TEMPERATURE, HEAT, AND THE FIRST LAW OF THERMODYNAMICS

1.// **If two objects are in thermal equilibrium with each other:**
A. they cannot be moving. B. they cannot be undergoing an elastic collision.
C. they cannot have different pressures. D. they cannot be at different temperatures.
D. they cannot be at different temperatures.
E. they cannot be falling in Earth's gravitational field. **Ans. D**

2.// **When two gases separated by a diathermal wall are in thermal equilibrium with each other:**
A. only their pressures must be the same. B. only their volumes must be the same.
C. they must have the same number of particles. D. they must have the same pressure and the same. volume E. only their temperatures must be the same. **Ans. E**

3.// **A balloon is filled with cold air and placed in a warm room. It is NOT in thermal equilibrium with the air of the room until:**
A. it rises to the ceiling. B. it sinks to the floor. C. it stops expanding.
D. it starts to contract. E. none of the above. **Ans. C**

4.// **Suppose object C is in thermal equilibrium with object A and with object B. The zeroth law of thermodynamics states:**
A. that C will always be in thermal equilibrium with both A and B.
B. that C must transfer energy to both A and B.
C. that A is in thermal equilibrium with B.
D. that A cannot be in thermal equilibrium with B.
E. nothing about the relationship between A and B. **Ans. C**

5.// **The zeroth law of thermodynamics allows us to define:**
A. work. B. pressure. C. temperature. D. thermal equilibrium.
E. internal energy. **Ans. C**

6.// **If the zeroth law of thermodynamics were not valid, which of the following could not be considered a property of an object?. A. Pressure. B. Center of mass energy.**
C. Internal energy D. Momentum. E. Temperature. **Ans. E**

7.// **The international standard thermometer is kept:**
A. near Washington, D.C. B. near Paris, France. C. near the north pole.
D. near Rome, Italy. E. nowhere (there is none). **Ans. E**

8.// **In constructing a thermometer it is NECESSARY to use a substance that:**
A. expands with rising temperature. B. expands linearly with rising temperature.
C. will not freeze. D. will not boil. E. undergoes some change when heated or cooled. **Ans. E**

9.// **The "triple point" of a substance is that point for which the temperature and pressure are such that:** **A. only solid and liquid are in equilibrium.** **B. only liquid and vapor are in equilibrium.** **C. only solid and vapor are in equilibrium.** **D. solid, liquid, and vapor are all in equilibrium.** **E. the temperature, pressure and density are all numerically equal.** **Ans. D**

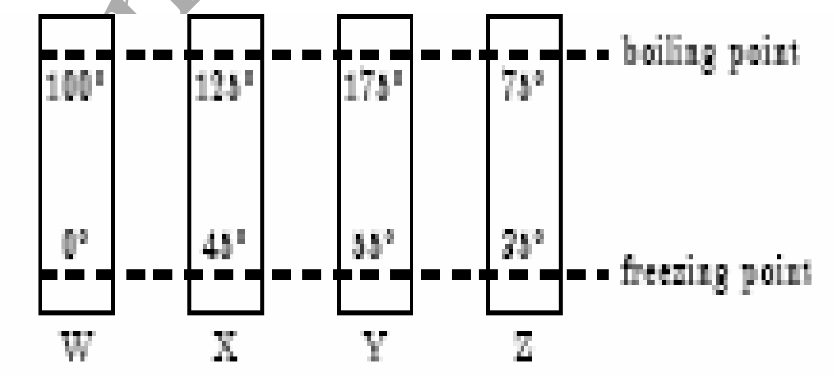
10.// **Constant-volume gas thermometers using different gases all indicate nearly the same temperature when in contact with the same object if:**
A. the volumes are all extremely large **B. the volumes are all the same.**
D. the pressures are all extremely large **C. the pressures are the same.**
E. the particle concentrations are all extremely small. **Ans. E**

11.// **A constant-volume gas thermometer is used to measure the temperature of an object. When the thermometer is in contact with water at its triple point (273.16 K) the pressure in the thermometer is 8.500×10^4 Pa. When it is in contact with the object the pressure is 9.650×10^4 Pa. The temperature of the object is:**
A. 37.0K. **B. 241K.** **C. 310K.** **D. 314K.** **E. 2020K.** **Ans. C**

12.// **When a certain constant-volume gas thermometer is in thermal contact with water at its triple point (273.16 K) the pressure is 6.30×10^4 Pa. For this thermometer a kelvin corresponds to a change in pressure of about:**
A. 4.34×10^2 Pa. **B. 2.31×10^2 Pa.** **C. 1.72×10^3 Pa.** **D. 2.31×10^3 Pa.**
E. 1.72×10^7 Pa. **Ans. B**

13.// **The diagram shows four thermometers, labeled W, X, Y, and Z. The freezing and boiling points of water are indicated. Rank the thermometers according to the size of a degree on their scales, smallest to largest.**

A. W, X, Y, Z.
B. Z, Y, X, W.
C. Z, Y, W, X.
D. Z, X, W, Y.
E. W, Y, Z, X.
ans: D



14.// **There is a temperature at which the reading on the Kelvin scale is numerically:**
A. equal to that on the Celsius scale. **B. lower than that on the Celsius scale**
C. equal to that on the Fahrenheit scale. **D. less than zero.**
E. none of the above. **Ans. C**

15.// **Fahrenheit and Kelvin scales agree numerically at a reading of:**
A. -40. **B. 0.** **C. 273.** **D. 301.** **E. 574.** **Ans. E**

16.// **Which one of the following statements is true?**
A. Temperatures differing by 25◦ on the Fahrenheit scale must differ by 45◦ on the Celsius Scale. **B. 40K corresponds to −40◦ C.**
C. Temperatures which differ by 10◦ on the Celsius scale must differ by 18◦ on the Fahrenheit scale. **D. Water at 90◦ C is warmer than water at 202◦ F.**
E. 0◦ F corresponds to −32◦ C. **Ans. C**

17.// **A Kelvin thermometer and a Fahrenheit thermometer both give the same reading for a certain sample. The corresponding Celsius temperature is:**
A. 574◦ C. **B. 232◦ C.** **C. 301◦ C.** **D. 614◦ C.** **E. 276◦ C.** **Ans. C**

18.// **Room temperature is about 20 degrees on the:**
A. Kelvin scale. **B. Celsius scale.** **C. Fahrenheit scale.** **D. absolute scale.**
E. C major scale. **Ans. B**

19.// **A thermometer indicates 98.6◦ C. It may be:**
A. outdoors on a cold day. **B. in a comfortable room.** **C. in a cup of hot tea.**
D. in a normal person's mouth. **E. in liquid air.** **Ans. C**

20.// **The air temperature on a summer day might be about:**
A. 0◦ C. **B. 10◦ C.** **C. 25◦ C.** **D. 80◦ C.** **E. 125◦ C.** **Ans. C**

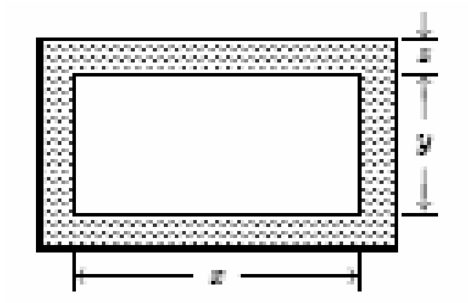
21.// **The two metallic strips that constitute some thermostats must differ in:**
A. length. **B. thickness.** **C. mass.** **D. rate at which they conduct heat.**
E. coefficient of linear expansion. **Ans. E**

22.// **Thin strips of iron and zinc are riveted together to form a bimetallic strip that bends when heated. The iron is on the inside of the bend because:**
A. it has a higher coefficient of linear expansion.
B. it has a lower coefficient of linear expansion. **C. it has a higher specific heat.**
D. it has a lower specific heat. **E. it conducts heat better.**
Ans. B

23.// **It is more difficult to measure the coefficient of volume expansion of a liquid than that of a solid because:**
A. no relation exists between linear and volume expansion coefficients.
B. a liquid tends to evaporate. **C. a liquid expands too much when heated.**
D. a liquid expands too little when heated. **E. the containing vessel also expands.**
Ans. E

24.// **A surveyor's 30-m steel tape is correct at 68◦ F. On a hot day the tape has expanded to 30.01 m. On that day, the tape indicates a distance of 15.52m between two points. The true distance between these points is:**
A. 15.50m. **B. 15.51m.** **C. 15.52m.** **D. 15.53m.** **E. 15.54m.** **Ans.. B**

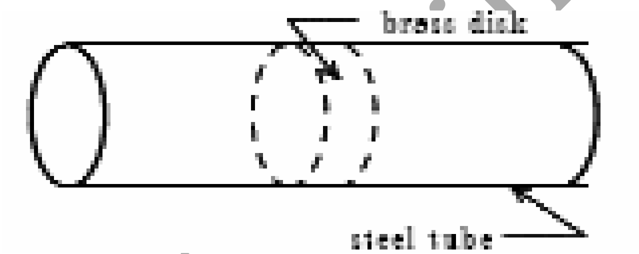
25.// **The figure shows a rectangular brass plate at 0° C in which there is cut a rectangular hole of dimensions indicated. If the temperature of the plate is raised to 150° C:**



A. x will increase and y will decrease.
B. both x and y will decrease.
C. x will decrease and y will increase.
D. both x and y will increase.
E. the changes in x and y depend on the dimension z.
ans. D

26.// **The Stanford linear accelerator contains hundreds of brass disks tightly fitted into a steel tube(see figure). The coefficient of linear expansion of the brass is 2.00×10^{-5} per C°. The system was assembled by cooling the disks in dry ice (-57° C) to enable them to just slide into the close-fitting tube. If the diameter of a disk is 80.00mm at 43° C, what is its diameter in the dry ice?**

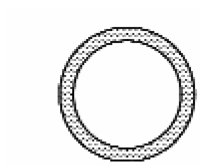
A. 78.40mm.
B. 79.68mm.
C. 80.16mm.
D. 79.84mm.
E. None of these.
Ans. D



27.// **When the temperature of a copper penny is increased by 100° C, its diameter increases by 0.17%. The area of one of its faces increases by:**

A. 0.17%. B. 0.34%. C. 0.51%. D. 0.13%. E. 0.27%. Ans. B

28.// **An annular ring of aluminum is cut from an aluminum sheet as shown. When this ring is heated:**



