Thermodynamics Written Test

(Rustin Invitational, January 2018)

Part 1: History and Basic Concepts of Thermodynamics

Write your answer in the appropriate space on the answer sheet. Each item is worth 1 point.

1. The study of thermodynamics developed out of a desire to _____.

A) improve weather forecasting
B) design better ovens for baking bread
C) better understand the properties of hydrated compounds
D) put a man on the Moon
E) increase the efficiency of early steam engines

2. Who was the first to formulate a concise definition of thermodynamics when he stated in 1854, "Thermo-dynamics is the subject of the relation of heat to forces acting between contiguous parts of bodies, and the relation of heat to electrical agency."?

A) Thomson B) Guericke C) Kelvin D) Joule E) Maxwell

3. In which century was Boyle's Law, a statement about the relationship between the pressure and volume of a gas, formulated?

A) the 1500s B) the 1600s C) the 1700s D) the 1800s E) the 1900s

4. Who developed the concepts of latent heat and heat capacity, which were necessary for the development of thermodynamics?

A) Watt B) Boltzmann C) Clausius D) Black E) Gibbs

5. Who is considered to be the "father of thermodynamics"?

A) Carnot B) Newton C) Einstein D) Helmholtz E) Hooke

Items 6-9 are each statements of one of the laws of thermodynamics. Match each statement to the number of the law as follows:

A) The Zeroth Law of Thermodynamics
B) The First Law of Thermodynamics
C) The Second Law of Thermodynamics
D) The Third Law of Thermodynamics
E) The Fourth Law of Thermodynamics

6. As a system approaches absolute zero, all processes cease and the entropy of the system approaches a minimum value.

7. Heat cannot spontaneously flow from a colder location to a hotter location.

8. If two systems are in thermal equilibrium with a third, they are in thermal equilibrium with each other.

9. The internal energy of an isolated system is constant.

10. What is an adiabatic process?

A) It is a constant volume process.
B) It is a constant temperature process.
C) It is a constant pressure process.
D) It is a process wherein no heat is exchanged between the system and the surroundings.
E) It is a process wherein no work is done on the surroundings by the system.

For each of the following processes described in items 11-17, indicate the principle mechanism of heat transfer as follows:

A) The principle mechanism of heat transfer is **conduction**.
B) The principle mechanism of heat transfer is **convection**.
C) The principle mechanism of heat transfer is **radiation**.

11. The Sun heating the Earth.

12. Burning your finger as a result of touching a hot pan.

13. Toasting bread in an electric toaster.

14. Heating a room in your house by allowing steam to pass through a radiator.

15. Heating a room in your house by using a blower to blow hot air through ducts and then through a vent into the room.

16. Heat escaping from Earth into space.

17. Heat rising from the first floor of a house to the second floor.

18. How many of the processes described in items 11-17 above are examples of heat transfer due to *natural* convection?

A) none B) one C) two D) three E) more than three

19. What is the freezing point of water in degrees Celsius?

20. What is the boiling point of water in the Kelvin temperature scale?

Part 2: Problem Solving (Single Concept)
Write your answer in the appropriate space on the answer sheet. Each item is worth 2 points.

Use the following information as necessary:

Heat capacity of liquid water	4.2 J/(g·K)
Latent heat of fusion of water	330 J/g
Latent heat of vaporization of water	2200 J/g

21. How much energy (in Joules) is required to melt 500 g of ice initially at 0°C?

22. How much energy (in Joules) is required to raise the temperature of 200 g of liquid water from 20°C to 50°C?

23. A closed container of gas is heated and allowed to expand. When 700 joules of heat is added to this system, it does 420 joules of work on the surroundings. By how much (in joules) does the internal energy of the gas increase during this process?

24. Convert 20°C into degrees Fahrenheit (°F).

25. Convert 10°F into degrees Celsius (°C).

26. Convert 40°C into Kelvin (K).

27. A constant temperature thermal reservoir is maintained at 300K. By how much (in J/K) does the entropy of the reservoir change if 1500 J of heat is added to the reservoir?

28. A heat engine is able to perform 180 J of work when it is supplied with 500 J of heat. What is the efficiency of this heat engine operating under these conditions?

29. A copper bar is wrapped in a perfectly insulating material leaving just the two ends exposed. One end is exposed to a thermal reservoir at 20°C and the other end is exposed to a thermal reservoir at 60°C. The bar is 2.0 meters long and each end of the bar has an area of 0.010 m^2. The thermal conductivity of copper is 400 W/(m·°C). At what rate (in watts) is heat transferred through the bar after the system has come to steady state?

30. An unknown material requires 5400 J of energy to raise its temperature by 2.0 K. If the mass of the material is 3.0 kg, what is the heat capacity (in J/(kg·K)) of the unknown material?

Part 3: Problem Solving (Multiple Concepts)
Write your answer in the appropriate space on the answer sheet. Each problem is worth 5 points.

Use the following information as necessary:

Heat capacity of liquid water	4.2 J/(g·K)
Latent heat of fusion of water	330 J/g
Latent heat of vaporization of water	2200 J/g

31. A cup of water, thermally isolated from its environment, contains 1000 grams of water initially at 20°C. If 150 g of ice at 0°C is added to the water, what is the temperature of the water (in °C) once the ice has all melted?

32. A pan of water on the stove holds 500 g of water. When the burner is turned on, it takes 2.0 minutes to heat the water from its initial temperature of 30°C to the boiling point, 100°C. How long (in minutes) after the water has reached its boiling point will it take for all of the water to boil away? Assume that heat is transferred to the water at a constant rate for the entire process.

33. A homeowner maintains his indoor temperature at 20°C. He finds that his house loses about 8000 kilojoules of heat each hour to the surroundings when the outdoor temperature is 0°C. How much heat can he expect his house to lose (in kilojoules) to the surroundings each hour if the outside temperature drops to -10°C?

34. Consider a three-step heat engine which consists of a gas in a closed container that is able to expand and contract. In the first step, 2000 joules of heat is added to the gas in the closed container while the volume of the container is held constant. No work is done by or on the gas during this first step. In the second step, 1020 joules of heat is added to the gas in the container as the volume of the container increases. The gas does 1020 joules of work on its surroundings during this second step. In the third step, the gas is cooled back to its initial temperature and pressure as the container returns to its original volume. During this third step, 2800 joules of heat escapes from the gas within the container and the surroundings does 800 joules of work on the gas within the container. Calculate the efficiency of this heat engine.

Answer Key for the Thermodynamics Written Test

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Part 1: (1 pt. each)

1. E
2. C
3. B
4. D
5. A
6. D
7. C
8. A
9. B
10. D
11. C
12. A
13. C
14. B
15. B
16. C
17. B
18. C
19. 0°C
20. 373 K

Part 2: (2 pts. each)

21. 1.65×10^5 J
22. 2.52×10^4 J
23. 280 J
24. 68° F
25. -12°C
26. 313 K
27. 5.0 J/K
28. 0.36
29. 80 W
30. 900 J/(kg·K)

Part 3: (5 pts each)

31. 7°C (accept 8°C)
32. 15 min
33. 1.2×10^4 kJ
34. 0.073 (7.3%)