Science Olympiad National Tournament
University of Southern California

Astronomy C

May 23, 2026

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Section A [40 points]

1. D	2. C	3. D	4. C	5. D	6. A
7. B	8. D	9. B	10. C	11. A	

12. [2 pts] (a) Mira/Omicron Ceti, (b) HP Tau
13. [2 pts] Image 4, 3, 2
14. [1 pt] Image 4

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15. [2 pts] (a) Helix Nebula/NGC 7293, (b) Tycho's SNR
16. [2 pts] Image 5 (1), remnant of inert core from progenitor star (1)

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17. [2 pts] (a) Orion Molecular Cloud Complex, (b) Sharpless 29/NGC 6559
18. [1 pt] UV radiation from young stars (Also accept just "UV radiation" or "young stars")

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19. [1 pt] G
20. [2 pts] 1.56 [1.50, 1.62] solar masses (1). The combined mass of the white dwarfs would exceed the Chandrasekhar limit (0.5), so this type Ia supernova would be more luminous than most type Ia supernovae OR multiple detonations would occur (0.5)
21. [2 pts] The system is moving away from us (1), and star A is slightly more massive than star B (Also accept they are similar mass) (1)

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22. [1 pt] Powered by the central pulsar (0.5), which continues to send energy into the nebula through ionization of the surrounding dust (0.5)
23. [1 pt] Gamma or x-ray radiation
24. [2 pts] These are shock fronts where the pulsar wind slams into surrounding material (1). They move because the pulsar wind itself is unstable, so the shock pattern ripples and moves (1).

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25. [1 pt] 8 magnitudes [5, 9]
26. [2 pts] Ultraviolet (1). Mira A sheds a lot of material (0.5), and moves at a high speed through the interstellar medium (0.5), leaving a trail of mass that creates the tail.
27. [2 pts] Outer shell of hydrogen, inner shell of helium, and a core of carbon and oxygen (0.5 per).

Section B [27 points]

28. C 29. B 30. D

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31. [1 pt] Accretion Disk
32. [2 pts] Accept any of: Red giant, red supergiant, asymptotic giant branch (AGB) (1). The large size of this star allows its Roche lobe to be filled (1)
33. [1 pt] Ignition of helium fusion

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34. [1 pt] Radius decreases
35. [1 pt] Gravitational collapse
36. [2 pts] Radiation pressure is now pushing outward on the collapsing material (1), halting free-fall (1).

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37. [1 pt] 0.2–0.3 solar masses
38. [2 pts] Helium ash (1) has built up in the center of the core (1).
39. [1 pt] Accept any of: Increased He content, decreased H content, decrease in ratio of C/N
40. [1 pt] Helium flash
41. [2 pts] Accept any (or any combination) of:
    - High temp in the deep core is required for He fusion;
    - The core is very H-poor, so H fusion cannot penetrate deeper;
    - Outward pressure from He fusion prevents the core from collapsing to the point of a continuous layer of He fusion.

    Otherwise, for partial credit: Discussion of He fusion in deep core (0.5) and/or H fusion in layer outside core (0.5).

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42. [2 pts] Lower (1), we see neutral hydrogen lines (1)
43. [1 pt] (Pressure) broadened with higher surface gravity (Half credit for just "changes width")
44. [2 pts] Star A (0.5), it has narrower spectral lines (1), and thus lower surface gravity (or any discussion of how broader spectral lines corresponds to higher radius/luminosity) (0.5).

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45. [1 pt] Accept any of: Helium doubly ionizes, helium becomes opaque
    (Half credit for just it "ionizes" or "changes in opacity")
46. [2 pts] Decreasing (0.5), the luminosity of the Cepheid is dropping during this transition (1), and period is proportional to luminosity (0.5)
47. [1 pt] High-mass stars evolve faster.

Section C [33 points]

48. [1 pt] Visual binary (since our telescope was able to resolve the angular displacement between them). Also accept eclipsing binary (as the 1-D assumption means they will overlap).

For the next three questions, making a mistake in the first can result in errors which propagate through. If they get the half credit answer to the first, the "carry through" values should be given full credit.