A. the aluminum expands outward and the hole remains the same in size.
B. the hole decreases in diameter.
C. the area of the hole expands the same percent as any area of the aluminum.
D. the area of the hole expands a greater percent than any area of the aluminum.
E. linear expansion forces the shape of the hole to be slightly elliptical. Ans. C

29.// **Possible units for the coefficient of volume expansion are:**

A. mm/C°. B. mm^3/C°. C. $(C^{\circ})^3$. D. $1/(C^{\circ})^3$. E. $1/C^{\circ}$. Ans. E

30.// **The mercury column in an ordinary medical thermometer doubles in length when its temperature changes from 95° F to 105° F. Choose the correct statement:**

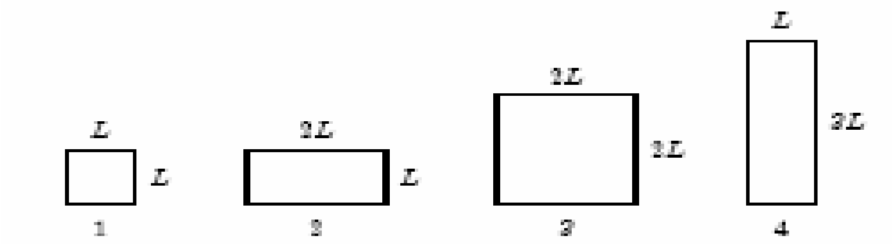
A. the coefficient of volume expansion of mercury is 0.1 per F°.
B. the coefficient of volume expansion of mercury is 0.3 per F°.
C. the coefficient of volume expansion of mercury is (0.1/3) per F°.
D. the vacuum above the column helps to "pull up" the mercury this large amount.
E. none of the above is true. Ans. E

31.// **The coefficient of linear expansion of iron is 1.0×10^{-5} per C°. The surface area of an iron cube, with an edge length of 5.0 cm, will increase by what amount if it is heated from 10° C to 60° C?**

A. 0.0125 cm^2. B. 0.025 cm^2. C. 0.075 cm^2. D. 0.15 cm^2. E. 0.30 cm^2.

Ans. D

32.// **The diagram shows four rectangular plates and their dimensions. All are made of the same material. The temperature now increases. Of these plates:**



A. the vertical dimension of plate 1 increases the most and the area of plate 1 increases the most.

B. the vertical dimension of plate 2 increases the most and the area of plate 4 increases the most.

C. the vertical dimension of plate 3 increases the most and the area of plate 1 increases the most.

D. the vertical dimension of plate 4 increases the most and the area of plate 3 increases the most.

E. the vertical dimension of plate 4 increases the most and the area of plate 4 increases the most.

Ans. D

33.// **The coefficient of linear expansion of steel is 11×10^{-6} per C°. A steel ball has a volume of exactly 100 cm^3 at 0° C. When heated to 100° C, its volume becomes:**

A. 100.33 cm^3. B. 100.0011 cm^3. C. 100.0033 cm^3. D. 100.000011 cm^3.

E. none of these.

Ans. A

34.// **The coefficient of linear expansion of a certain steel is 0.000012 per C°. The coefficient of volume expansion, in $(C^\circ)^{-1}$, is:**

A. $(0.000012)^3$. B. $(4\pi/3)(0.000012)^3$. C. 3×0.000012. D. 0.000012

E. depends on the shape of the volume to which it will be applied.

Ans. C

35.// **Metal pipes, used to carry water, sometimes burst in the winter because:**

A. metal contracts more than water. B. outside of the pipe contracts more than the inside.

C. metal becomes brittle when cold. D. ice expands when it melts

E. water expands when it freezes.

Ans. E

36.// **A gram of distilled water at 4° C:**

A. will increase slightly in weight when heated to 6° C

B. will decrease slightly in weight when heated to 6° C

C. will increase slightly in volume when heated to 6° C

D. will decrease slightly in volume when heated to 6° C

E. will not change in either volume or weight.

Ans. D

37.// **Heat is:**
A. energy transferred by virtue of a temperature difference.
B. energy transferred by macroscopic work.
C. energy content of an object.
D. a temperature difference
E. a property objects have by virtue of their temperatures. **Ans. A**

38.// **Heat has the same units as:. A. temperature. B. work. C. energy/time**
D. heat capacity. E. energy/volume. **Ans. B**

39.// **A calorie is about:. A. 0.24 J. B. 8.3J. C. 250 J. D. 4.2J.**
E. 4200 J. **Ans. D**

40.// **The heat capacity of an object is:**
A. the amount of heat energy that raises its temperature by 1◦ C.
B. the amount of heat energy that changes its state without changing its temperature.
C. the amount of heat energy per kilogram that raises its temperature by 1◦ C.
D. the ratio of its specific heat to that of water.
E. the change in its temperature caused by adding 1 J of heat. **Ans. A**

41.// **The specific heat of a substance is:**
A. the amount of heat energy to change the state of one gram of the substance.
B. the amount of heat energy per unit mass emitted by oxidizing the substance.
C. the amount of heat energy per unit mass to raise the substance from its freezing to its boiling point.
D. the amount of heat energy per unit mass to raise the temperature of the substance by 1◦ C.
E. the temperature of the object divided by its mass. **Ans. D**

42.// **Two different samples have the same mass and temperature. Equal quantities of energy are absorbed as heat by each. Their final temperatures may be different because the samples have different: A. thermal conductivities. B. coefficients of expansion.**
C. densities. D. volumes. E. heat capacities.
Ans. E

43.// **The same energy Q enters five different substances as heat.**
The temperature of 3 g of substance A increases by 10K.
The temperature of 4 g of substance B increases by 4K.
The temperature of 6 g of substance C increases by 15K.
The temperature of 8 g of substance D increases by 6K.
The temperature of 10 g of substance E increases by 10K.
Which substance has the greatest specific heat?. **Ans. B**

44.// **For constant-volume processes the heat capacity of gas A is greater than the heat capacity of gas B. We conclude that when they both absorb the same energy as heat at constant volume:**

A. the temperature of A increases more than the temperature of B
B. the temperature of B increases more than the temperature of A
C. the internal energy of A increases more than the internal energy of B
D. the internal energy of B increases more than the internal energy of A
E. A does more positive work than B. **Ans. B**

45.// **The heat capacity at constant volume and the heat capacity at constant pressure have different values because:**

A. heat increases the temperature at constant volume but not at constant pressure
B. heat increases the temperature at constant pressure but not at constant volume
C. the system does work at constant volume but not at constant pressure
D. the system does work at constant pressure but not at constant volume
E. the system does more work at constant volume than at constant pressure. **Ans. D**

46.// **A cube of aluminum has an edge length of 20 cm. Aluminum has a density 2.7 times that of water (1 g/cm^3) and a specific heat 0.217 times that of water (1 cal/g · C◦). When the internal energy of the cube increases by 47000 cal its temperature increases by:**

A. 5C◦. **B. 10C◦.** **C. 20C◦.** **D. 100C◦.** **E. 200C◦.** **Ans. B**

47.// **An insulated container, filled with water, contains a thermometer and a paddle wheel. The paddle wheel can be rotated by an external source. This apparatus can be used to determine:**

A. specific heat of water. **B. relation between kinetic energy and absolute temperature.**
C. thermal conductivity of water. **D. efficiency of changing work into heat**
E. mechanical equivalent of heat. **Ans. E**

48.// **Take the mechanical equivalent of heat as 4 J/cal. A 10-g bullet moving at 2000m/s plunges into 1 kg of paraffin wax (specific heat 0.7 cal/g ·C◦). The wax was initially at 20◦ C. Assuming that all the bullet's energy heats the wax, its final temperature (in ◦ C) is:**

A. 20.14. **B. 23.5.** **C. 20.006.** **D. 27.1.** **E. 30.23.**
Ans. D

49.// **The energy given off as heat by 300 g of an alloy as it cools through 50C◦ raises the temperature of 300 g of water from 30◦C to 40◦ C. The specific heat of the alloy (in cal/g · C◦) is:**

A. 0.015. **B. 0.10.** **C. 0.15.** **D. 0.20.** **E. 0.50.** **Ans. D**

50.// **The specific heat of lead is 0.030 cal/g · C◦. 300 g of lead shot at 100◦ C is mixed with 100 g of water at 70◦ C in an insulated container. The final temperature of the mixture is:**

A. 100◦ C. **B. 85.5◦ C.** **C. 79.5◦ C.** **D. 74.5◦ C.** **E. 72.5◦ C.** **Ans. E**

51.// **Object A, with heat capacity CA and initially at temperature TA, is placed in thermal contact with object B, with heat capacity CB and initially at temperature TB. The combination is thermally isolated. If the heat capacities are independent of the temperature and no phase changes occur, the final temperature of both objects is:**

A. $(C_AT_A - C_BT_B)/(C_A + C_B)$. **B.** $(C_AT_A + C_BT_B)/(C_A + C_B)$

C. $(C_AT_A - C_BT_B)/(C_A - C_B)$ **D.** $(C_A - C_B)|T_A - T_B|$.

E. $(C_A + C_B)|T_A - T_B|$. **Ans. B**

52.// **The heat capacity of object B is twice that of object A. Initially A is at 300K and B is at 450 K. They are placed in thermal contact and the combination is isolated. The final temperature of both objects is:** **A. 200K.** **B. 300K.** **C. 400K.**

D. 450K. **E. 600K.** **Ans. C**

53.// **A heat of transformation of a substance is:**

A. the energy absorbed as heat during a phase transformation.

B. the energy per unit mass absorbed as heat during a phase transformation.

C. the same as the heat capacity. **D. the same as the specific heat**

E. the same as the molar specific heat.

Ans. B

54.// **The heat of fusion of water is cal/g. This means 80 cal of energy are required to:**

A. raise the temperature of 1 g of water by 1K. **B. turn 1 g of water to steam**

C. raise the temperature of 1 g of ice by 1K. **D. melt 1 g of ice**

E. increase the internal energy of 80 g of water by 1 cal. **Ans. D**

55.// **Solid A, with mass M, is at its melting point TA. It is placed in thermal contact with solid B, with heat capacity CB and initially at temperature TB (TB > TA). The combination is thermally isolated. A has latent heat of fusion L and when it has melted has heat capacity CA. If A completely melts the final temperature of both A and B is:**

