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Science Olympiad at the University of Pennsylvania

Trial: Solar Power C - Answer Key

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Total Score: 221 points

Directions:

1. The point values for each question are denoted in the directions or the number within the parentheses.
2. Work is not required; however, incorrect solutions are eligible for partial credit.
3. Full credit necessitates correct significant figures and units.

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Multiple Choice (2 points each) - 50 total points

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

True or False (1 point each) - 15 total points

1. F
2. F
3. T
4. F
5. T
6. T
7. F
8. F
9. T
10. T
11. T
12. F
13. T
14. F
15. F

Short Answer (2 points each) - 10 total points

1. Law of conservation of energy
2. Newton's law of cooling
3. Open system
4. Internal energy
5. Ocean thermal energy conversion

Completion (2 points each) - 20 total points

1. Work
2. Transducer
3. Heat capacity
4. Rayleigh number
5. Iceland
6. Bay of Fundy
7. Coal
8. Spain
9. Brazil
10. Philippines

Labeling (Each letter is worth 1 point) - 18 total points

1. *(9 total points)*

A. Anti-reflection coating
B. Transparent adhesive
C. Cover glass
D. n-layer semiconductor
E. p-layer semiconductor
F. Front contact
G. Current
H. p-n junction
I. Back contact

2. *(9 total points)*

A. Containment structure
B. Control rods
C. Steam generator
D. Reactor core
E. Reactor vessel
F. Turbine
G. Generator
H. Power lines
I. Transformer

Temperature Scales (1 point each) - 8 total points

1. 5 - Romer
2. 1 - Reaumer
3. 8 - Celsius
4. 4 - Deslisle
5. 3 - Newton
6. 7 - Kelvin
7. 2 - Rankine
8. 6 - Fahrenheit

Mathematical Equations - 13 total points

$$W = \int_C \mathbf{F} \cdot \mathrm{d}\mathbf{s}$$

1. (2 points)

2. *(7 total points)*
    a. (1 point) Carnot's theorem/rule
    b. (1 point) Second
    c. (1 point) Absolute temperature of the cold reservoir
    d. (1 point) Absolute temperature of the hot reservoir
    e. (3 points) No, because Carnot's theorem applies to heat engines converting thermal energy to work, while fuel cells and batteries convert chemical energy to work

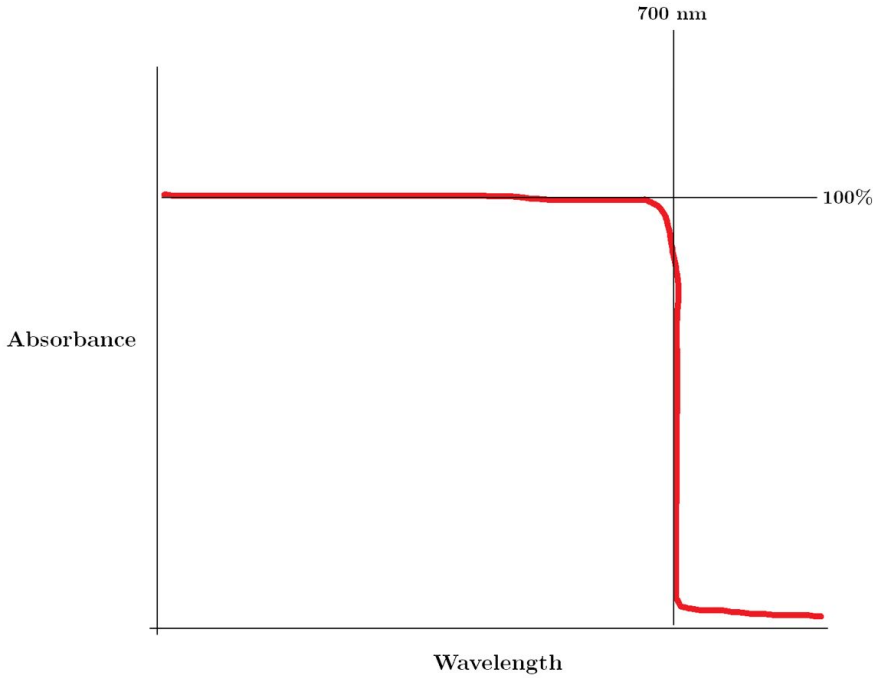
$$\phi_q = \epsilon\sigma T^4$$

3. (2 points)

4. (2 points; do **not** award partial credit) $[^\circ\mathrm{C}] = ([^\circ\mathrm{F}] - 32) \times {}^5\!/_9$

Material Properties by Aditya - 41 total points

1. *(9 total points)*
    a. (3 points; no partial credit awarded) B, C, A
    b. (2) C
    c. (2) It increases
    d. (2) It will increase the band gap.
2. *(16 total points)*
    a. (2) 700 nm
    b. (8 points total)



- *(4 points total) 2 points per correct axis title.*
    - x-axis should be titled "Wavelength " (2)
    - y-axis should be titled "Absorbance" (2)
- *4 points for the correct shape*
    - Only award 2 points if the graph does not have sharp transitions (sharp transitions seen in the provided graph)

    c. (2) Red
    d. (4) 1.78 eV

Material Properties by Aditya (continued)

3. *(16 total points)*

    a. *(6 points)* Some of the photon's energy will go into promoting an electron from the valence band to the conduction band (2) (i.e. it overcomes the band gap), but the extra energy will simply be dissipated as heat (2) (i.e. wasted) instead of being converted into useful electrical energy (2)

    b. *(10 points; award full credit if the general principle is addressed)*

    Answers will vary in how they are presented, but the science is the same. In a conventional silicon PV, any energy from a photon that is greater than that of the band gap is wasted as heat (2). As a result, we want to minimize the amount of energy exceeding the bandgap (2). By splitting a high-energy exciton into two lower-energy ones (2), less energy (if any) will be above the band gap (2), reducing the amount of energy wasted as heat (2).

    An example of a possibly helpful analogy: imagine you have a 90-pound suitcase you want to bring onto a plane, but the limit for checked bags is 50 pounds. If you divide the contents of the big suitcase into two smaller suitcases so that they each weigh 45 pounds, then you can bring everything on. However, if you stick with one big suitcase, you'll be forced to discard 40 pounds of stuff. Here, the 90-pound suitcase is the high-energy singlet exciton, the 45-pound suitcases are the lower-energy triplet excitons, the 50-pound limit is the bandgap of the PV cell, and the 40 pounds extra you'd have to leave behind is the energy you'd waste as heat.

Estimathon (2 points each) - 18 total points

1. 4-6 e14 J
2. 4-8e15 J
3. 4-6e24J
4. 1e-8%
5. 1-3e8$
6. 1-2e11$
7. 2-5e2 W
8. 3-5 e10 J
9. 2-4e8s

Calculation - 28 total points

1. (3 points) 3.51 C
2. *(16 total points)*
    a. (10 points)
        1.) Ice rises in temperature from -10.0 to 0.00 C (2)
        2.) Ice melts at 0.00 C (2)
        3.) Liquid water rises in temperature from 0.00 C to 100.0 C (2)
        4.) Liquid water boils at 100.0 C (2)
        5.) Steam rises in temperature from 100.0 to 120.0 C (2)
    b. (6 points) 191 kJ
3. (6 points) 9.06 kJ
    a. award 3 points if the answer is correct but not in kJ e.g. 9060 J
4. (3 points; award full credit if the general principle is addressed)
    The difference in temperature between the core of the planet and its surface which drives a continuous conduction of thermal energy in the form of heat from the core to the surface.