



Exploring the World of Science

University of Michigan Science Olympiad
2021 Invitational Tournament

Solar Power C

Test length: 50 Minutes

Team name: _____ **Team number:** _____

Student names: _____

Solar Power C - Solar Power C - University of Michigan Div C - 02-20-2021

Instructions (shown before students start the test)

Welcome to the University of Michigan 2021 Invitational Solar Power C test! Make sure you have a stable internet connection and are ready to compete!

For this test, you are allowed the following resources:

- A Google Meet/Zoom/Skype/Phone/Video call with your partner
- A binder, printed or in pdf format on your computer
- Programmable/Non-programmable calculator
- Scratch paper

You **MAY NOT** take advantage of the following resources. Doing so will result in a disqualification plus 30 points added to your team's overall score.

- ANY internet resource
- Help from any person other than your partner
- A printed version of the test

Introduction (shown after students start the test)

This test consists of 55 questions for a total of 100 points and you will have 50 minutes to complete it.

The Tiebreakers for this test will be: **50, 51, 52, 53, 54, 55** (in that order)

If you experience technical difficulties during the test:

- Immediately contact the event supervisor through the classroom feature on Scilympiad, stating clearly what issue you are having.
- If your work is not saving/submitting, take screenshots of your answers on Scilympiad and submit them to this google form (<https://docs.google.com/forms/d/19cRQLafN7EARRS7tZHC-8HOCt4B1F-4fYOSIION1kro/edit>). Try to stay within your allotted 50 minutes.

You may find the following information useful:

| Substance | Specific Heat (J/kg*K) |
|-----------------|------------------------|
| Aluminum | 910 |
| Copper | 390 |
| Ethanol | 2428 |
| Ice (near 0 °C) | 2100 |
| Iron | 470 |
| Lead | 130 |
| Nickel | 440 |
| Silver | 234 |
| Water (liquid) | 4190 |

| Substance | Melting Point (°C) | Heat of Fusion (J/kg) | Boiling Point (°C) | Heat of Vaporization (J/kg) |
|-----------|--------------------|-----------------------|--------------------|-----------------------------|
| Water | 0.00 | 334*10E3 | 100.00 | 2256*10E3 |

| Substance | Thermal Conductivity (W/m*K) |
|-----------|------------------------------|
| Aluminum | 205.0 |
| Concrete | 0.8 |

| | |
|------------|-------|
| Copper | 385.0 |
| Lead | 34.7 |
| Fiberglass | 0.04 |
| Styrofoam | 0.027 |

1. (2.00 pts) What is the kinetic energy of a 3 kg block with a velocity of 5 m/s?

- ☐ A) 7.5 J
- ☐ B) 15 J
- ☐ C) 22.5 J
- ☐ D) 37.5 J
- ☐ E) 45 J
- ☐ F) 75 J

2. (3.00 pts)

A solar panel generates 300 W of electricity in direct sunlight. For this solar panel, 20% of incident sunlight is converted to electricity, 30% is reflected by the panel, and the rest is converted to heat. How much heat is dissipated during 10 hours of operation?

- ☐ A) 5.4 MJ
- ☐ B) 10.8 MJ
- ☐ C) 16.2 MJ
- ☐ D) 27.0 MJ
- ☐ E) 43.2 MJ
- ☐ F) 54.0 MJ

3. (2.00 pts) Consider a piston containing 3 L of helium gas with a temperature of 40°C. What is the average kinetic energy of a helium atom?

- ☐ A) 5.522E-22 J
- ☐ B) 8.284E-22 J
- ☐ C) 2.485E-21 J
- ☐ D) 4.323E-21 J
- ☐ E) 6.485E-21 J
- ☐ F) 1.946E-20 J

4. (2.00 pts) Consider the piston from the previous question. What is the root mean square velocity of a helium atom in the piston?

- ☐ A) 499.3 m/s
- ☐ B) 706.3 m/s
- ☐ C) 1140.6 m/s
- ☐ D) 1287.1 m/s
- ☐ E) 1397.1 m/s
- ☐ F) 1976.2 m/s

5. (2.00 pts) What are the fixed point(s) of the Fahrenheit temperature scale?

- ☐ A) The freezing point of water and the boiling point of water
- ☐ B) The triple point of water and the boiling point of water
- ☐ C) Absolute zero
- ☐ D) Absolute zero and the boiling point of water
- ☐ E) Absolute zero and the triple point of water

6. (2.00 pts) What are the fixed point(s) of the Kelvin temperature scale?

- ☐ A) The freezing point of water and the boiling point of water
- ☐ B) The triple point of water and the boiling point of water
- ☐ C) Absolute zero
- ☐ D) Absolute zero and the boiling point of water
- ☐ E) Absolute zero and the triple point of water

7. (2.00 pts) Convert 60°C to Kelvin.

