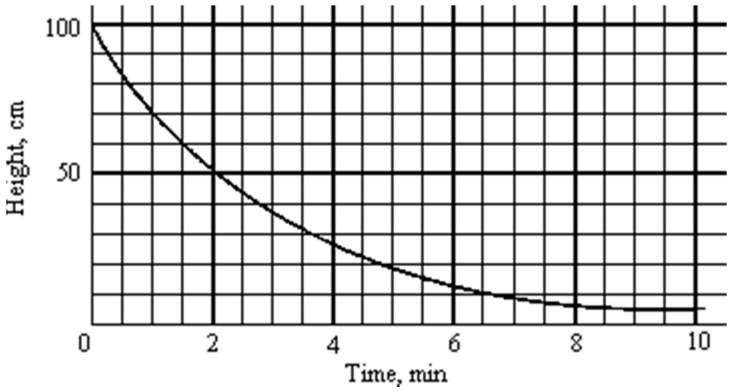
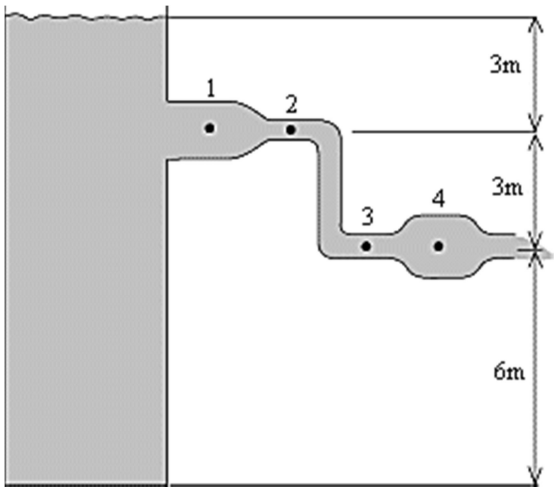
1231: BEHAVIOUR OF MATTER
250 MULTIPLE CHOICE QUESTION

1. A metal block suspended from a spring balance is submerged in water. You observe that the block displaces 55 cm^3 of water and that the balance reads 4.3 N. What is the density of the block?
   A) 7.0 g/cm^3
   B) 8.0 g/cm^3
   C) 9.0 g/cm^3
   D) 1.1 g/cm^3
   E) 1.2 g/cm^3

2. 

   The height of a water column as a function of time is given in the graph. From this graph, the time constant of the process is
   A) 0.85 min
   B) 1.4 min
   C) 2.0 min
   D) 2.9 min
   E) infinite

3.



Water is discharged from the tank in the manner shown. At which point is the pressure the least?

A) 1
B) 2
C) 3
D) 4
E) The pressure is the same at all points.

4. According to Pascal's principle, the pressure at every point in a confined liquid
A) depends only on the density of the liquid.
B) is equal to the weight of the liquid.
C) is the same.
D) is changed the same amount by an externally applied pressure.
E) is equal to the externally applied pressure.

5. A small sphere of wood with a density $\rho = 0.40$ g/cm^3 is held at rest well under the surface of a pool of water. The magnitude of the initial acceleration of the sphere when it is released is
A) 15 m/s^2
B) 9.8 m/s^2
C) 33 m/s^2
D) 23 m/s^2
E) 3.4 m/s^2

6. A tube with a radius of 4.2 cm is holding oil that has a density of 0.92 g/cm^3. The pressure in the oil at a depth of 64 cm from the top of the surface is
A) 5.8×10^2 Pa
B) 5.8×10^3 Pa
C) 1.0×10^2 Pa
D) 1.0×10^6 Pa
E) 1.7×10^3 Pa

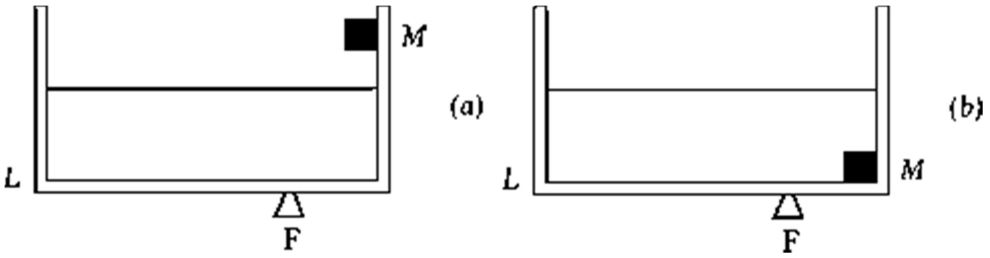
7. Water from a tap is flowing at a uniform rate of 24 cm^3/s into a cylindrical container. An exit tube is mounted on the side of the container at height $h/2$ from the base. The height h of the water remains constant. The volume flow at which the water leaves the container is
   A) 12 cm^3/s
   B) 24 cm^3/s
   C) 36 cm^3/s
   D) 48 cm^3/s
   E) 72 cm^3/s