A. $(C_AT_A + C_BT_B - ML)/(C_A + C_B)$. **B.** $(C_AT_A - C_BT_B + ML)/(C_A + C_B)$.

C. $(C_AT_A - C_BT_B - ML)/(C_A + C_B)$. **D.** $(C_AT_A + C_BT_B + ML)/(C_A - C_B)$.

E. $(C_AT_A + C_BT_B + ML)/(C_A - C_B)$. **Ans. A**

56.// **During the time that latent heat is involved in a change of state:**

A. the temperature does not change. **B. the substance always expands**

C. a chemical reaction takes place **D. molecular activity remains constant.**

E. kinetic energy changes into potential energy. **Ans. A**

57.// **The formation of ice from water is accompanied by:**

A. absorption of energy as heat. **B. temperature increase.**

C. decrease in volume. **D. an evolution of heat.**

E. temperature decrease. **Ans. A**

58.// **How many calories are required to change one gram of 0◦ C ice to 100◦ C steam? The latent heat of fusion is 80 cal/g and the latent heat of vaporization is 540 cal/g. The specific heat of water is 1.00 cal/g · K.**

A. 100. **B. 540.** **C. 620.** **D. 720.** **E. 900.** **Ans. D**

59.// **Ten grams of ice at −20◦ C is to be changed to steam at 130◦ C. The specific heat of both ice and steam is 0.5 cal/g · C◦. The heat of fusion is 80 cal/g and the heat of vaporization is 540 cal/g. The entire process requires:**

A. 750 cal. B. 1250 cal. C. 6950 cal. D. 7450 cal. E. 7700 cal.

Ans. D

60.// **Steam at 1 atm and 100◦ C enters a radiator and leaves as water at 1 atm and 80◦ C. Take the heat of vaporization to be 540 cal/g. Of the total energy given off as heat, what percent arises from the cooling of the water?**

A. 100. B. 54. C. 26. D. 14. E. 3.6. **Ans. E**

61.// **A certain humidifier operates by raising water to the boiling point and then evaporating it. Every minute 30 g of water at 20◦ C are added to replace the 30 g that are evaporated. The heat of fusion of water is 333 kJ/kg, the heat of vaporization is 2256 kJ/kg, and the specific heat is 4190 J/kg · K. How many joules of energy per minute does this humidifier require?**

A. 3.0×10^4. B. 8.8×10^4. C. 7.8×10^4. D. 1.1×10^5. E. 2.0×10^4.

Ans. B

62.// **A metal sample of mass M requires a power input P to just remain molten. When the heater is turned off, the metal solidifies in a time T. The specific latent heat of fusion of this metal is:**

A. P/MT. B. T/PM. C. PM/T. D. PMT. E. PT/M. **Ans. E**

63.// **Fifty grams of ice at 0◦ C is placed in a thermos bottle containing one hundred grams of water at 6◦ C. How many grams of ice will melt? The heat of fusion of water is 333 kJ/kg and the specific heat is 4190 J/kg · K.**

A. 7.5. B. 2.0. C. 8.3. D. 17. E. 50. **Ans. A**

64.// **According to the first law of thermodynamics, applied to a gas, the increase in the internal energy during any process:**

A. equals the heat input minus the work done on the gas.
B. equals the heat input plus the work done on the gas.
C. equals the work done on the gas minus the heat input.
D. is independent of the heat input.
E. is independent of the work done on the gas. **Ans. B**

65.// **Pressure versus volume graphs for a certain gas undergoing five different cyclic processes are shown below. During which cycle does the gas do the greatest positive work?**
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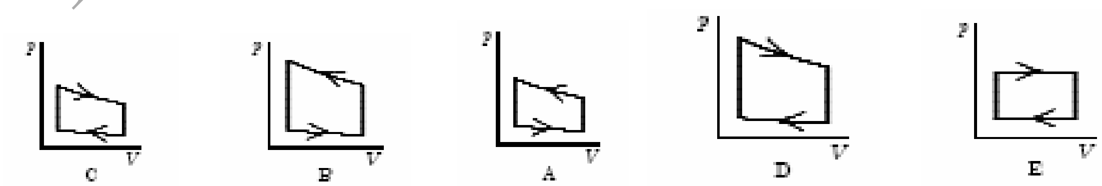


Ans. D

66.// **During an adiabatic process an object does 100 J of work and its temperature decreases by 5K. During another process it does 25 J of work and its temperature decreases by 5K. Its heat capacity for the second process is:**
A. 20 J/K. B. 24 J/K. C. 5 J/K. D. 15 J/K. E. 100 J/K. **Ans. D**

67.// **A system undergoes an adiabatic process in which its internal energy increases by 20 J. Which of the following statements is true?**
A. 20 J of work was done on the system. B. 20 J of work was done by the system.
C. the system received 20 J of energy as heat. D. the system lost 20 J of energy as heat.
E. none of the above are true. **Ans. A**

68.// **In an adiabatic process:**
A. the energy absorbed as heat equals the work done by the system on its environment.
B. the energy absorbed as heat equals the work done by the environment on the system.
C. the absorbed as heat equals the change in internal energy.
D. the work done by the environment on the system equals the change in internal energy.
E. the work done by the system on its environment equals to the change in internal energy.
Ans. D

69.// **In a certain process a gas ends in its original thermodynamic state. Of the following, which is possible as the net result of the process?**
A. It is adiabatic and the gas does 50 J of work.
B. The gas does no work but absorbs 50 J of energy as heat.
C. The gas does no work but loses 50 J of energy as heat.
D. The gas loses 50 J of energy as heat and does 50 J of work.
E. The gas absorbs 50 J of energy as heat and does 50 J of work. **Ans. E**

70.// **Of the following which might NOT vanish over one cycle of a cyclic process?**
A. the change in the internal energy of the substance. B. the change in pressure of the substance. C. the work done by the substan D. the change in the volume of the substance.
E. the change in the temperature of the substance. **Ans. C**

71.// **Of the following which might NOT vanish over one cycle of a cyclic process?**
A. the work done by the substance minus the energy absorbed by the substance as heat.
B. the change in the pressure of the substance. C. the energy absorbed by the substance as heat. D. the change in the volume of the substance. E. the change in the temperature of the substance. **Ans. C**

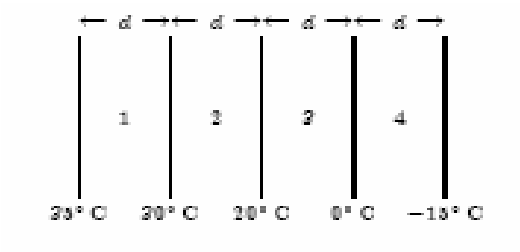
72.// **The unit of thermal conductivity might be: A. cal · cm/(s · C°). B. cal/(cm · s · C°).**
C. cal · s/(cm · C°). D. cm · s · C°C/cal. E. C°/(cal · cm · s). **Ans. B**

73.// **A slab of material has area A, thickness L, and thermal conductivity k. One of its surfaces (P) is maintained at temperature T_1 and the other surface (Q) is maintained at a lower temperature T2. The rate of heat flow by conduction from P to Q is:**
A. $kA(T_1 - T_2)/L^2$. B. kL(T1 − T2)/A. C. $kA(T_1 - T_2)/L$.
D. $k(T_1 - T_2)/(LA)$. E. $LA(T_1 - T_2)/k$. **Ans. C**

74.// **The rate of heat flow by conduction through a slab does NOT depend upon the:**
A. temperature difference between opposite faces of the slab. B. thermal conductivity of the slab. C. slab thickness. D. cross-sectional area of the slab. E. specific heat of the slab. **Ans. E**

75.// **The rate of heat flow by conduction through a slab is Pcond. If the slab thickness is doubled, its cross-sectional area is halved, and the temperature difference across it is doubled, then the rate of heat flow becomes: A. 2Pcond. B. Pcond/2. C. Pcond. D. Pcond/8. E. 8Pcond.** **Ans. B**

76.// **The diagram shows four slabs of different materials with equal thickness, placed side by side. Heat flows from left to right and the steady-state temperatures of the interfaces are given. Rank the materials according to their thermal conductivities, smallest to largest.**



A. 1, 2, 3, 4
B. 2, 1, 3, 4
C. 3, 4, 1, 2
D. 3, 4, 2, 1
E. 4, 3, 2, 1
Ans. D

77.// **Inside a room at a uniform comfortable temperature, metallic objects generally feel cooler to the touch than wooden objects do. This is because:**
A. a given mass of wood contains more heat than the same mass of metal.
B. metal conducts heat better than wood. C. heat tends to flow from metal to wood.
D. the equilibrium temperature of metal in the room is lower than that of wood.
E. the human body, being organic, resembles wood more closely than it resembles metal.
Ans. B

78.// **On a very cold day, a child puts his tongue against a fence post. It is much more likely that his tongue will stick to a steel post than to a wooden post. This is because:**
A. steel has a higher specific heat. B. steel is a better radiator of heat
C. steel has a higher specific gravity. D. steel is a better heat conductor
E. steel is a highly magnetic material. **Ans. D**

79.// **An iron stove, used for heating a room by radiation, is more efficient if:**
A. its inner surface is highly polished. B. its inner surface is covered with aluminum paint. C. its outer surface is covered with aluminum paint. D. its outer surface is rough and black. E. its outer surface is highly polished. **Ans. D**

80.// **To help keep buildings cool in the summer, dark colored window shades have been replaced by light colored shades. This is because light colored shades:**
A. are more pleasing to the eye. B. absorb more sunlight. C. reflect more sunlight. D. transmit more sunlight. E. have a lower thermal conductivity.
Ans. C

81.// **Which of the following statements pertaining to a vacuum flask (thermos) is NOT correct?**

A. Silvering reduces radiation loss.
B. Vacuum reduces conduction loss.
C. Vacuum reduces convection loss.
D. Vacuum reduces radiation loss.
E. Glass walls reduce conduction loss.

Ans. D

82.// **A thermos bottle works well because:**

A. its glass walls are thin
B. silvering reduces convection.
C. vacuum reduces heat radiation
D. silver coating is a poor heat conductor.
E. none of the above.