- ☐ A) -213.15 K
- ☐ B) 15.56 K
- ☐ C) 140.0 K
- ☐ D) 288.71 K
- ☐ E) 333.15 K
- ☐ F) 413.15 K

8. (2.00 pts) Convert 45°F to Celsius.

- ☐ A) 7.22 C
- ☐ B) 35.0 C
- ☐ C) 66.58 C
- ☐ D) 113.0 C
- ☐ E) 280.37 C
- ☐ F) 328.15

9. (2.00 pts) What is the joule in terms of SI base units?

- ☐ A) $1J$
- ☐ B) $1W \cdot s$
- ☐ C) $1m/s^2$

- ☐ D) $1\text{kg} \cdot \text{m}/\text{s}^2$
- ☐ E) $1\text{kg} \cdot \text{m}^2/\text{s}^2$
- ☐ F) $1\text{kg} \cdot \text{m}^2/\text{s}^3$

10. (2.00 pts) What is the SI unit for heat current?

- ☐ A) kg
- ☐ B) J
- ☐ C) W
- ☐ D) J/m
- ☐ E) J/m^2
- ☐ F) W/m^2

11. (2.00 pts) Which is the correct ordering of renewable energy sources from least to greatest electricity generation?

- ☐ A) Hydroelectric, Geothermal, OTEC, Solar, Wind
- ☐ B) Geothermal, OTEC, Solar, Wind, Hydroelectric
- ☐ C) Geothermal, OTEC, Solar, Hydroelectric, Wind
- ☐ D) OTEC, Geothermal, Solar, Hydroelectric, Wind
- ☐ E) Solar, OTEC, Geothermal, Wind, Hydroelectric
- ☐ F) OTEC, Geothermal, Hydroelectric, Wind, Solar

12. (2.00 pts) What is the maximum theoretical efficiency of a solar cell?

- ☐ A) 25%
- ☐ B) 33%
- ☐ C) 50%
- ☐ D) 69%
- ☐ E) 87%
- ☐ F) 100%

13. (2.00 pts) What is the maximum efficiency for a solar cell on Earth with incoming radiation coming only from the Sun?

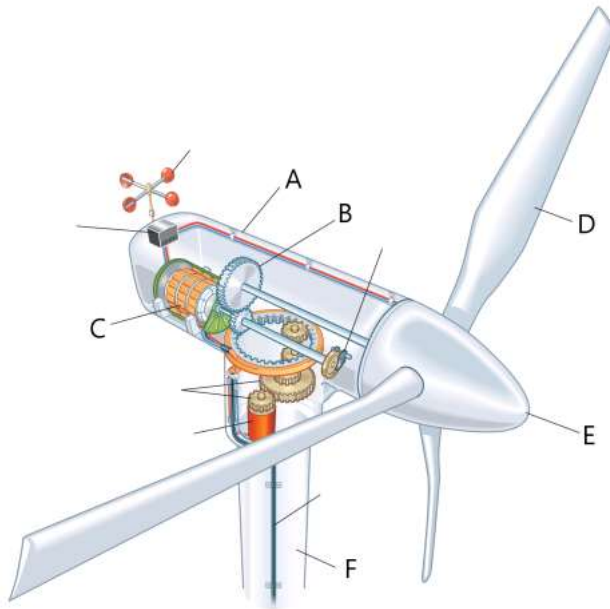
- ☐ A) 25%
- ☐ B) 33%

- ☐ C) 50%
- ☐ D) 69%
- ☐ E) 87%
- ☐ F) 100%

14. (2.00 pts) What is the maximum efficiency for a solar cell with a single p-n junction?

- ☐ A) 25%
- ☐ B) 33%
- ☐ C) 50%
- ☐ D) 69%
- ☐ E) 87%
- ☐ F) 100%

15. (1.00 pts) The following diagram of a wind turbine will be used for the next 6 questions.



What is part A?

16. (1.00 pts) What is part B?

17. (1.00 pts) What is part C?

18. (1.00 pts) What is part D?

19. (1.00 pts) What is part E?

20. (1.00 pts) What is part F?

21. (2.00 pts) Which of the following is an accurate description of hydroelectric power generation?

- ☐ A) In the past 20 years, annual and monthly hydroelectric generation have remained constant
- ☐ B) In the past 20 years, annual hydroelectric generation has remained constant, but monthly hydroelectric generation has varied significantly within each year
- ☐ C) In the past 20 years, annual hydroelectric generation has varied significantly, but monthly hydroelectric generation has remained constant within each year
- ☐ D) In the past 20 years, annual and monthly hydroelectric generation have varied significantly

22. (2.00 pts) Which country is the world's largest producer of hydroelectric energy?