49. [2 pts] 237.4 pc [224, 251] (Half credit: 118.7 pc [113, 125])

50. [3 pts] 2.90 $M_\odot$ [2.75, 3.05] (Carry through: 0.362 $M_\odot$ [0.344, 0.380])
(Partial credit for: Newton's 3rd law, identifying the correct period (4429 days), identifying either of the relevant angular separations or au equivalents (0.5 each))

51. [2 pts] 2.27 $M_\odot$ [2.17, 2.37] (Carry through: 0.284 $M_\odot$ [0.270, 0.298], other wrong answers to 50 were carried through) (Half credit for identifying $r_a M_a = r_b M_b$ or a variant)

52. [2 pts] III (1), accept an answer that correctly invokes Kepler's second law, and gives a correct justification for why III is the periapsis (1). Answers that correctly reason that Eccentrus-B must be moving rapidly to achieve the change seen in angular displacement or that Eccentrus-B spends little time at this displacement can be accepted to.

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53. [1 pt] 1630 years [1620, 1640]

54. [2 pts] Ratio of 1 : 1960 [1940, 1980] (1.5), cloud Trojan is more likely to collapse and form stars (0.5)
(If ratio is inverted (1), cloud Bruin is more likely to collapse (0.5))

55. [1 pt] B

56. [1 pt] $t/t_\odot = 8/4100 = 0.00195 \implies 1 : 513$ [508, 513]

57. [2 pts] $F = \frac{1.579\times10^{30}}{4\pi(1.543\times10^{19})^2} = 5.28\times10^{-10}\ \mathrm{W/m^2}$ [5.01, 5.55]

58. [2 pts] H → He, He → C, C → O, Si → Fe

59. [1 pt] Each successive fuel leads to less energy per nucleon due to the curve flattening (0.5), which means that each stage burns through its fuel faster, so each stage is shorter than the previous (0.5).

60. [2 pts] $\Delta E = \frac{3}{5}GM^2(\frac{1}{R_i} - \frac{1}{R_f}) = 2.73\times10^{46}$ J [2.45, 2.87] (1.5); 273 [245, 287] times solar MS energy output (0.5).
(If no 3/5 factor, award (1.5))

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61. [2 pts] $n_1 = 1$, $n_2 = -\frac{1}{2}$, $n_3 = \frac{1}{2}$ (0.5 per, and 0.5 for any) and $\Pi_0 = CR^1 P^{-1/2} \rho^{1/2}$ (No partial credit for work)

62. [2 pts] $\Pi_0 = 55.2\,\mathrm{d}$ [52.1, 58.0] (1). Yes (0.5), Classical Cepheids generally have periods from a few days to a few weeks (0.5) (1 to 100 days).

63. [1 pt] Since $\Pi_0 \propto 1/\sqrt{\rho}$ and white dwarfs have a greater density than Cepheid stars (0.5), ZZ Ceti stars would have a shorter period (0.5).

64. [3 pts] $\bar{M}_V = -5.85$ [−5.90, −5.80] (1) $\Rightarrow L = 1.88 \times 10^4\,\mathrm{L_\odot}$ [1.78, 1.98] (1) $\Rightarrow T_{\mathrm{eff}} = 4890\,\mathrm{K}$ [4840, 5140] (1) (Half credit for 4790 K [4550, 4840] for using V_{bol})

65. [2 pts] Pulsation period would decrease at higher overtones (0.5), since the acoustic distance between nodes decreases with each increasing overtone (1.5).

66. [1 pt] The distance from the center of the star to the first nodal line is always the region with the highest average sound speed (0.5), so acoustic waves travel the farthest over a given pulsation period (0.5).
(No credit for only mentioning greater density)

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Statistics

Overall Results

	Mean	Median	St. Dev.	Max
Total Score	50.0	52.5	19.8	85
Section A	25.4	27.5	7.2	35.5
Section B	11.5	11	6.4	24.5
Section C	13.1	12.5	8.5	29.5