Ans. E

THE KINETIC THEORY OF GASES

83.// **Evidence that a gas consists mostly of empty space is the fact that:**
A. the density of a gas becomes much greater when it is liquefied
B. gases exert pressure on the walls of their containers. **C. gases are transparent.**
D. heating a gas increases the molecular motion. **E. nature abhors a vacuum.**
Ans. A

84.// **Air enters a hot-air furnace at 7◦ C and leaves at 77◦ C. If the pressure does not change each entering cubic meter of air expands to:**
A. 0.80m^3. **B. 1.25m^3.** **C. 1.9m^3.** **D. 7.0m^3.** **E. 11m^3.** **Ans. B**

85.// **273 cm^3 of an ideal gas is at 0◦ C. It is heated at constant pressure to 10◦ C. It will now occupy:** **A. 263 cm^3.** **B. 273 cm^3.** **C. 283 cm^3.**
D. 278 cm^3. **E. 293 cm^3.** **Ans. C**

86.// **Two identical rooms in a house are connected by an open doorway. The temperatures in the two rooms are maintained at different values. Which room contains more air?**
A. the room with higher temperature. **B. the room with lower temperature.**
C. the room with higher pressure. **D. neither because both have the same pressure.**
E. neither because both have the same volume. **Ans. B**

87.// **It is known that 28 g of a certain ideal gas occupy 22.4 liters at standard conditions (0◦ C, 1 atm). The volume occupied by 42 g of this gas at standard conditions is:**
A. 14.9 liters. **B. 22.4 liters.** **C. 33.6 liters.** **D. 42 liters.**
E. more data are needed. **Ans. C**

88.// **An automobile tire is pumped up to a gauge pressure of 2.0 × 10^5 Pa when the temperature is 27◦ C. What is its gauge pressure after the car has been running on a hot day so that the tire temperature is 77◦ C? Assume that the volume remains fixed and take atmospheric pressure to be 1.013 × 10^5 Pa.**
A. 1.6 × 10^5 Pa. **B. 2.6 × 10^5 Pa.** **C. 3.6 × 10^5 Pa.** **D. 5.9 × 10^5 Pa.**
E. 7.9 × 10^5 Pa. **Ans. A**

89.// **A sample of an ideal gas is compressed by a piston from 10m^3 to 5m^3 and simultaneously cooled from 273◦ C to 0◦ C. As a result there is:**
A. an increase in pressure. **B. a decrease in pressure.** **C. a decrease in density.**
D. no change in density. **E. an increase in density.** **Ans. E**

90.// **A 2-m^3 weather balloon is loosely filled with helium at 1 atm (76 cm Hg) and at 27◦ C. At an elevation of 20, 000 ft, the atmospheric pressure is down to 38 cm Hg and the helium has expanded, being under no constraint from the confining bag. If the temperature at this elevation is -48◦ C, the gas volume (in m^3) is:**
A. 3. **B. 4.** **C. 2.** **D. 2.5.** **E. 5.3.** **Ans. A**

91.// **Oxygen (molar mass = 32 g) occupies a volume of 12 liters when its temperature is 20◦ C and its pressure is 1 atm. Using R = 0.082 liter · atm/mol · K, calculate the mass of the oxygen:**

A. 6.4g. **B. 10. g7.** **C. 16 g.** **D. 32 g.** **E. 64 g.** **Ans. C**

92.// **An ideal gas occupies 12 liters at 293K and 1 atm (76 cm Hg). Its temperature is now raised to 373K and its pressure increased to 215 cm Hg. The new volume is:**

A. 0.2 liters. **B. 5.4 liters.** **C. 13.6 liters.** **D. 20.8 liters.**
E. none of these. **Ans. B**

93.// **Use R = 8.2×10^{-5} m^3 · atm/mol · K and NA = 6.02×10^{23} mol^{-1}. The approximate number of air molecules in a 1m3 volume at room temperature (300K and atmospheric pressure is:**

A. 41. **B. 450.** **C. 2.5×10^{25}.** **D. 2.7×10^{26}.** **E. 5.4×10^{26}.** **Ans. C**

94.// **An air bubble doubles in volume as it rises from the bottom of a lake (1000 kg/m^3). Ignoring any temperature changes, the depth of the lake is:**

A. 21m. **B. 0.76m.** **C. 4.9m.** **D. 10m.** **E. 0.99m.** **Ans. D**

95.// **An isothermal process for an ideal gas is represented on a p-V diagram by:**

A. a horizontal line. **B. a vertical line.** **C. a portion of an ellipse**
D. a portion of a parabola. **E. a portion of a hyperbola.** **Ans. E**

96.// **An ideal gas undergoes an isothermal process starting with a pressure of 2×10^5 Pa and a volume of 6 cm^3. Which of the following might be the pressure and volume of the final state?**

A. 1×10^5 Pa and 10 cm^3. **B. 3×10^5 Pa and 6 cm^3.**
C. 4×10^5 Pa and 4 cm^3. **D. 6×10^5 Pa and 2 cm^3.**
E. 8×10^5 Pa and 2 cm^3. **Ans. D**

97.// **The pressures p and volumes V of five ideal gases, with the same number of molecules, are given below. Which has the highest temperature?**

A. p = 1×10^5 Pa and V = 10cm^3. **B. p = 3×10^5 Pa and V = 6cm^3.**
C. p = 4×10^5 Pa and V = 4cm^3. **D. p = 6×10^5 Pa and V = 2cm^3.**
E. p = 8×10^5 Pa and V = 2cm^3. **Ans. B**

98.// **During a slow adiabatic expansion of a gas:**

A. the pressure remains constant. **B. energy is added as heat.**
C. work is done on the gas. **D. no energy enters or leaves as heat.**
E. the temperature is constant. **Ans. D**

99.// **An adiabatic process for an ideal gas is represented on a p-V diagram by:**

A. a horizontal line. **B. a vertical line.** **C. a hyperbola.** **D. a circle.**
E. none of these. **Ans. E**

100. // **A real gas undergoes a process that can be represented as a curve on a p-V diagram. The work done by the gas during this process is:**
A. pV. **B. $p(V_2 - V_1)$.** **C. $(p_2 - p_1)V$.** **D. $\int pdV$.**
E. V dp. **Ans. D**

101.// **A real gas is changed slowly from state 1 to state 2. During this process no work is done on or by the gas. This process must be:**
A. isothermal. **B. adiabatic.** **C. isovolumic.** **D. isobaric.**
E. a closed cycle with state 1 coinciding with state 2. **Ans. C**

102.// **A given mass of gas is enclosed in a suitable container so that it may be maintained at constant volume. Under these conditions, there can be no change in what property of the gas?**
A. Pressure. **B. Density.** **C. Molecular kinetic energy.** **D. Internal energy.**
E. Temperature. **Ans. B**

103.// **A quantity of an ideal gas is compressed to half its initial volume. The process may be adiabatic, isothermal, or isobaric. Rank those three processes in order of the work required of an external agent, least to greatest.**
A. adiabatic, isothermal, isobaric. **B. adiabatic, isobaric, isothermal.**
C. isothermal, adiabatic, isobaric **D. isobaric, adiabatic, isothermal.**
E. isobaric, isothermal, adiabatic. **Ans. E**

104.// **During a reversible adiabatic expansion of an ideal gas, which of the following is NOT true?** **A. pV^{γ} = constant.** **B. pV = nRT.** **C. $TV^{\gamma-1}$ = constant.**
D. $|W| = \int pdV$. **E. pV = constant.** **Ans. E**

105.// **In order that a single process be both isothermal and isobaric:**
A. one must use an ideal gas. **B. such a process is impossible.**
C. a change of phase is essential. **D. one may use any real gas such as N_2.**
E. one must use a solid. **Ans. C**

106.// **Over 1 cycle of a cyclic process in which a system does net work on its environment:**
A. the change in the pressure of the system cannot be zero.
B. the change in the volume of the system cannot be zero.
C. the change in the temperature of the system cannot be zero.
D. the change in the internal energy of the system cannot be zero.
E. none of the above. **Ans. E**

107.// **Evidence that molecules of a gas are in constant motion is:**
A. winds exert pressure. **B. two gases interdiffuse quickly.**
C. warm air rises. **D. energy as heat is needed to vaporize a liquid.**
E. gases are easily compressed. **Ans. B**

108.// **According to the kinetic theory of gases, the pressure of a gas is due to:**
A. change of kinetic energy of molecules as they strike the wall.
B. change of momentum of molecules as the strike the wall.
C. average kinetic energy of the molecules. **D. force of repulsion between the molecules.**
E. rms speed of the molecules. **Ans. B**

109.// **The force on the walls of a vessel of a contained gas is due to:**
A. the repulsive force between gas molecules.
B. a slight loss in the speed of a gas molecule during a collision with the wall.
C. a change in momentum of a gas molecule during a collision with the wall.
D. elastic collisions between gas molecules.
E. inelastic collisions between gas molecules. **Ans. C**

110.// **A gas is confined to a cylindrical container of radius 1 cm and length 1m. The pressure exerted on an end face, compared with the pressure exerted on the long curved face, is:**
A. smaller because its area is smaller
B.smaller because most molecules cannot traverse the length of the cylinder without undergoing collisions **C. larger because the face is flat**
D. larger because the molecules have a greater distance in which to accelerate before they strike the face. **E. none of these.** **Ans. E**

111.// **Air is pumped into a bicycle tire at constant temperature. The pressure increases because:**
A. more molecules strike the tire wall per second. **B. the molecules are larger**
C. the molecules are farther apart. **D. each molecule is moving faster.**
E. each molecule has more kinetic energy. **Ans. A**

112.// **The temperature of a gas is most closely related to:**
A. the kinetic energy of translation of its molecules. **B. its total molecular kinetic energy.**
C. the sizes of its molecules. **D. the potential energy of its molecules.**
E. the total energy of its molecules. **Ans. A**

113.// **The temperature of low pressure hydrogen is reduced from 100◦ C to 20◦ C. The rms speed of its molecules decreases by approximately:**
A. 80%. **B. 89%.** **C. 46%.** **D. 21%.** **E. 11%.** **Ans. E**

114.// **The mass of an oxygen molecule is 16 times that of a hydrogen molecule. At room temperature, the ratio of the rms speed of an oxygen molecule to that of a hydrogen molecule is:**
A. 16. **B. 4.** **C. 1.** **D. 1/4.** **E. 1/16.** **Ans. D**