- ☐ A) Canada
- ☐ B) China
- ☐ C) Germany
- ☐ D) India
- ☐ E) Japan
- ☐ F) United States

23. (2.00 pts) Which of the following is the most common type of hydroelectric power plant?

- ☐ A) Diversion
- ☐ B) Inversion
- ☐ C) Lake
- ☐ D) Ocean
- ☐ E) Storage
- ☐ F) Pumped Storage

24. (1.00 pts) True/False: Tidal turbines are more efficient than wind turbines.

- ☐ True
- ☐ False

25. (1.00 pts) True/False: Tidal energy plants have a longer lifespan than solar panels.

☐ True ☐ False

26. (1.00 pts) True/False: There is more tidal energy available than solar energy.

☐ True ☐ False

27. (1.00 pts) True/False: The United States is the world's largest producer of tidal energy.

☐ True ☐ False

28. (1.00 pts) True/false: OTEC is more efficient than solar power.

☐ True ☐ False

29. (1.00 pts) True/false: OTEC is continuously available.

☐ True ☐ False

30. (1.00 pts) True/false: OTEC can be used in heating systems.

☐ True ☐ False

31. (1.00 pts) True/false: OTEC can be used in agriculture.

☐ True ☐ False

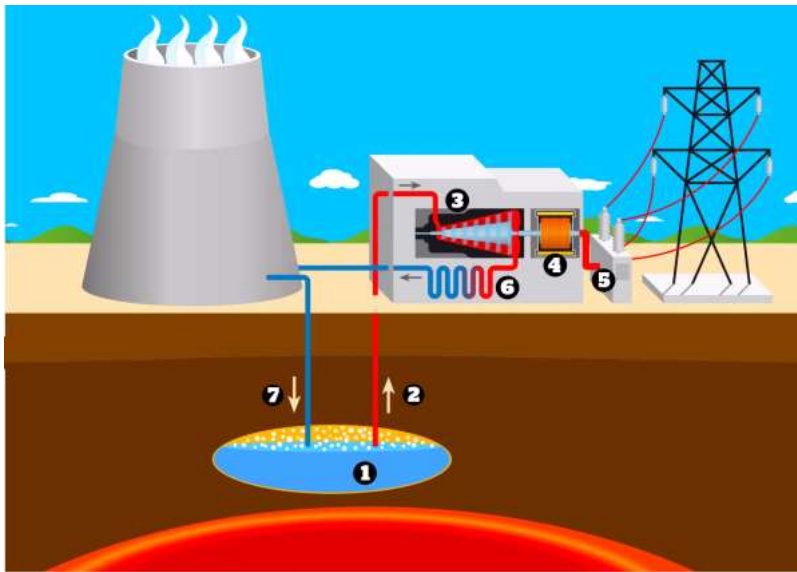
32. (1.00 pts) True/false: OTEC plants can be used to improve nearby water quality.

☐ True ☐ False

33. (1.00 pts) True/False: OTEC is used in the US power grid.

☐ True ☐ False

34. (1.00 pts) The following diagram of a geothermal power plant will be used for the next 7 questions.



What is part 1?

35. (1.00 pts) Part 2 is a(n) _____ well.

36. (1.00 pts) What is part 3?

37. (1.00 pts) What is part 4?

38. (1.00 pts) What is part 5?

39. (1.00 pts) What is part 6?

40. (1.00 pts) Part 7 is a(n) _____ well.

41. (2.00 pts) Why is fiberglass difficult to recycle?

- ☐ A) It isn't durable enough to reuse
- ☐ B) There isn't enough market demand
- ☐ C) It is difficult to process with typical machinery
- ☐ D) It contaminates other plastics
- ☐ E) It is a thermosetting polymer

42. (2.00 pts) Why is LDPE (used in grocery bags) difficult to recycle?

- ☐ A) It isn't durable enough to reuse
- ☐ B) There isn't enough market demand
- ☐ C) It is difficult to process with typical machinery
- ☐ D) It contaminates other plastics
- ☐ E) It is a thermosetting polymer

43. (2.00 pts) How many times can a milk jug be recycled?

- ☐ A) 0
- ☐ B) 1
- ☐ C) 2-3
- ☐ D) 4-10
- ☐ E) 10+

44. (2.00 pts) How many times can a glass bottle be recycled?

- ☐ A) 0
- ☐ B) 1
- ☐ C) 2-3
- ☐ D) 4-10
- ☐ E) 10+

45. (2.00 pts) What does low-carbon energy mean?

- ☐ A) A certain type of fossil fuel
- ☐ B) An energy process that does not use carbon-based products
- ☐ C) An energy process that uses energy contained in carbon atoms
- ☐ D) Any type of renewable energy
- ☐ E) An energy process that does not produce carbon dioxide

46. (2.00 pts) Why is battery storage used alongside solar and wind power?

