Science Olympiad
Solon Invitational
February 3, 2024

Astronomy C Answer Key

ANSWER KEY ANSWER KEY
ANSWER KEY ANSWER KEY
ANSWER KEY ANSWER KEY
ANSWER KEY ANSWER KEY
ANSWER KEY ANSWER KEY
ANSWER KEY ANSWER KEY
ANSWER KEY ANSWER KEY
ANSWER KEY ANSWER KEY

Section A (75 points)

1. F	2. T	3. F	4. F	5. F
6. T	7. F	8. F	9. F	10. T
11. A	12. C	13. A	14. D	15. D
16. D	17. A	18. D	19. A	20. B
21. A	22. B	23. C	24. C	25. D
26. B	27. C	28. C	29. A	30. B

31. [1 pt] 18 observations

32. [2 pts] Accept -62:40 to -62:41. It is not visible from Solon, Ohio as their difference is greater than 90 degrees.

33. [3 pts] A bright point-like source, plus a diagonal line of emission.

34. [2 pts] Proxima Centauri

35. [2 pts] ACIS instrument and HETG grating

36. [3 pts] Most energy is below 2 keV, with spikes at 1 keV, 1.8 keV, and a smaller one at 7.5 keV. No penalty if this last peak is not mentioned.

37. [3 pts] Highly variable, with a flare at 408610000 seconds. It is possible that other peaks could be mentioned.

38. [3 pts] Yes. Variable throughout the observation, with flaring at about 3-4 times the "average" emission.

39. [3 pts] This is a cool M-dwarf/red dwarf. X-rays are usually associated with hot, compact objects.

40. [3 pts] X-ray flaring would probably mean that life would not be possible on any exoplanet around Alpha Centauri. (Other answers may be possible...)

Section B (75 points)

1. (a) [1.5 pts] SVS 13

   (b) [1.5 pts] NGC 1333

   (c) [3 pts] Image 4, Spitzer

2. (a) [2 pts] AB Aur and AB Aur b

   (b) [3 pts] Herbig Ae (Half credit for Ae/Be or Be) and gas giant/(condensing) planet/brown dwarf

   (c) [3 pts] Disk instability

3. (a) [2 pts] Image 7

   (b) [2 pts] The two HST filters used for observation

   (c) [2 pts] Rotation period of 2M1207 b

   (d) [3 pts] Both are unimodal **[2 pts]**. Period has a long tail towards high values whereas amplitude is symmetric **[1 pt]**. (Accept answers referring to normal distributions/bell curves and left/right skewed distributions.)

   Do not accept answers with

   - quantitative values (e.g. the mode of the period is 11 d) as the question asks to describe a general shape of the distributions
   - or a description of the two-dimensional distribution (e.g. bullet-shaped, ellipse with a long tail) as the question asks to consider the univariate/marginal distribution.

   (e) [3 pts] Period will have an asymmetric error with more in the positive direction than the negative (e.g. $p = 11.10^{+2.00}_{-1.20}$). Amplitude will have a symmetric error (e.g. $A = (1.36 \pm 0.23)\%$).

4. (a) [1 pt] HR 8799

   (b) [2 pts] Image 17

   (c) [2 pts] A: HR 8799 b; B: HR 8799 d; C: HR 8799 c

   (d) [2 pts] Direct imaging

5. (a) [1 pt] Orbit period equals rotation period. Same side always facing the host star.

   (b) [2 pts] Infrared

   (c) [2 pts] JWST

   (d) [3 pts] The planet is passing behind the host star, blocking the radiation emitted from the surface of the planet. (Half credit for only saying occultation or eclipse.)

   (e) [2 pts] $\lambda = 2.77\,\mu\text{m}$ or orange points

   (f) [3 pts] Because the planet is tidally locked, there exists a steep temperature drop across its terminator (which marks the transition from sunside to nightside). So we expect the thermal emission of the planet to decrease as its sunside rotates away from view.

6. (a) [1 pt] Carina Nebula

   (b) [2 pts] 7500-8500 ly

   (c) [1 pt] Bok globule

   (d) [3 pts] (Photo)ionization due to high-energy OB stars.