115.// **The rms speed of an oxygen molecule at 0◦ C is 460m/s. If the molar mass of oxygen is 32 g and that of helium is 4 g, then the rms speed of a helium molecule at 0◦ C is:**
A. 230m/s. **B. 326m/s.** **C. 650m/s.** **D. 920m/s.** **E. 1300m/s.**
Ans. E

116.// **A sample of argon gas (molar mass 40 g) is at four times the absolute temperature of a sample of hydrogen gas (molar mass 2 g). The ratio of the rms speed of the argon molecules to that of the hydrogen is:**
A. 1. B. 5. C. 1/5. D. √5. E. 1/√5. **Ans. D**

117.// **If the molecules in a tank of hydrogen have the same rms speed as the molecules in a tank of oxygen, we may be sure that: A. the pressures are the same B. the hydrogen is at the higher temperature. C. the hydrogen is at the greater pressure. D. the temperatures are the same. E. the oxygen is at the higher temperature.** **Ans. E**

118.// **The principle of equipartition of energy states that the internal energy of a gas is shared equally: A. among the molecules. B. between kinetic and potential energy. C. among the relevant degrees of freedom. D. between translational and vibrational kinetic energy. E. between temperature and pressure.** **Ans. C**

119.// **The number of degrees of freedom of a rigid diatomic molecule is:**
A. 2 B. 3 C. 4 D. 5 E. 6 **Ans. D**

120.// **The number of degrees of freedom of a triatomic molecule is:**
A. 1 B. 3 C. 6 D. 8 E. 9 **Ans. E**

121.// **Five molecules have speeds of 2.8, 3.2, 5.8, 7.3, and 7.4m/s. Their root-mean-square speed is closest to:**
A. 5.3m/s B. 5.7m/s C. 7.3m/s D. 28m/s E. 32m/s **Ans. B**

122.// **The speeds of 25 molecules are distributed as follows: 5 in the range from 2 to 3m/s, 10 in the range from 3 to 4m/s, 5 in the range from 4 to 5m/s, 3 in the range from 5 to 6m/s, 1 in the range from 6 to 7m/s, and 1 in the range from 7 to 8m/s. Their average speed is about:**
A. 2m/s. B. 3m/s. C. 4m/s D. 5m/s E. 6m/s
Ans. C

123.// **In a system of N gas molecules, the individual speeds are v1, v2, . . ., vN. The rms speed of these molecules is:**

A. $\frac{1}{N}\sqrt{v_1 + v_2 + \ldots + v_N}$ B. $\frac{1}{N}\sqrt{v_1^2 + v_2^2 + \ldots + v_N^2}$ C. $\sqrt{(v_1^2 + v_2^2 + \ldots + v_N^2)/N}$
D. $\sqrt{[(v_1 + v_2 + \ldots + v_N)/N]^2}$ E. $\sqrt{(v_1 + v_2 + \ldots + v_N)^2/N}$
Ans. C

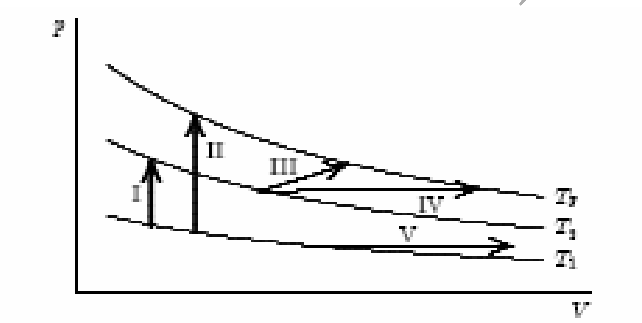
124.// **A system consists of N gas molecules, each with mass m. Their rms speed is vrms. Their total translational kinetic energy is: A. $(1/2)m(Nv_{rms})^2$. B. $(1/2)N(mv_{rms})^2$. C. $(1/2)mv^2_{rms}$. D. $(1/2)Nmv^2_{rms}$. E. $N[(1/2)mv_{rms}]^2$.** **Ans. D**

125.// **The average speeds v and molecular diameters d of five ideal gases are given below. The number of molecules per unit volume is the same for all of them. For which is the collision rate the greatest?** **A.** $v = v_0$ and $d = d_0$. **B.** $v = 2v_0$ and $d = d_0/2$
C. $v = 3v_0$ and $d = d_0$. **D.** $v = v_0$ and $d = 2d_0$ **E.** $v = 4v_0$ and $d = d_0/2$. **Ans. D**

126.// **The internal energy of an ideal gas depends on:**
A. the temperature only. **B. the pressure only.** **C. the volume only.**
D. the temperature and pressure only. **E. temperature, pressure, and volume.**
Ans. A

127.// **The diagram shows three isotherms for an ideal gas, with $T_3 - T_2$ the same as $T_2 - T_1$. It also shows five thermodynamic processes carried out on the gas. Rank the processes in order of the change in the internal energy of th gas, least to greatest.**

A. I, II, III, IV, V
B. V, then I, III, and IV tied, then II
C. V, I, then III and IV tied, then II
D. IV, V, III, I, II
E. II, I, then III, IV, and V tied
Ans. B



128.// **An ideal gas of N monatomic molecules is in thermal equilibrium with an ideal gas of the same number of diatomic molecules and equilibrium is maintained as the temperature is increased. The ratio of the changes in the internal energies $\Delta E_{dia}/\Delta E_{mon}$ is:**
A. 1/2 **B. 3/5** **C. 1** **D. 5/3** **E. 2** **Ans. D**

129.// **Two ideal gases, each consisting of N monatomic molecules, are in thermal equilibrium with each other and equilibrium is maintained as the temperature is increased. A molecule of the first gas has mass m and a molecule of the second has mass 4m. The ratio of the changes in the internal energies $\Delta E_{4m}/\Delta E_m$ is:**
A. 1/4 **B. 1/2** **C. 1** **D. 2** **E. 4** **Ans. C**

130.// **Three gases, one consisting of monatomic molecules, one consisting of diatomic molecules, and one consisting of polyatomic molecules, are in thermal equilibrium with each other and remain in thermal equilibrium as the temperature is raised. All have the same number of molecules. The gases with the least and greatest change in internal energy are respectively:**
A. polyatomic, monatomic. **B. monatomic, polyatomic.** **C. diatomic, monatomic.**
D. polyatomic, diatomic. **E. monatomic, diatomic.** **Ans. B**

131.// **An ideal gas of N diatomic molecules has temperature T. If the number of molecules is doubled without changing the temperature, the internal energy increases by:**
A. 0 **B. (1/2)NkT** **C. (3/2)NkT** **D. (5/2)NkT**
E. 3NkT **Ans. D**

132.// Both the pressure and volume of an ideal gas of diatomic molecules are doubled. The ratio of the new internal energy to the old, both measured relative to the internal energy at 0K, is

A. 1/4 B. 1/2 C. 1 D. 2 E. 4 Ans. E

133.// The pressure of an ideal gas of diatomic molecules is doubled by halving the volume. The ratio of the new internal energy to the old, both measured relative to the internal energy at 0K, is:

A. 1/4 B. 1/2 C. 1 D. 2 E. 4 Ans. C

134.// When work W is done on an ideal gas of N diatomic molecules in thermal isolation the temperature increases by: A. W/2Nk B. W/3Nk C. 2W/3Nk D. 2W/5Nk E. W/Nk Ans. D

135.// When work W is done on an ideal gas of diatomic molecules in thermal isolation the increase in the total rotational energy of the molecules is:

A. 0 B. W/3 C. 2W/3 D. 2W/5 E. W Ans. D

136.// When work W is done on an ideal gas of diatomic molecules in thermal isolation the increase in the total translational kinetic energy of the molecules is:

A. 0 B. 2W/3 C. 2W/5 D. 3W/5 E. W Ans. D

137.// The pressure of an ideal gas is doubled in an isothermal process. The root-mean-square speed of the molecules:

A. does not change. B. increases by a factor of √2. C. decreases by a factor of 1/√2. D. increases by a factor of 2. E. decreases by a factor of 1/2. Ans. A

138.// The Maxwellian speed distribution provides a direct explanation of:

A. thermal expansion B. the ideal gas law C. heat D. evaporation E. boiling Ans. D

139.// For a gas at thermal equilibrium the average speed v, the most probable speed v_p, and the root-mean-square speed v_{rms} are in the order:

A. $v_p < v_{rms} < v$ B. $v_{rms} < v_p < v$ C. $v < v_{rms} < v_p$ D. $v_p < v < v_{rms}$ E. $v < v_p < v_{rms}$ Ans. D

140.// The average speed of air molecules at room temperature is about:

A. zero. B. 2m/s (walking speed). C. 30m/s (fast car) D. 500m/s (supersonic airplane) E. 3×10^8 m/s (speed of light) Ans. D

141.// The root-mean-square sped of molecules in a gas is:

A. the most probable speed. B. that speed such that half the molecules are moving faster than vrms and the other half are moving slower. C. the average speed of the molecules. D. the square root of the square of the average speed. E. none of the above. Ans. E

142.// **According to the Maxwellian speed distribution, as the temperature increases the number of molecules with speeds within a small interval near the most probable speed:**
A. increases. B. decreases. C. increases at high temperatures and decreases at low. D. decreases at high temperatures and increases at low.
E. stays the same. **Ans. B**

143.// **According to the Maxwellian speed distribution, as the temperature increases the most probable speed:**
A. increases. B. decreases. C. increases at high temperatures and decreases at low. D. decreases at high temperatures and increases at low.
E. stays the same. **Ans. A**

144.// **According to the Maxwellian speed distribution, as the temperature increases the average speed:**
A. increases. B. decreases. C. increases at high temperatures and decreases at low.
D. decreases at high temperatures and increases at low.
E. stays the same. **Ans. A**

145.// **As the pressure in an ideal gas is increased isothermally the average molecular speed:**
A. increases. B. decreases. C. increases at high temperature, decreases at low.
D. decreases at high temperature, increases at low.
E. stays the same. **Ans. E**

146.// **As the volume of an ideal gas is increased at constant pressure the average molecular speed:**
A. increases. B. decreases. C. increases at high temperature, decreases at low.
D. decreases at high temperature, increases at low.
E. stays the same. **Ans. A**