- ☐ A) Charging batteries is cheaper than other forms of energy conversion

- ☐ B) Using batteries increases the efficiency of power generation systems
- ☐ C) Power grids cannot directly handle the output of power generation systems
- ☐ D) Solar and wind power are not consistently available

47. (2.00 pts) When times are the peak hours for electricity demand in the US?

- ☐ A) 9 PM - 3 AM
- ☐ B) 3 AM - 9 AM
- ☐ C) 9 AM - 3 PM
- ☐ D) 3 PM - 9 PM

48. (2.00 pts) A hot plate is used to heat 2 L of water from 30°C to 80°C. How much work is done by the hot plate?

- ☐ A) 1.048E5 J
- ☐ B) 2.095E5 J
- ☐ C) 4.190E5 J
- ☐ D) 1.354E6 J
- ☐ E) 2.708E6 J
- ☐ F) 4.190E6 J

49. (2.00 pts) Consider the hot plate from the previous question. If ethanol is used instead of water, how much work is done? Note that ethanol has a density of 789 kg/m³.

- ☐ A) 1.214E5 J
- ☐ B) 1.653E5 J
- ☐ C) 1.916E5 J
- ☐ D) 2.248E5 J
- ☐ E) 3.077E5 J
- ☐ F) 3.306E5 J

50. (4.00 pts) Which is a more effective thermal insulator: a 1.0 mm thick sheet of fiberglass, or a 1.0 m thick block of aluminum?

- ☐ A) The sheet of fiberglass has a **lower** thermal resistance than the block of aluminum, so it is more effective.
- ☐ B) The sheet of fiberglass has a **higher** thermal resistance than the block of aluminum, so it is more effective.
- ☐ C) The block of aluminum has a **lower** thermal resistance than the sheet of fiberglass, so it is more effective.
- ☐ D) The block of aluminum has a **higher** thermal resistance than the sheet of fiberglass, so it is more effective.
- ☐ E) Both are equally effective thermal insulators.

51. (4.00 pts) A block of lead with mass 200 g and temperature 150°C is dropped into a 500 mL beaker of water at room temperature (20°C). What is the equilibrium temperature?

- ☐ A) 21.595 °C
- ☐ B) 21.661 °C
- ☐ C) 23.915 °C
- ☐ D) 25.421 °C
- ☐ E) 26.351 °C

☐ F) 28.994 °C

52. (4.00 pts)

A 300 g metal block with temperature 90°C is dropped into a 250 mL beaker of water at room temperature (20°C). After a long time, the temperature of the water is measured at 28.3°C. What metal is the block made from?

- ☐ A) Lead, since the block has a specific heat of 130 J/kg*K
- ☐ B) Silver, since the block has a specific heat of 234 J/kg*K
- ☐ C) Copper, since the block has a specific heat of 390 J/kg*K
- ☐ D) Nickel, since the block has a specific heat of 440 J/kg*K
- ☐ E) Iron, since the block has a specific heat of 470 J/kg*K
- ☐ F) Aluminum, since the block has a specific heat of 910 J/kg*K

53. (4.00 pts)

Consider a copper wire with diameter 1.0 mm and length 1.0 m. One end of the wire is placed in an ice bath, and the other end is placed in a pot of boiling water. What is the heat current through the wire?

- ☐ A) 0.0302 W
- ☐ B) 0.0385 W
- ☐ C) 0.113 W
- ☐ D) 0.121 W
- ☐ E) 11.3 W
- ☐ F) 38.5 W

54. (4.00 pts)

Hot coffee (85°C) is poured into a styrofoam cup. If the cup is left at room temperature (20°C), what is the rate of heat transfer? Model the cup as a closed cylinder with height 10.0 cm, diameter 5.0 cm, and thickness 2.0 mm.

- ☐ A) 5.301 W
- ☐ B) 11.350 W
- ☐ C) 17.230 W
- ☐ D) 22.531 W
- ☐ E) 25.525 W
- ☐ F) 27.567 W

55. (4.00 pts) How much energy is needed to raise the temperature of a 100 g block of ice from -25°C to 25°C?

- ☐ A) 10.2 kJ
- ☐ B) 17.825 kJ
- ☐ C) 20.95 kJ
- ☐ D) 38.5 kJ
- ☐ E) 43.875 kJ
- ☐ F) 48.975 kJ

Congratulations on completing the University of Michigan 2021 Invitational Solar Power C test!

If you have any questions or concerns pertaining to this event, please email tec.umichscioly@umich.edu (mailto:tec.umichscioly@umich.edu), and we will try to get back to you as soon as we can.