7. (a) [2 pts] Transit

   (b) [3 pts] Blue and yellow (Do not accept answers with the name of the planets), 3:2 mean-motion resonance

   (c) [1 pt] Green (Do not accept answers with the name of the planet)

   (d) [2 pts] 2 or 3

   (e) [2 pts] Limb darkening

   (f) [3 pts] Snow lines mark the radius at which ices and other rocky materials condense **[1 pt]**. A greater amount of solid material **[1 pt]** and a weaker influence of gravity **[1 pt]** from the host star increases the rate of core growth.

   (g) [3 pts] The force of gravity exceeds the pressure-gradient force/gas pressure/hydrostatic pressure. (Do not accept pressure or thermal pressure.)

   (h) [1 pt] TW Hya

   (i) [3 pts] An outer planet on a highly eccentric orbit would be able to dip into the orbits of the inner planets and a series of close encounters with them could transfer energy/momentum to or from them, affecting their orbits.

   (j) [2 pts] It may have a long period or an inclination too high to form a transit.
   (Do not accept planet too small, dip would be too small, orbit too wide or similar answers.)

Section C (50 points)

1. [2 pts] 138 pc [131, 145]
2. [2 pts] +3.45 [3.28, 3.62]
3. [3 pts] 0.882 $R_\odot$ [0.838, 0.926]
4. [3 pts] 1.40 $M_\odot$ [1.33, 1.47]
5. [2 pts] 0.0157 [0.0149, 0.0165]; if using given values, 0.0122 [0.0116, 0.0128]
6. [4 pts] 44.1 h [41.9, 46.3] (Half credit for 34.3 h [32.6, 36.0] or 39.2 h [37.2, 41.2])
   If using given values, 69.6 h [66.1, 73.1] (Half credit for 55.8 h [53.0, 58.6] or 62.7 h [59.6, 65.8])
7. [4 pts] Appropriate x- and y-axis label **[1 pt]**. Units not necessary. Trapezoid shape **[1 pt]**. Indicate transit depth with either δ or value in Question 5 **[0.5 pts]**. Time between four contacts are 4.91 h, 34.3 h, and 4.91 h **[0.5 pts each]**. If using given values, 6.93 h, 55.8 h, and 6.93 h.
8. [3 pts] Planets with small orbits **[1.5 pt]** and large host stars **[1.5 pt]**.
9. [2 pts] 4.04″ [3.84, 4.24]
10. [2 pts] 1.48×10^{-9} $L_\odot$ [1.41×10^{-9}, 1.55×10^{-9}]
11. [2 pts] There is a large range of magnitudes in both the x-axis (wavelength) and y-axis (intensity). If a linear scale were used for either axis, it would be difficult to recognize the key features in the plot.
12. [2 pts] The peak at 0.5 µm corresponds to the reflected sunlight **[1 pt]** and the peak at 9-20 µm corresponds to thermal emission **[1 pt]**.
13. [2 pts] [-66.2, 16.6] °C (Half credit for [3860, 6970] °C)
14. [2 pts] 100 µm gives the best contrast ratio of 10^{-4}.
15. [4 pts] Mirrors at normal temperatures emit infrared radiation of their own, contributing a thermal noise that degrades the measurements of the telescope **[2 pts]**. Methods to mitigate it are: radiators, heat shields, and telescope placement at L2 **[1 pt each, up to 2]**.
16. [3 pts] The flux from Jupiter is over 20 times greater **[1 pt]**. It is useless to have a high contrast ratio if the telescope cannot even detect Jupiter **[2 pts]**.
17. [2 pts] 13.0 km s^{-1} [12.4, 13.7]
18. [2 pts] 13.0 m s^{-1} [12.4, 13.7]
19. [2 pts] The maximum velocity that can be observed is multiplied by a $\sin i$, where i is the inclination of the orbit relative to Proxima Centauri b, which in the "best" case is equal to 1 for an edge-on orbit.
20. [2 pts] No **[1 pt]**, the minimum velocity that can be resolved is 2000 m s^{-1} **[1 pt]** which is much greater than the Sun's wobble.