147.// **Two ideal monatomic gases are in thermal equilibrium with each other. Gas A is composed of molecules with mass m while gas B is composed of molecules with mass 4m. The ratio of the average molecular speeds v_A/v_B is:**
A. 1/4 B. 1/2 C. 1 D. 2 E. 4 **Ans. D**

148.// **Ideal monatomic gas A is composed of molecules with mass m while ideal monatomic gas B is composed of molecules with mass 4m. The average molecular speeds are the same if the ratio of the temperatures T_A/T_B is:**
A. 1/4 B. 1/2 C. 1 D. 2 E. 4 **Ans. A**

149.// **Two monatomic ideal gases are in thermal equilibrium with each other. Gas A is composed of molecules with mass m while gas B is composed of molecules with mass 4m. The ratio of the average translational kinetic energies K_A/K_B is:**
A. 1/4 B. 1/2 C. 1 D. 2 E. 4 **Ans. C**

150.// **Ideal monatomic gas A is composed of molecules with mass m while ideal monatomic gas B is composed of molecules with mass 4m. The average translational kinetic energies are the same if the ratio of the temperatures T_A/T_B is:**

A. 1/4 B. 1/2 C. 1 D. 2 E. 4 **Ans. C**

151.// **Which of the following change when the pressure of an ideal gas is changed isothermally?**

A. Mean free path. B. Root-mean-square molecular speed. C. Internal energy
D. Most probable kinetic energy. E. Average speed **Ans. A**

152.// **When an ideal gas undergoes a slow isothermal expansion:**

A. the work done by the gas is the same as the energy absorbed as heat.
B. the work done by the environment is the same as the energy absorbed as heat.
C. the increase in internal energy is the same as the energy absorbed as heat.
D. the increase in internal energy is the same as the work done by the gas.
E. the increase in internal energy is the same as the work done by the environment.

Ans. A

153.// **The pressure of an ideal gas is doubled during a process in which the energy given up as heat by the gas equals the work done on the gas. As a result, the volume is:**

A. doubled. B. halved. C. unchanged. D. need more information to answer.
E. nonsense; the process is impossible. **Ans. B**

154.// **The energy absorbed as heat by an ideal gas for an isothermal process equals:**

A. the work done by the gas. B. the work done on the gas.
C. the change in the internal energy of the gas. D. the negative of the change in internal energy of the gas. E. zero since the process is isothermal. **Ans. A**

155.// **An ideal gas has molar specific heat C_p at constant pressure. When the temperature of n moles is increased by ΔT the increase in the internal energy is:**

A. $nC_p \Delta T$ B. $n(C_p + R) \Delta T$ C. $n(C_p - R) \Delta T$ D. $n(2C_p + R) \Delta T$
E. $n(2C_p - R) \Delta T$ **Ans. C**

156.// **The temperature of n moles of an ideal monatomic gas is increased by ΔT at constant pressure. The energy Q absorbed as heat, change ΔE_{int} in internal energy, and work W done by the environment are given by:**

A. $Q = (5/2)nR\,\Delta T$, $\Delta E_{int} = 0$ $W = -nR\Delta T$
B. $Q = (3/2)nR\,\Delta T$, $\Delta E_{int} = (5/2)nR\,\Delta T$, $W = -(3/2)nR\,\Delta T$
C. $Q = (5/2)nR\,\Delta T$, $\Delta E_{int} = (5/2)nR\,\Delta T$, $W = 0$
D. $Q = (3/2)nR\,\Delta T$, $\Delta E_{int} = 0$, $W = -nR\Delta T$
E. $Q = (5/2)nR\,\Delta T$, $\Delta E_{int} = (3/2)nR\,\Delta T$, $W = -nR\,\Delta T$ **Ans. E**

157.// **The temperature of n moles of an ideal monatomic gas is increased by ΔT at constant volume. The energy Q absorbed as heat, change ΔEint in internal energy, and work W done by the environment are given by:**
A. $Q = (5/2)nR\,\Delta T$, $\Delta E_{int} = 0$, $W = 0$
B. $Q = (3/2)nR\,\Delta T$, $\Delta E_{int} = (3/2)nR\,\Delta T$, $W = 0$
C. $Q = (3/2)nR\,\Delta T$, $\Delta E_{int} = (1/2)nR\,\Delta T$ $W = -\,nR\,\Delta t$
D. $Q = (5/2)nR\,\Delta T$, $\Delta E_{int} = (3/2)nR\,\Delta T$, $W = -\,nR\,\Delta T$
E. $Q = (3/2)nR\,\Delta T$ $\Delta E_{int} = 0$ $W = -\,(3/2)nR\,\Delta T$ **Ans. B**

158.// **The heat capacity at constant volume of an ideal gas depends on:**
A. the temperature **B. the pressure.** **C. the volume.**
D. the number of molecules. **E. none of the above** **Ans. D**

159.// **The specific heat at constant volume of an ideal gas depends on:**
A. the temperature. **B. the pressure.** **C. the volume.**
D. the number of molecules. **E. none of the above.** **Ans. E**

160.// **The difference between the molar specific heat at constant pressure and the molar specific heat at constant volume for an ideal gas is:**
A. the Boltzmann constant k. **B. the universal gas constant R.**
C. the Avogadro constant N_A **D. kT** **E. RT** **Ans. B**

161.// **An ideal monatomic gas has a molar specific heat C_v at constant volume of:**
A. R **B. 3R/2** **C. 5R/2** **D. 7R/2** **E. 9R/2** **Ans. B**

162.// **The specific heat C_v at constant volume of a monatomic gas at low pressure is proportional to Tn where the exponent n is:**
A. −1 **B. 0** **C. 1** **D. 1/2** **E. 2** **Ans. B**

163.// **An ideal diatomic gas has a molar specific heat at constant pressure C_p of:**
A. R **B. 3R/2** **C. 5R/2** **D. 7R/2** **E. 9R/2** **Ans. D**

164.// **The specific heat of a polyatomic gas is greater than the specific heat of a monatomic gas because:**
A. the polyatomic gas does more positive work when energy is absorbed as heat.
B. the monatomic gas does more positive work when energy is absorbed as heat.
C. the energy absorbed by the polyatomic gas is split among more degrees of freedom.
D. the pressure is greater in the polyatomic gas.
E. a monatomic gas cannot hold as much heat. **Ans. C**

165.// **The ratio of the specific heat of a gas at constant volume to its specific heat at constant pressure is:**
A. 1. **B. less than 1.** **C. more than 1.**
D. has units of pressure/volume. **E. has units of volume/pressure.** **Ans. B**

166.// **The ratio of the specific heat of an ideal gas at constant volume to its specific heat at constant pressure is:**
A. R B. 1/R C. dependent on the temperature. D. dependent on the pressure.
E. different for monatomic, diatomic, and polyatomic gases. **Ans. E**

167.// **Consider the ratios of the heat capacities $\gamma = C_p/C_v$ for the three types of ideal gases: monatomic, diatomic, and polyatomic.**
A. γ is the greatest for monatomic gases.
B. γ is the greatest for polyatomic gases.
C. γ is the same only for diatomic and polyatomic gases.
D. γ is the same only for monatomic and diatomic gases.
E. γ is the same for all three. **Ans. A**

168.// **$TV^{\gamma-1}$ is constant for an ideal gas undergoing an adiabatic process, where γ is the ratio of heat capacities C_p/C_v. This is a direct consequence of:**
A. the zeroth law of thermodynamics alone
B. the zeroth law and the ideal gas equation of state.
C. the first law of thermodynamics alone
D. the ideal gas equation of state alone.
E. the first law and the equation of state. **Ans. E**

169.// **Monatomic, diatomic, and polyatomic ideal gases each undergo slow adiabatic expansions from the same initial volume and the same initial pressure to the same final volume. The magnitude of the work done by the environment on the gas:**
A. is greatest for the polyatomic gas.
B. is greatest for the diatomic gas. C. is greatest for the monatomic gas.
D. is the same only for the diatomic and polyatomic gases.
E. is the same for all three gases. **Ans. A**

170.// **The mean free path of a gas molecule is:**
A. the shortest dimension of the containing vessel.
B. the cube root of the volume of the containing vessel.
C. approximately the diameter of a molecule.
D. average distance between adjacent molecules.
E. average distance a molecule travels between intermolecular collisions. **Ans. E**

171.// **The mean free path of molecules in a gas is:**
A. the average distance a molecule travels before escaping.
B. the average distance a molecule travels between collisions.
C. the greatest distance a molecule travels between collisions.
D. the shortest distance a molecule travels between collisions.
E. the average distance a molecule travels before splitting apart. **Ans. B**

172.// **The mean free path of air molecules at room temperature and atmospheric pressure is about:**
A. 10^{-3} m B. 10_{-5} m C. 10_{-7} m D. 10^{-9} m E. 10^{-11} m **Ans. C**

173.// **The mean free path of molecules in a gas is proportional to:**
A. the molecular cross-sectional area.
B. the reciprocal of the molecular cross-sectional area.
C. the root-mean-square molecular speed.
D. the square of the average molecular speed.
E. the molar mass. **Ans. B**

174.// **The mean free path of molecules in a gas is proportional to:**
A. the molecular diameter.
B. the reciprocal of the molecular diameter.
C. the molecular concentration.
D. the reciprocal of the molecular concentration.
E. the average molecular speed. **Ans. D**

175.// **In a certain gas the molecules are 5.0×10^{-9} m apart on average, have a mean free path of 5.0×10^{-6} m, and have an average speed of 500m/s. The rate at which a molecule has collisions with other molecules is about:**
A. 10^{-11} s^{-1} B. 10^{-8} s^{-1} C. 1 s^{-1} D. 10^{8} s^{-1} E. 10^{11} s^{-1} **Ans. D**

176.// **If the temperature T of an ideal gas is increased at constant pressure the mean free path:**
A. decreases in proportion to 1/T.
B. decreases in proportion to $1/T^2$.
C. increases in proportion to T.
D. increases in proportion to T^2.
E. does not change **Ans. C**

