Science Olympiad
UT Invitational
October 26, 2024

Astronomy C Answer Key

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Section A (60 points)

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

Section B (18 points)

1. [1 pt] 4
2. [2 pts] 2022-02-20. Half credit for 2022-02-21.
3. [2 pts] ACIS
4. [3 pts] 5″ (Accept 4–6″)
5. [3 pts] 220.5 au (Accept 176–265 au)
6. [4 pts] Upper star (secondary): At a constant brightness of ∼15 counts/sec with no noticeable change.

   Lower star (primary): At a constant brightness of ∼40 counts/sec until $t \approx 761\,794\,200\,\mathrm{s}$, where it increases to ∼60 counts/sec.

   Half credit for any other qualitative or quantitative description that suggests the light curve was correctly generated.
7. [3 pts] The primary has a 50 % (Accept 40–70 %) increase in brightness.

Section C (55 points)

1. (a) [1.5 pts] 30 Doradus or Tarantula Nebula
   (b) [2 pts] X-ray and infrared (1 each)
   (c) [2 pts] JWST
   (d) [2 pts] Protostars

2. (a) [1.5 pts] PSR B1257+12
   (b) [2 pts] (Millisecond) pulsar
   (c) [2 pts] 3
   (d) [3 pts] The Arecibo (1) telescope measured the time of arrivals (TOAs) of the pulsar pulses (1). Gravitational perturbations (1) from the orbiting planets caused the TOA to vary sinusoidally.

3. (a) [2 pts] Radial-velocity or doppler spectroscopy
   (b) [3 pts] It's in an elliptical orbit (1). If it was in a circular orbit, it would exhibit a sinusoidal radial-velocity curve, which is not the case. Any justification based on the shape of the curve (2).
   (c) [2 pts] Accept 0.923 to 0.934

4. (a) [2 pts] Image 4 (0.5) because pressure decreases with altitude (1.5) and it has lower pressure.
   (b) [2 pts] Weather patterns with storms and fronts
   (c) [3 pts] The dayside-nightside temperature gradient is more strongly maintained (1.5) since Image 4 is at a higher altitude and the thermal time scale is shorter (1.5).

5. (a) [3 pts] Accept 6 or 7
   (b) [2 pts] Can't determine the radius of exoplanets detected only by the radial-velocity method
   (c) [2 pts] (Hot) Neptune desert
   (d) [3 pts] Exoplanets so close to their host star would either have enough mass to remain Jupiter-sized or their primordial atmosphere would be completely eroded.
   (1) for *only* mentioning the exoplanet is close or hot.

6. (a) [3 pts] Planets form from protoplanetary disks (1), which spin in the same direction (1) as their star. So, we'd expect objects formed from them to have the same behavior (1).
   (b) [3 pts] Horizontal line showing the orbit of WASP-17b (1) with its direction or orbital axis. WASP-17 placed at the center of the orbit with a spin direction 150° clockwise or counterclockwise from the orbital axis (2).
   (c) [2 pts] Rossiter–McLaughlin effect

7. (a) [3 pts] HD 80606, WASP-17b, WASP-121b, LTT 9779b, GJ 1214 b, K2-18b, TOI-270d, LHS 3844b, WD 1856+534, Kepler-62, AU Microscopii (1 for 8–11; 2 for 12–14; 3 for 15–16 correct)
   (or NOT: Orion Nebula, 30 Doradus, PSR B1257+12, 55 Cancri, Epsilon Eridani)
   (b) [2 pts] (Orion Nebula) 412 pc (Accept 390–450 pc)
   (c) [2 pts] Direct imaging

Section D (37 points)

Award up to half credit for correct work with incorrect answer

1. (a) [3 pts] $0.8''$ (Exact). *Only* (1) for $0.4''$.

   (b) [3 pts] 5.51 (Exact)

   (c) [3 pts] $0.492\,\mathrm{L}_\odot$ (Accept 0.48–$0.55\,\mathrm{L}_\odot$)

   (d) [3 pts] 5550 K (Accept 5450–5700 K). If using $L = 0.7\,\mathrm{L}_\odot$, 6060 K (Accept 6010–6110 K)

   (e) [3 pts] 521 nm (Accept 510–530 nm). If using $T = 4160\,\mathrm{K}$, 697 nm (Accept 690–710 nm)

   (f) [4 pts] 173 K (Accept 168–178 K). If using $T = 4160\,\mathrm{K}$, 130 K (Accept 125–135 K) (3)
   Since this is below the freezing point of water, is not in the habitable zone (1).

2. (a) [4 pts] $a\cos(i) = bR_s$. Since $0 \leqslant b \leqslant 1$, $i \geqslant \cos^{-1}(R_s/a)$. ($i \geqslant \cos^{-1}((R_s + R_p)/a)$ also accepted)

   (b) [3 pts] $d = (R_p/R_s)^2$. *Only* (1) for $d = (R_s^2 - R_p^2)/(R_s^2)$.

   (c) [4 pts] From Kepler's third law, $a^3 = \frac{GM_s}{4\pi^2}T^2$ (1).
   Substituting into the circular orbit velocity formula $v_p = \sqrt{\frac{GM_s}{a}}$ (1), we get $v_p = (\frac{2\pi GM_s}{T})^{1/3}$ (2).

   (d) [4 pts] Because the planet and host star orbit around their center of mass, $M_p v_p = M_s v_s$, where v_s is the true velocity of the star, which equals $v_{\max}$ in the case of an edge-on orbit. So we can write:

   $$M_p = \frac{M_s v_{\max}}{v_p}.$$

   Only (3) for $M_p = (M_s v_s)/v_p$.

   (e) [3 pts] If the orbit is not edge-on, $v_{\max} = v_s \sin(i)$, as $v_{\max}$ is the radial component of the star's true velocity. So we get:

   $$M_p = \frac{M_s v_{\max}}{v_p \sin(i)}.$$