8. You are floating in a boat in a swimming pool. There are some large stones, with a density of 2.5 g/cm^3, in the boat. You throw the stones out of the boat and they sink to the bottom of the pool. The water level h, measured vertically at the end of the pool _____as the stones are thrown out.
   A) decreases
   B) increases
   C) There is not enough information to solve the problem.
   D) stays the same
   E) None of these is correct.

9. A flat plate with a negligible mass and an area of 1.0 cm^2 is placed in a horizontal position well beneath the surface in a liquid that is not moving. The pressure at the location of the plate is P Pa. The total force that arises from the pressure of the liquid on this plate is
   A) P N, directed down.
   B) $P \times 10^{-4}$ N, directed down.
   C) P N, directed up.
   D) $P \times 10^{-4}$ N, directed up.
   E) zero.

10. A block of wood of mass 300 g and density 0.75 g/cm^3 is floating on the surface of a liquid of density 1.1 g/cm^3. What mass of lead (density = 11.3 g/cm^3) must be added to the block in order for the combination just to be submerged?
    A) 440 g
    B) 820 g
    C) 140 g
    D) 155 g
    E) none of the above

11.



A large tub is half full of water. A mass $M = 25.0$ kg, which has a specific gravity of 2.5, is attached to the right-hand side of the tub, out of the water. The entire apparatus balances perfectly horizontally on a fulcrum at F, as in *(a)*. The tub is clamped in place and M is lowered to the bottom, completely submerged, as in *(b)*. When the clamps are removed, the tub

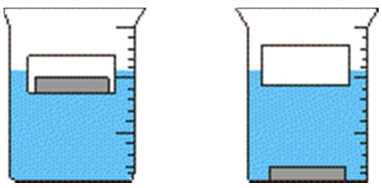
A) remains balanced.
B) tips, with point *L* going down.
C) tips, with point L going up.
D) There is not enough information to solve the problem.
E) None of these is correct.

12. A glass is filled with water. The gauge pressure at the top of the glass is zero and the gauge pressure at the bottom is P. A second glass with three times the height and twice the diameter is also filled with water. What is the pressure at the bottom of the second glass?

A) P
B) $2P$
C) $3P$
D) $3P/2$
E) $3P/4$

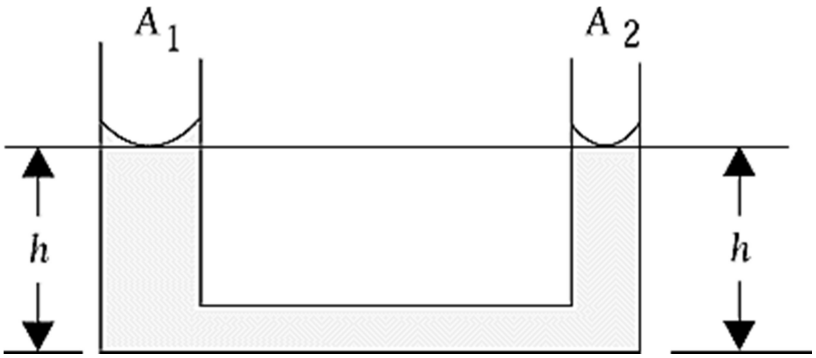
Use the following to answer question 13:

A beaker is filled with water. A small plastic container contains a solid bar of aluminum, which has a mass of 40 g, and is placed on the water so that it floats. The water level reads 60 ml. Next, the bar of aluminum is taken out of the container and placed in the water so that it sinks to the bottom.



13. The water level in the beaker _____
    A) drops.
    B) stays unchanged.
    C) rises.
    D) depends on the type of container
    E) unable to tell

14.

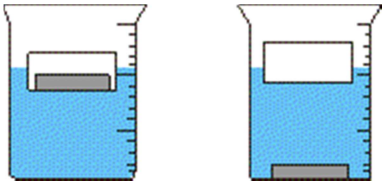


An open U-tube has water to a height h on both sides, as shown. The cross-sectional area of the left-hand tube is $A_1 = 1.50$ cm^2, and that of the right-hand tube is $A_2 = 0.50$ cm^2. A light oil (which does not mix with water) with a density of 0.83 g/cm^3 is added to the right-hand side. When equilibrium is reached, which of the following is correct?