177.// **A certain ideal gas has a temperature 300K and a pressure 5.0×10^{4} Pa. The molecules have a mean free path of 4.0×10^{-7} m. If the temperature is raised to 350K and the pressure is reduced to 1.0×10^{4} Pa the mean free path is then:**
A. 6.9×10^{-8} m B. 9.3×10^{-8} m C. 3.3×10^{-7} m
D. 1.7×10^{-6} m E. 2.3×10^{-6} m **Ans. E**

ENTROPY AND THE SECOND LAW OF THERMODYNAMICS

178.// In a reversible process the system:
A. is always close to equilibrium states
B. is close to equilibrium states only at the beginning and end
C. might never be close to any equilibrium state
D. is close to equilibrium states throughout, except at the beginning and end
E. is none of the above **Ans. A**

179.// A slow (quasi-static) process is NOT reversible if:
A. the temperature changes. **B. energy is absorbed or emitted as heat.**
C. work is done on the system. **D. friction is present.**
E. the pressure changes. **Ans. D**

180.// The difference in entropy $\Delta S = S_B - S_A$ for two states A and B of a system can be computed as the integral $\int dQ/T$ provided:
A. A and B are on the same adiabat.
B. A and B have the same temperature.
C. a reversible path is used for the integral.
D. the change in internal energy is first computed.
E. the energy absorbed as heat by the system is first computed. **Ans. C**

181.// Possible units of entropy are:
A. J B. J/K C. J^{-1} D. liter.atm E. cal/mol **Ans. B**

182.// Which of the following is NOT a state variable?
A. Work. **B. Internal energy.**
C. Entropy. **D. Temperature.**
E. Pressure. **Ans. A**

183.// The change in entropy is zero for:
A. reversible adiabatic processes
B. reversible isothermal processes
C. reversible processes during which no work is done
D. reversible isobaric processes
E. all adiabatic processes **Ans. A**

184.// Which of the following processes leads to a change in entropy of zero for the system undergoing the process?
A. Non-cyclic isobaric (constant pressure).
B. Non-cyclic isochoric (constant volume).
C. Non-cyclic isothermal (constant temperature).
D. Any closed cycle.
E. None of these. **Ans. D**

185.// **Rank, from smallest to largest, the changes in entropy of a pan of water on a hot plate, as the temperature of the water**

1. goes from 20◦ C to 30◦ C **2. goes from 30◦ C to 40◦ C**

3. goes from 40◦ C to 45◦ C **4. goes from 80◦ C to 85◦ C**

A. 1, 2, 3, 4 **B. 4, 3, 2, 1** **C. 1 and 2 tie, then 3 and 4 tie**

D. 3 and 4 tie, then 1 and 2 tie **E. 4, 3, 2, 1** **Ans. E**

186.// **An ideal gas expands into a vacuum in a rigid vessel. As a result there is:**

A. a change in entropy. **D. an increase of pressure.** **B. a change in temperature.**

E. a decrease of internal energy. **C. a change in phase.** **Ans. A**

187.// **Consider all possible isothermal contractions of an ideal gas. The change in entropy of the gas:**

A. is zero for all of them. **B. does not decrease for any of them.**

C. does not increase for any of them.

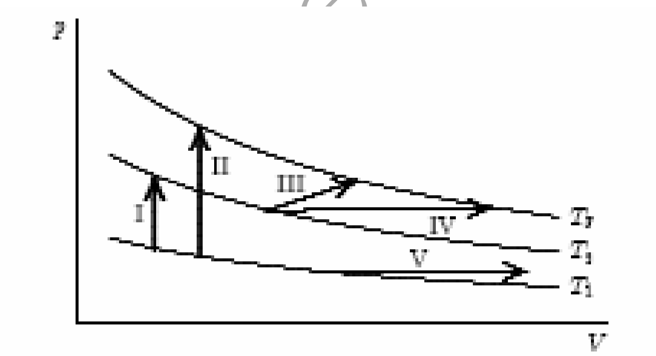
D. increases for all of them. **E. decreases for all of them.** **Ans. E**

188.// **An ideal gas is to taken reversibly from state i, at temperature T_1, to any of the other states labeled I, II, III, IV, and V on the p-V diagram below. All are at the same temperature T_2. Rank the five processes according to the change in entropy of the gas, least to greatest.**

A. I, II, III, IV, V **B. V, IV, III, II, I**

C. I, then II, III, IV, and V tied **D. I, II, III, and IV tied, then V**

E. I and V tied, then II, III, IV **Ans. A**



189.// **An ideal gas, consisting of n moles, undergoes a reversible isothermal process during which the volume changes from V_i to V_f . The change in entropy of the thermal reservoir in contact with the gas is given by:**

A. $nR(V_f - V_i)$ **B. $nR \ln(V_f - V_i)$** **C. $nR \ln(V_i/V_f)$** **D. $nR \ln(V_f/V_i)$**

E. none of the above (entropy can't be calculated for a reversible process)

Ans. C

190.// **One mole of an ideal gas expands reversibly and isothermally at temperature T until its volume is doubled. The change of entropy of this gas for this process is:**

A. Rln 2 **B. (ln 2)/T** **C. 0** **D. RT ln 2**

E. 2R **Ans. A**

191.// **An ideal gas, consisting of n moles, undergoes an irreversible process in which the temperature has the same value at the beginning and end. If the volume changes from V_i to V_f, the change in entropy of the gas is given by:**
A. $nR(V_f - V_i)$ B. $nR\ln(V_f - V_i)$ C. $nR\ln(V_i/V_f)$ D. $nR\ln(V_f/V_i)$
E. none of the above (entropy can't be calculated for an irreversible process)
Ans. D

192.// **The temperature of n moles of a gas is increased from T_i to T_f at constant volume. If the molar specific heat at constant volume is C_V and is independent of temperature, then change in the entropy of the gas is:**
A. $nC_V\ln(T_f/T_i)$ B. $nC_V\ln(T_i/T_f)$ C. $nC_V\ln(T_f - T_i)$ D. $nC_V\ln(1 - T_i/T_f)$
E. $nC_V(T_f - T_i)$ **Ans. A**

193.// **Consider the following processes: The temperature of two identical gases are increased from the same initial temperature to the same final temperature. Reversible processes are used. For gas A the process is carried out at constant volume while for gas B it is carried out at constant pressure. The change in entropy:**
A. is the same for A and B B. is greater for A C. is greater for B
D. is greater for A only if the initial temperature is low
E. is greater for A only if the initial temperature is high **Ans. C**

194.// **A hot object and a cold object are placed in thermal contact and the combination is isolated. They transfer energy until they reach a common temperature. The change ΔS_h in the entropy of the hot object, the change ΔS_c in the entropy of the cold object, and the change ΔS_{total} in the entropy of the combination are:**
A. $\Delta S_h > 0, \Delta S_c > 0, \Delta S_{total} > 0$ B. $\Delta S_h < 0, \Delta S_c > 0, \Delta S_{total} > 0$
C. $\Delta S_h < 0, \Delta S_c > 0, \Delta S_{total} < 0$ D. $\Delta S_h > 0, \Delta S_c < 0, \Delta S_{total} > 0$
E. $\Delta S_h > 0, \Delta S_c < 0, \Delta S_{total} < 0$ **Ans. B**

195.// **Let S_I denote the change in entropy of a sample for an irreversible process from state A to state B. Let S_R denote the change in entropy of the same sample for a reversible process from state A to state B. Then:**
A. $S_I > S_R$ B. $S_I = S_R$ C. $S_I < S_R$ D. $S_I = 0$ E. $S_R = 0$ **Ans. B**

196.// **For all adiabatic processes:**
A. the entropy of the system does not change.
B. the entropy of the system increases.
C. the entropy of the system decreases.
D. the entropy of the system does not increase.
E. the entropy of the system does not decrease. **Ans. E**

197.// **For all reversible processes involving a system and its environment:**
A. the entropy of the system does not change.
B. the entropy of the system increases.
C. the total entropy of the system and its environment does not change.
D. the total entropy of the system and its environment increases.
E. none of the above. **Ans. C**

198.// For all irreversible processes involving a system and its environment:
A. the entropy of the system does not change. B. the entropy of the system increases.
C. the total entropy of the system and its environment does not change.
D. the total entropy of the system and its environment increases.
E. none of the above. **Ans. D**

199.// According to the second law of thermodynamics:
A. heat energy cannot be completely converted to work.
B. work cannot be completely converted to heat energy.
C. for all cyclic processes we have dQ/T < 0.
D. the reason all heat engine efficiencies are less than 100% is friction, which is unavoidable.
E. all of the above are true. **Ans. A**

200.// Consider the following processes:
I. Energy flows as heat from a hot object to a colder object.
II. Work is done on a system and an equivalent amount of energy is rejected as heat by the system.
III. Energy is absorbed as heat by a system and an equivalent amount of work is done by the system. Which are never found to occur?.
A. Only I B. Only C. Only III D. Only II and III
E. I, II, and III **Ans. C**

201.// An inventor suggests that a house might be heated by using a refrigerator to draw energy as heat from the ground and reject energy as heat into the house. He claims that the energy supplied to the house as heat can exceed the work required to run the refrigerator. This:
A. is impossible by first law. B. is impossible by second law.
C. would only work if the ground and the house were at the same temperature.
D. is impossible since heat energy flows from the (hot) house to the (cold) ground.
E. is possible. **Ans. E**

202.// In a thermally insulated kitchen, an ordinary refrigerator is turned on and its door is left open. The temperature of the room:
A. remains constant according to the first law of thermodynamics.
B. increases according to the first law of thermodynamics.
C. decreases according to the first law of thermodynamics.
D. remains constant according to the second law of thermodynamics.
E. increases according to the second law of thermodynamics. **Ans. B**

203.// A heat engine:
A. converts heat input to an equivalent amount of work. B. converts work to an equivalent amount of heat. C. takes heat in, does work, and loses energy as heat.
D. uses positive work done on the system to transfer heat from a low temperature reservoir to a high temperature reservoir.
E. uses positive work done on the system to transfer heat from a high temperature reservoir to a low temperature reservoir. **Ans. C**

204.// **A heat engine absorbs energy of magnitude $|Q_H|$ as heat from a high temperature reservoir, does work of magnitude |W|, and transfers energy of magnitude $|Q_L|$ as heat to a low temperature reservoir. Its efficiency is:**
A. $|Q_H|/|W|$ B. $|Q_L|/|W|$ C. $|Q_H|/|Q_L|$ D. $|W|/|Q_H|$
E. $|W|/|Q_L|$ **Ans. D**

