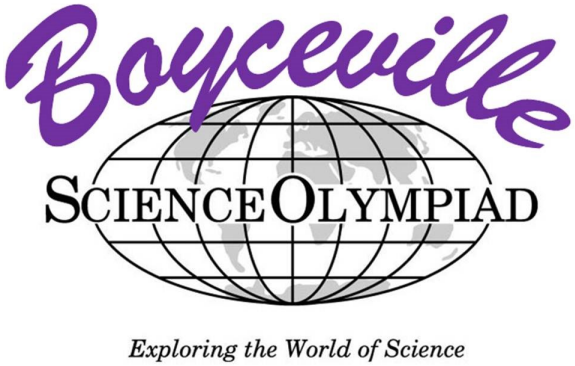
Science Olympiad
Boyceville Invitational
December 7, 2024

Astronomy C Answer Key



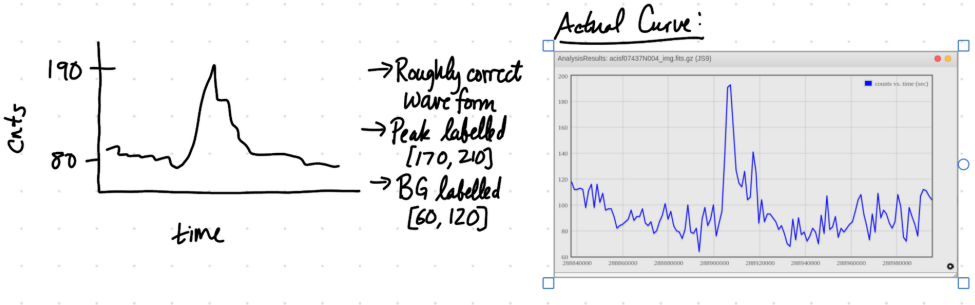
ANSWER KEY ANSWER KEY
ANSWER KEY ANSWER KEY
ANSWER KEY ANSWER KEY
ANSWER KEY ANSWER KEY
ANSWER KEY ANSWER KEY
ANSWER KEY ANSWER KEY
ANSWER KEY ANSWER KEY
ANSWER KEY ANSWER KEY

Section A (40 points)

1. B
2. B
3. B
4. A
5. D
6. ABDC
7. BADC
8. D
9. A
10. D
11. A
12. B
13. Hydrogen fusion
14. C
15. B
16. High mass and small orbit distance
17. B
18. The exoplanet and its star form from the same material.
19. D
20. High velocity ejecta hit dense pockets of interstellar medium and form shocks. The shocked material is ionized and excited which then produces emissions.

Section B (15 points)

1. Five spectral peaks at 915 eV, 1480 eV, 1750 eV, 2130 eV, and 7480 eV. (Accept within ±10 %)
   Don't deduct for omitting 1480 eV or 7480 eV peaks.
2. Accept 300 to 800.
3. Rotation of the accretion disk.
4. 19.4 h (Accept 18.8–19.7). Half credit for 69 000 s (Accept 68 000–71 000).
5. 43.6 h. Half credit for 1.57×10^5 s. Exposure is greater than object's period.
6. [3 pts]



7. Rotation from brightness variations. For instance, clumps in the disk or envelope transiting the star, or dark sunspots on the star rotating in and out of view.

Section C (45 points)

1. A	2. J	3. C	4. H	5. F
6. H or I	7. B	8. E	9. G	10. D

11. (a) Stellar wind from young stars pushes gas and dust out

    (b) [3 pts] The blue star is older (1). Its stellar wind has had enough time to clear out the material it formed in. The stars in the colored regions are newly forming protostars still shrouded in dust. Any justification based on the presence of the cavity (2).

    (c) Near-Infrared Camera (NIRCam)

    Only (1) if mentions infrared or JWST.

12. (a) Rotational period equals orbital period (1). Moon, Phobos, Deimos, Pluto/Charon, etc. (1)

    (b) Quartz

    (c) Transmission spectroscopy

13. (a) Optical (left), infrared (right) (1 each)

    (b) Transit

    (c) Limb darkening, grazing/high impact factor (1 each)

14. (a) Epsilon Eridani

    (b) Radial-velocity

    (c) Magnetic activity led to doppler jitter

Section D (40 points)

Award up to half credit for correct work with incorrect answer

1. (a) [2 pts] $d = 1/p$. $d = 3260\,\text{ly}$ (Accept 3250–3270)

   (b) [2 pts] No, the system is stationary (1). When both of the curves "meet", the orbital component of their radial velocity is 0 so we get the radial velocity of the system (1).

   (c) [2 pts] The maximum radial velocity represents the true velocity of the star.

   (d) [3 pts] $vP = 2\pi r$. $r_A = 4.13 \times 10^9\,\text{m}$ (Accept 3.71–4.54) and $r_B = 8.25 \times 10^9\,\text{m}$ (Accept 7.42–9.08)
   Only (2) if r_A and r_B flipped.

   (e) [3 pts] $a = r_A + r_B$ and $G(M_A + M_B)/(4\pi^2) = a^3/P^2$. $M_A + M_B = 8.35\,\text{M}_\odot$ (Accept 7.51–9.19)

   (f) [2 pts] $M_A r_A = M_B r_B$. $M_A = 5.57\,\text{M}_\odot$ (Accept 5.00–6.13) and $M_B = 2.78\,\text{M}_\odot$ (Accept 2.50–3.06)
   Only (1.5) if M_A and M_B flipped.

2. (a) [2 pts] $T = b/\lambda$. $T = 9660\,\text{K}$ (Accept 8700–10 600)

   (b) [2 pts] A (1), 0 or 1 (1)

   (c) [1 pt] Star B

   (d) [2 pts] When radial velocity is zero (2). (Also accept $\phi = 0, 1$ (1) and $\phi = 0.5$ (1))

   (e) [3 pts] $v_r/c = \Delta\lambda/\lambda_0$. $v_r = -40\,\text{km}\,\text{s}^{-1}$ (Exact) (2). Moving towards Earth (1).

   (f) [2 pts] $v_B \sin(2\pi\phi) = v_r \Rightarrow \phi = 0.532$ or 0.968. Multiple answers accepted: 0.10, 1.40, 1.60, and 2.90 d.

3. (a) [2 pts] Coronagraph

   (b) [3 pts] $1.22(\lambda/d) = \sin\theta_R \approx \theta_R$. $\theta_R = 1.22 \times 10^{-6}\,\text{rad}$ (Exact)

   (c) [2 pts] Planets are primarily bright in infrared and, more importantly, the brightness ratio between the planet and its star is highest for infrared. (Accept either justification)
   Only (1) if mentions infrared.

   (d) [3 pts] $M = -2.5\log_{10} L$. $+0.933$ (Exact)

   (e) [4 pts] Identify expression for:

   - absorbed heat $[\dot{Q}_{\text{in}} = L \times (\pi D^2/4)/(4\pi d^2) \times (1 - \alpha)]$ (1)
   - and emitted heat $[\dot{Q}_{\text{out}} = \varepsilon\sigma T_{\text{eq}}^4 \times (\pi D^2/2)]$ (1).

   $T_{\text{eq}} = 282\,\text{K} = 9.08\,^\circ\text{C}$ (Accept 0–20) (1.5). Yes, it is habitable (0.5).
   Only (1) if using "standard" equilibrium temperature formula.