Section A Results

#	%	#	%	#	%	#	%	#	%	#	%
1	46	3	86	5	58	7	71	9	75	11	17
2	51	4	86	6	10	8	66	10	75		

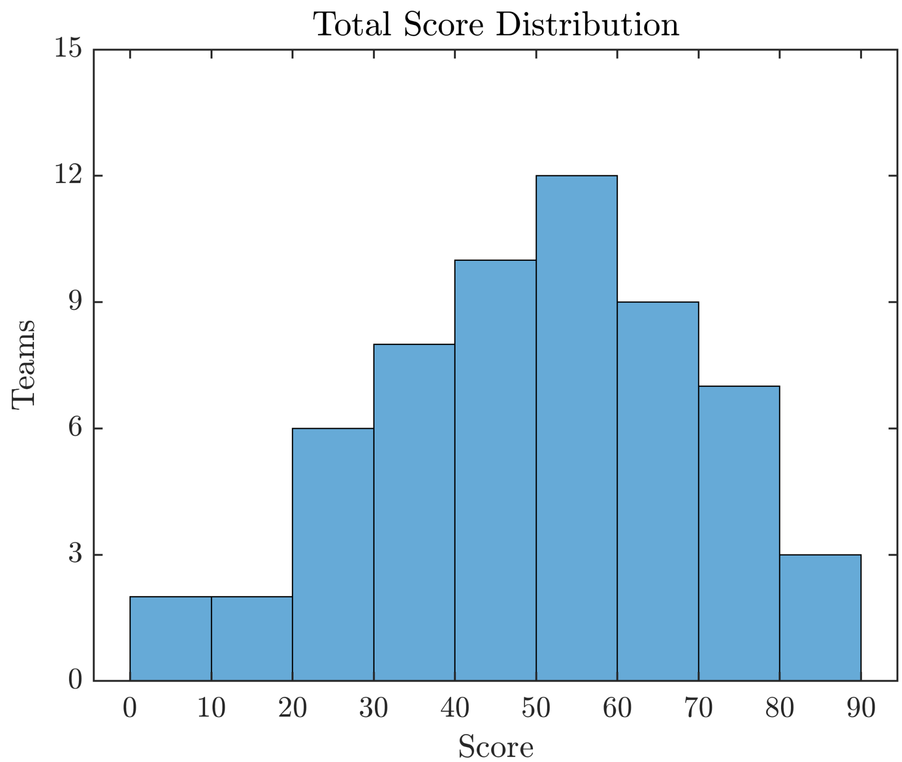
#'s	Mean	Median	St. Dev.	Max
12–14	4.1	5	1.2	5
15–16	3.5	4	0.9	4
17–18	2.2	2.5	1.0	3
19–21	2.9	3.5	1.2	5
22–24	1.7	1.5	1.1	4
25–27	3.2	3.5	1.5	5