205.// **The temperatures T_C of the cold reservoirs and the temperatures T_H of the hot reservoirs for four Carnot heat engines are**
engine 1: T_C = 400K and T_H = 500K
engine 2: T_C = 500K and T_H = 600K
engine 3: T_C = 400K and T_H = 600K
engine 4: T_C = 600K and T_H = 800K
Rank these engines according to their efficiencies, least to greatest
A. 1, 2, 3, 4 B. 1 and 2 tie, then 3 and 4 tie C. 2, 1, 3, 4
D. 1, 2, 4, 3 E. 2, 1, 4, 3 **Ans. E**

206.// **A Carnot heat engine runs between a cold reservoir at temperature T_C and a hot reservoir at temperature T_H. You want to increase its efficiency. Of the following, which change results in the greatest increase in efficiency? The value of ΔT is the same for all changes.**
A. Raise the temperature of the hot reservoir by ΔT
B. Raise the temperature of the cold reservoir by ΔT
C. Lower the temperature of the hot reservoir by ΔT
D. Lower the temperature of the cold reservoir by ΔT
E. Lower the temperature of the hot reservoir by 1/2 ΔT and raise the temperature of the cold reservoir by 1/2 ΔT. **Ans. D**

207. 31.// **A certain heat engine draws 500 cal/s from a water bath at 27◦ C and transfers 400 cal/s to a reservoir at a lower temperature. The efficiency of this engine is:**
A. 80% B. 75% C. 55% D. 25% E. 20% **Ans. E**

208.// **A heat engine that in each cycle does positive work and loses energy as heat, with no heat energy input, would violate:**
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. Newton's second law. **Ans. B**

209.// **A cyclical process that transfers energy as heat from a high temperature reservoir to a low temperature reservoir with no other change would violate:**
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. none of the above. **Ans. E**

210.// **On a warm day a pool of water transfers energy to the air as heat and freezes. This is a direct violation of: 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. none of the above. **Ans. C**

211.// **A heat engine in each cycle absorbs energy of magnitude $|Q_H|$ as heat from a high temperature reservoir, does work of magnitude |W|, and then absorbs energy of magnitude $|Q_L|$ as heat from a low temperature reservoir. If $|W| = |Q_H| + |Q_L|$ this engine violates:**
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. none of the above. **Ans. C**

212.// **A heat engine in each cycle absorbs energy from a reservoir as heat and does an equivalent amount of work, with no other changes. This engine violates:**
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. none of the above. **Ans. C**

213.// **A Carnot cycle:**
A. is bounded by two isotherms and two adiabats on a p-V graph.
B. consists of two isothermal and two constant volume processes.
C. is any four-sided process on a p-V graph. **D. only exists for an ideal gas.**
E. has an efficiency equal to the enclosed area on a p-V diagram. **Ans. A**

214.// **According to the second law of thermodynamics:**
A. all heat engines have the same efficiency.
B. all reversible heat engines have the same efficiency.
C. the efficiency of any heat engine is independent of its working substance.
D. the efficiency of a Carnot engine depends only on the temperatures of the two reservoirs.
E. all Carnot engines theoretically have 100% efficiency. **Ans. D**

215.// **A Carnot heat engine operates between 400K and 500 K. Its efficiency is:**
A. 20% **B. 25%** **C. 44%** **D. 79%** **E. 100%** **Ans. A**

216.// **A Carnot heat engine operates between a hot reservoir at absolute temperature T_H and a cold reservoir at absolute temperature T_C. Its efficiency is:**
A. T_H/T_C **B. T_C/T_H** **C. $1 - T_H/T_C$** **D. $1 - T_C/T_H$** **E. 100%**
Ans. D

217.// **A heat engine operates between a high temperature reservoir at T_H and a low temperature reservoir at T_L. Its efficiency is given by $1 - T_L/T_H$:**
A. only if the working substance is an ideal gas. **B. only if the engine is reversible.**
C. only if the engine is quasi-static. **D. only if the engine operates on a Stirling cycle.**
E. no matter what characteristics the engine has. **Ans. B**

218.// **The maximum theoretical efficiency of a Carnot heat engine operating between reservoirs at the steam point and at room temperature is about:**
A. 10% **B. 20%** **C. 50%** **D. 80%** **E. 99%**
Ans. B

219.// **An inventor claims to have a heat engine that has an efficiency of 40% when it operates between a high temperature reservoir of 150◦ C and a low temperature reservoir of 30◦ C. This engine:**
A. must violate the zeroth law of thermodynamics.
B. must violate the first law of thermodynamics.
C. must violate the second law of thermodynamics.
D. must violate the third law of thermodynamics.
E. does not necessarily violate any of the laws of thermodynamics. **Ans. C**

220.// **A Carnot heat engine and an irreversible heat engine both operate between the same high temperature and low temperature reservoirs. They absorb the same energy from the high temperature reservoir as heat. The irreversible engine:**
A. does more work.
B. transfers more energy to the low temperature reservoir as heat.
C. has the greater efficiency.
D. has the same efficiency as the reversible engine.
E. cannot absorb the same energy from the high temperature reservoir as heat without violating the second law of thermodynamics. **Ans. B**

221.// **A perfectly reversible heat pump with a coefficient of performance of 14 supplies energy to a building as heat to maintain its temperature at 27◦ C. If the pump motor does work at the rate of 1 kW, at what rate does the pump supply energy to the building as heat?**
A. 15kW **B. 3.85kW** **C. 1.35kW**
D. 1.07kW **E. 1.02kW** **Ans. A**

222.// **A heat engine operates between 200K and 100 K. In each cycle it takes 100 J from the hot reservoir, loses 25 J to the cold reservoir, and does 75 J of work. This heat engine violates:**
A. both the first and second laws of thermodynamics.
B. the first law but not the second law of thermodynamics.
C. the second law but not the first law of thermodynamics.
D. neither the first law nor the second law of thermodynamics.
E. cannot answer without knowing the mechanical equivalent of heat. **Ans. C**

223.// **A refrigerator absorbs energy of magnitude $|Q_C|$ as heat from a low temperature reservoir and transfers energy of magnitude $|Q_H|$ as heat to a high temperature reservoir. Work W is done on the working substance. The coefficient of performance is given by:**
A. $|Q_C|/W$ **B.** $|Q_H|/W$ **C.** $(|Q_C| + |Q_H|)/W$
D. $W/|Q_C|$ **E.** $W/|Q_H|$ **Ans. A**

224.// **A reversible refrigerator operates between a low temperature reservoir at T_C and a high temperature reservoir at T_H. Its coefficient of performance is given by:**
A. $(T_H - T_C)/T_C$ **B.** $T_C/(T_H - T_C)$ **C.** $(T_H - T_C)/T_H$
D. $T_H/(T_H - T_C)$ **E.** $T_H(T_H + T_C)$ **Ans. B**

225.// **An Carnot refrigerator runs between a cold reservoir at temperature T_C and a hot reservoir at temperature T_H. You want to increase its coefficient of performance. Of the following, which change results in the greatest increase in the coefficient? The value of ΔT is the same for all changes.**
A. Raise the temperature of the hot reservoir by ΔT
B. Raise the temperature of the cold reservoir by ΔT
C. Lower the temperature of the hot reservoir by ΔT
D. Lower the temperature of the cold reservoir by ΔT
E. Lower the temperature of the hot reservoir by 1/2 ΔT and raise the temperature of the cold reservoir by 1/2 ΔT. **Ans. B**

226.// **For one complete cycle of a reversible heat engine, which of the following quantities is NOT zero?**
A. the change in the entropy of the working gas. **B. the change in the pressure of the working gas.**
C. the change in the internal energy of the working gas. **D. the work done by the working gas.**
E. the change in the temperature of the working gas. **Ans. D**

227.// **Twenty-five identical molecules are in a box. Microstates are designated by identifying the molecules in the left and right halves of the box. The multiplicity of the configuration with 15 molecules in the right half and 10 molecules in the left half is:**
A. 1.03×10^{23} **B. 3.27×10^{6}** **C. 150** **D. 25** **E. 5**
Ans. B

228.// **Twenty-five identical molecules are in a box. Microstates are designated by identifying the molecules in the left and right halves of the box. The Boltzmann constant is 1.38×10^{-23} J/K. The entropy associated with the configuration for which 15 molecules are in the left half and 10 molecules are in the right half is:**
A. 2.07×10^{-22} J/K **B. 7.31×10^{-22} J/K** **C. 4.44×10^{-23} J/K**
D. 6.91×10^{-23} J/K **E. 2.22×10^{-23} J/K** **Ans. A**

229.// **The thermodynamic state of a gas changes from one with 3.8×10^{18} microstates to one with 7.9×10^{19} microstates. The Boltzmann constant is 1.38×10^{-23} J/K. The change in entropy is:**
A. ΔS = 0 **B. ΔS = 1.04×10^{-23} J/K** **C. ΔS = -1.04×10^{-23} J/K**
D. ΔS = 4.19×10^{-23} J/K **E. ΔS = -4.19×10^{-23} J/K** **Ans. D**

230.// **Let k be the Boltzmann constant. If the configuration of the molecules in a gas changes so that the multiplicity is reduced to one-third its previous value, the entropy of the gas changes by:**
A. ΔS = 0 **B. ΔS = 3k ln 2** **C. ΔS = −3k ln 2**
D. ΔS = −k ln 3 **E. ΔS = k ln 3** **Ans. D**

231.// **Let k be the Boltzmann constant. If the configuration of molecules in a gas changes from one with a multiplicity of M_1 to one with a multiplicity of M_2, then entropy changes by:**

A. $\Delta S = 0$ **B. $\Delta S = k(M_2 - M_1)$** **C. $\Delta S = kM_2/M_1$**

D. $\Delta S = k \ln(M_2 M_1)$ **E. $\Delta S = k \ln(M_2/M_1)$** **Ans. E**

232.// **Let k be the Boltzmann constant. If the thermodynamic state of a gas at temperature T changes isothermally and reversibly to a state with three times the number of microstates as initially, the energy input to the gas as heat is:**

A. $Q = 0$ **B. $Q = 3kT$** **C. $Q = -3kT$**

D. $kT \ln 3$ **E. $-kT \ln 3$** **Ans. D**