A) The level on the right-hand side is higher than that on the left.
B) The level on the right-hand side is lower than that on the left.
C) The levels of the two sides are the same.
D) The difference in the heights depends on A_1 and A_2.
E) None of these is correct.

Use the following to answer question 15:

A beaker is filled with water. A small plastic container contains a solid bar of aluminum, which has a mass of 40 g, and is placed on the water so that it floats. The water level reads 60 ml. Next, the bar of aluminum is taken out of the container and placed in the water so that it sinks to the bottom.

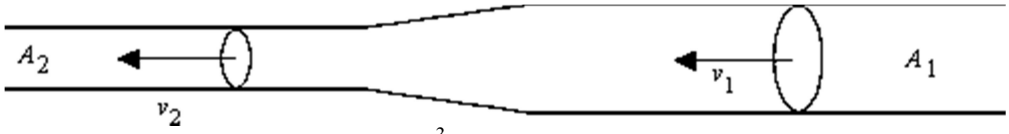


15. By how much does the water level change? (density of Al is 2.7 g/cm^3)
    A) 40 ml
    B) 14.8 ml
    C) 25.2 ml
    D) 0 ml
    E) 30 ml

16. Bernoulli's equation for nonviscous flow can be stated as

$$P_1 + \rho g y_1 + \frac{1}{2}\rho v_1 2 = P_2 + \rho g y_2 + \frac{1}{2}\rho v_2 2$$

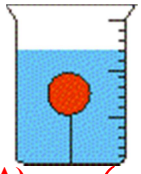
A fluid is flowing through a horizontal tube that changes in cross-sectional area from $A_1 = 0.75\ \text{cm}^2$ to $A_2 = 0.030\ \text{cm}^2$.



When $v_1 = 3.5$ cm/s, $\rho = 1.4\ \text{g/cm}^3$, and viscosity is neglected, the difference between pressure P_2 at A_2 and P_1 at A_1 is

A) $54 \times 10^5\ \text{dyn/cm}^2$, with P_1 higher.
B) $59\ \text{dyn/cm}^2$, with P_2 higher.
C) $59\ \text{dyn/cm}^2$, with P_1 higher.
D) $8.3 \times 10^2\ \text{dyn/cm}^2$, with P_2 higher.
E) None of these is correct.

17. A beaker is filled with water. A ball of mass m and density $\rho < \rho_{water}$ is tied to a string. The other end of the string is then tied to the bottom of the beaker so that the ball is completely submerged. What is the tension in the string?



A) $mg\left(\frac{\rho_{water}}{\rho} - 1\right)$

B) $mg\frac{\rho_{water}}{\rho}$

C) mg

D) $mg\left(1 - \frac{\rho}{\rho_{water}}\right)$

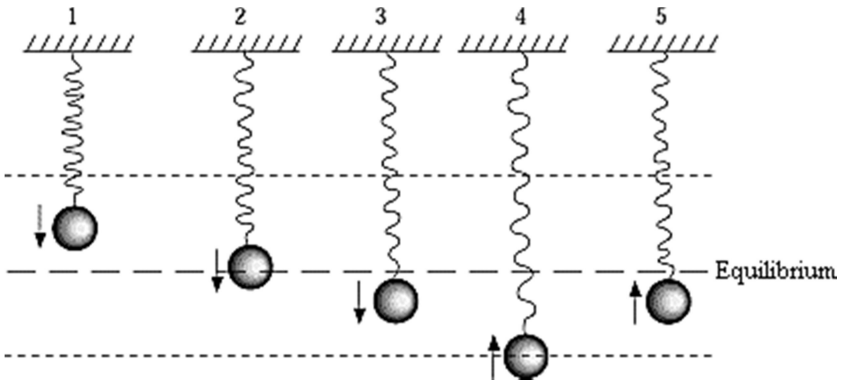
E) $mg\frac{\rho}{\rho_{water}}$

18. Cities across the U.S. supply fresh water to the residents at constant pressure by the use of water towers. If the diameter, d_2, of the pipe coming out of the tower is 25 cm, and the diameter, d_1, of the pipe at your home is 2.0 cm, what is the ratio of the velocity of the water at d_1 compared to d_2? Assume that all the taps are off except yours.
    A) 12.5
    B) 156
    C) 0.0064
    D) 0.08
    E) 25

19. A hurricane strength wind is blowing at a speed of 100 km/hr over a flat roof of 100 m^2. Assuming the inside of the house to be at 1 atm pressure and the density of air is 1.3 kg/m^3, calculate the pressure difference between the inside and the outside of the roof.
    A) 500 Pa lower outside
    B) 1000 Pa higher outside
    C) 500 Pa lower inside
    D) 1000 Pa lower outside
    E) 18 Pa lower outside

20. A hypodermic needle can be thought of as a large area pipe leading to a small area pipe that opens into the vein. The diameter of the plunger is 1.2 cm and the needle diameter is 0.15 cm. If the gauge pressure in the vein is 25 mmHg, what minimum force is needed on the plunger in order for a fluid flow into the vein to occur?
    A) 0.38 N
    B) 0.19 N
    C) 0.0060 N
    D) 31 N
    E) 0.12 N

21.