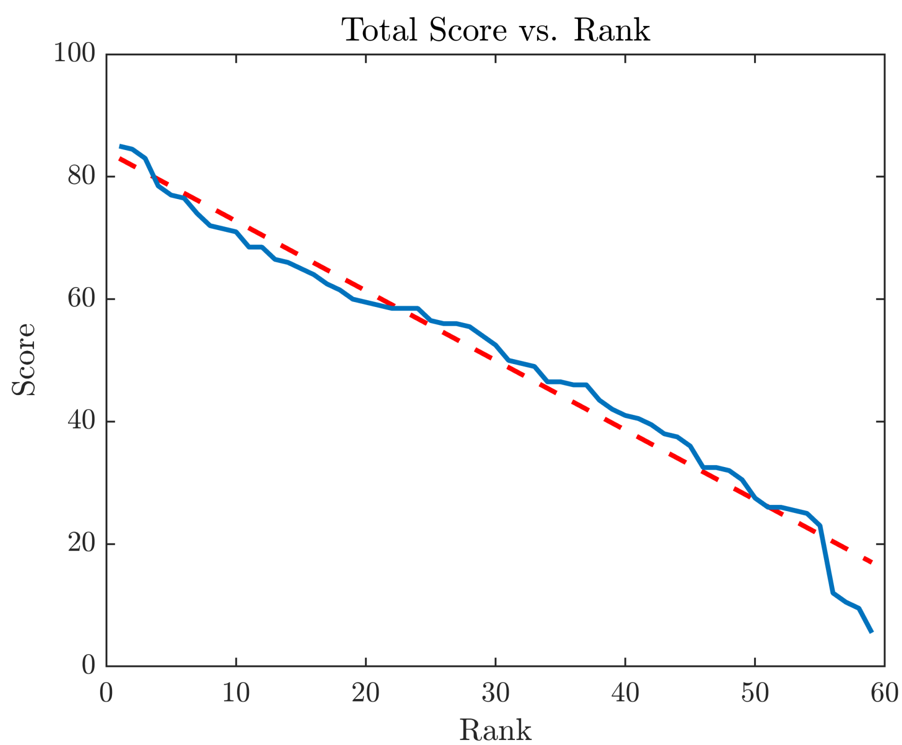
Section B Results

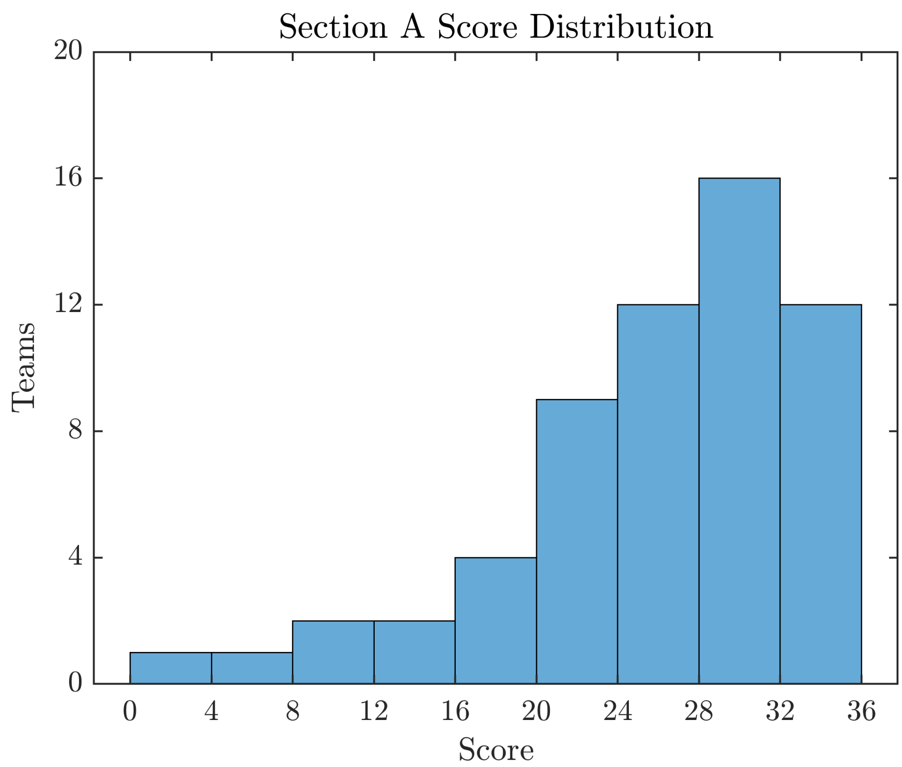
#'s	Mean	Median	St. Dev.	Max
28–30	2.0	2	1.0	3
31–33	1.8	2	1.2	4
34–36	2.4	3	1.3	4
37–41	2.9	3	2.5	7
42–44	1.5	1	1.5	5
45–47	1.0	0.5	1.1	4

