R⊙
Main sequence
I
II
III
IV
V
VI


G
x10 13
Power density (watts/m3)
Ultraviolet
Visible
I
II
III
Wavelength (nm)


H
Effective Height (km)
Wavelength (μm)
I
O3
O2
H2O
H2O
O3
H2O
II
CO2
O2 H2O
O3
H2O
CH4 O3
HNO3
CO2
H2O


I
Radial Velocity (m/s)
Phase
I
II
Radial Velocity (m/s)
Phase
II


J
Observed Brightness
Time (years)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35

ASTRONOMY

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Team Name: _____ Team #: C_____

Student Names: _____

Answer Sheet

- Write all answers on this answer sheet.
- Write your team number at the top of each page.
- If you take this answer sheet apart, staple it back together at the end.
- If you need extra space to continue an answer, you can use the back of this answer sheet. Just be sure to label which question you are continuing.
- If you show work on numerical problems, you will be eligible for partial credit.

Team #: C

SECTION A – TOPIC-SPECIFIC

1. A B C D
2. A B C D
3. A B C D
4. A B C D
5. A B C D
6. A B C D
7. _____
   _____
8. A B C D
9. _____
10. (a) H H^+ H^- H_2
    (b) H H^+ H^- H_2
    (c) H H^+ H^- H_2
11. A B C D
12. _____
    _____
13. I II III
14. _____
    _____
    _____
15. _____
16. _____
17. _____
    _____
18. Herbig Ae/Be / T Tauri
19. I II III IV
20. _____
    _____

SECTION B – OBJECTS/SYSTEMS

21. _____
22. _____
23. *i* *ii* *iii* *iv* *v*
24. *i* *ii* *iii* *iv* *v*
25. *i* *ii* *iii* *iv* *v*
26. *i* *ii* *iii* *iv* *v*
27. *i* *ii* *iii* *iv* *v*
28. A B C D
29. _____
30. A B C D
31. A B C D
32. A B C
33. _____
34. _____
35. _____
    _____
36. _____
    _____
    _____
    _____
37. _____
    _____
    _____
38. _____
39. _____ days
40. _____
    _____
    _____

Team #: C

SECTION C – ANALYSIS

41. I II III IV V VI

42. I II III IV V VI

43. I II III IV V VI

44. I II III IV V VI

45. Luminosity: _____ $L_\odot$

Radius: _____ $R_\odot$

46. Increase / Decrease / Stay Constant

47.

_____ pc

48.

_____

49. Yes / No

_____

_____

50. (I) Red / White / Blue

(II) Red / White / Blue

(III) Red / White / Blue

51. Hottest _____>_____>_____ Coolest

52. _____

_____

_____

_____

53. I II

_____

_____

54. I II

55. I II

56. _____

_____

_____

_____

57. _____ years

58.

_____ $M_\odot$

59. Yes / No

_____

_____

60. _____

_____

_____

_____

_____

_____

ASTRONOMY

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Team Name: Key Team #: C Key

Student Names: Answer Key, Answer Key

Answer Sheet

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Team #: C KEY

SECTION A – TOPIC-SPECIFIC

1 1. A B C (D)
1 2. A (B) C D
1 3. A (B) C D
1 4. A B C (D)
1 5. A B (C) D
1 6. A B C (D)
2 7. The star runs out of hydrogen in its core.
1 8. (A) B C D
2 9. OBAFGKM
3 10. (a) (H) H^+ H^- H_2
(b) H (H^+) H^- H_2
(c) H H^+ H^- (H_2)
1 11. (A) B C D
2 12. Young stellar objects; Young, hot stars
1 13. I (II) III
2 14. Material in a cool molecular cloud begins collapsing by gravity.
2 15. Accretion
2 16. Debris Disk
One of; 2 17. Sunspots/Hotspots; Variable Accretion; Variation in dust extinction
1 18. (Herbig Ae/Be) / T Tauri
1 19. I II III (IV)
One of: 2 20. Radioactive decay; Kinetic/Impacts; Gravitational contraction/core formation

SECTION B – OBJECTS/SYSTEMS

2 21. Orion Nebula
2 22. Epsilon Eridani
1 23. *i* (*ii*) *iii* *iv* *v*
1 24. *i* *ii* *iii* (*iv*) *v*
1 25. (*i*) *ii* *iii* *iv* *v*
1 26. *i* *ii* *iii* *iv* (*v*)
1 27. *i* *ii* (*iii*) *iv* *v*
1 28. A (B) C D
2 29. SiO_2 or Quartz
2 30. A (B) C D
1 31. (A) B C D
1 32. (A) B C
2 33. Haze
3 34. High Albedo
2 35. Shock fronts from stellar winds.
3 36. This can cause gas to compress, triggering gravitational collapse and star formation.
3 37. It is so hot that these metal vapors escape and do not condense into clouds
2 38. Gemstones; Fe; Rubies; Sapphires
2 39. 5 days
2 40. Strips the atmospheres of surrounding planets.

Team #: C KEY

SECTION C – ANALYSIS

1 41. I II **III** IV V VI

1 42. I II III IV V **VI**

1 43. I II III IV **V** VI

2 44. I II **III** IV V **VI** ← Accept Either

2 45. Luminosity: **500 - 1000** $L_\odot$

Radius: **100** $R_\odot$

2 46. **Increase** / Decrease / Stay Constant

2 47. $d = \frac{1}{p} = \frac{1}{0.003}$"

~~769~~ **323** pc

3 48. $m - M = -5 + 5 \log d$

$11.5 - M = -5 + 5 \log(323)$

$M = 3.96$

3 49. **Yes** / No

The temp + abs mag place it on the Main Sequence on H-R

3 50. (I) Red / White / **Blue**

(II) Red / **White** / Blue

(III) **Red** / White / Blue

2 51. Hottest **I** > **II** > **III** Coolest

3 52. When the planet passes in front of the star, we take a spectrum and subtract the star's spectrum.

3 53. I **II**

The atmosphere contains numerous CO_2, H_2O, and CH_4 lines.

2 54. I **II**

2 55. **I** II

2 56. The planet passing in front of the star.

2 57. **0.25** years

3 58. In these units, $p^2 = \frac{a^3}{M} \Rightarrow M = \frac{(0.4\,AU)^3}{(0.25\,yr)^2}$

1.02 $M_\odot$

3 59. Yes / **No**

Solar-mass star w/ 25 solar radius size.

3 60. Estimate the transit depth, which gives the ratio of areas. Sqrt to get ratio of radii. Then, scale R_{star} by the ratio to get R_{planet}.