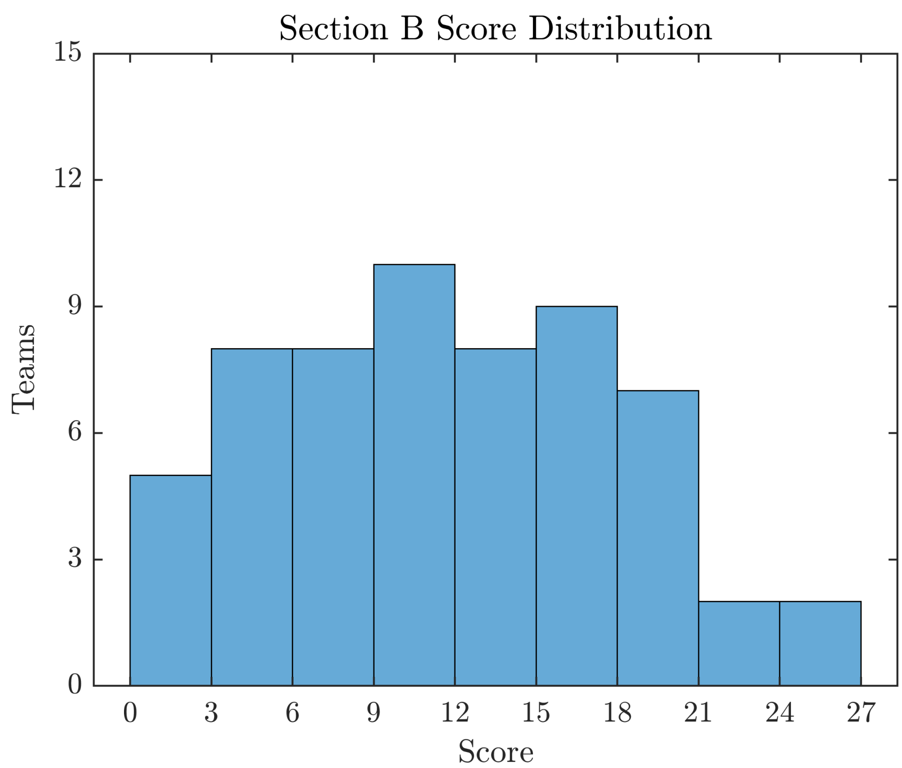
Section C Results

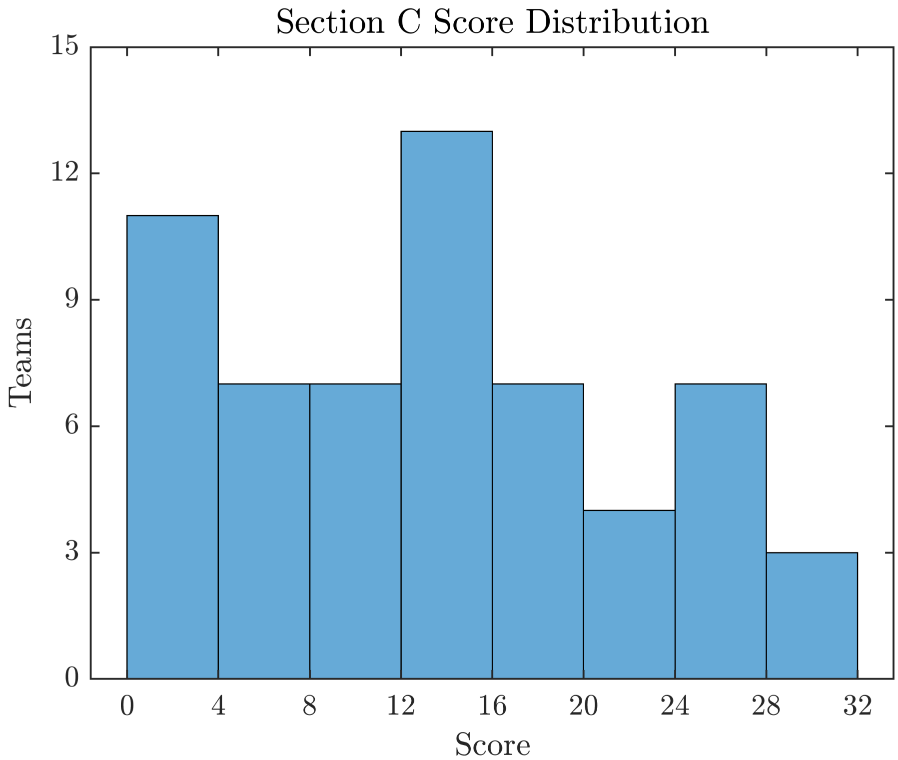
#'s	Mean	Median	St. Dev.	Max
48–52	2.8	2	2.8	9.5
53–60	6.2	7	3.4	11.5
61–66	4.1	3.5	3.3	10.5


Total Score Distribution
Teams
Score
0
3
6
9
12
15
0
10
20
30
40
50
60
70
80
90


Total Score vs. Rank
Score
Rank
0
20
40
60
80
100
0
10
20
30
40
50
60


Section A Score Distribution
Teams
0
4
8
12
16
20
0
4
8
12
16
20
24
28
32
36
Score


Section B Score Distribution
Teams
0
3
6
9
12
15
0
3
6
9
12
15
18
21
24
27
Score


Section C Score Distribution
Teams
Score
0
3
6
9
12
15
0
4
8
12
16
20
24
28
32