A body on a spring is vibrating in simple harmonic motion about an equilibrium position indicated by the dashed line. The figure above that shows the body with maximum acceleration is

A) 1
B) 2
C) 3
D) 4
E) 5

22. A simple way to test if a device can withstand high "g-force" is to attach the device to a vibrating platform. Suppose a device has to withstand up to 5g's, and the amplitude of the oscillation is 5 cm, the frequency of the vibration should be

A) 5 Hz
B) 981 Hz
C) 31.3 Hz
D) 44.3 Hz
E) 62.6 Hz

23. When the displacement of an object in simple harmonic motion is one-quarter of the amplitude *A,* the potential energy is what fraction of the total energy?

A) $\frac{1}{4}$
B) $\frac{1}{2}$
C) 1/16
D) There is not enough information provided to answer correctly
E) None of these is correct.

24. A clock keeps accurate time when the length of its simple pendulum is L. If the length of the pendulum is increased a small amount, which of the following is true?
A) The clock will run slow.
B) The clock will run fast.
C) The clock will continue to keep accurate time.
D) The answer cannot be determined without knowing the final length of the pendulum.
E) The answer cannot be determined without knowing the percentage increase in the length of the pendulum.

25. A giant simple pendulum has a time period of 5.00 s at a particular place. If the time period is changed to 4.65 s by shortening the string by 1.0 m, calculate the acceleration due to gravity at this place.
A) 9.18 m/s^2
B) 9.81 m/s^2
C) 9.99 m/s^2
D) 10.3 m/s^2
E) 8.31 m/s^2

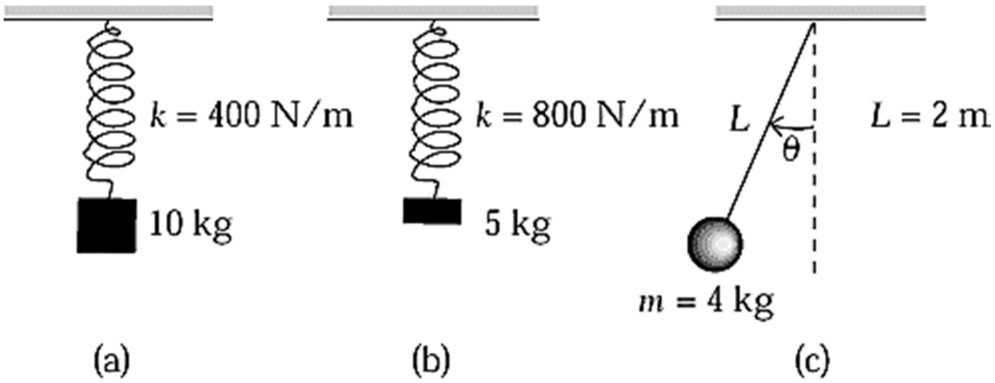
26. A body oscillates with simple harmonic motion according to the equation

$$x = 6.0 \cos(3t + \pi/3)$$

where the units are SI. The speed of the body when it has a displacement of 3 m is
A) $6\pi\sqrt{3}$ m/s
B) 6π m/s
C) 9π m/s
D) $9\pi\sqrt{3}$ m/s
E) 18π m/s

27. A simple pendulum on Earth has a period T. The period of this pendulum could be decreased by
A) increasing the mass of the pendulum bob.
B) taking the pendulum to the moon.
C) taking the pendulum to the planet Jupiter ($M_{\text{Jupiter}} = 315 M_{\text{Earth}}$).
D) decreasing the mass of the pendulum bob.
E) increasing the length of the wire supporting the pendulum.

28.



The order, from shortest to longest, of the *periods* of the oscillatory systems shown in the figure above is

A) a, b, c
B) b, a, c
C) c, b, a
D) c, a, b
E) a, c, b

29. The acceleration of a particle moving with simple harmonic motion is given by

$$a = -16.0x,$$

where x is in meters and a is in meters per second squared. The period of the motion is

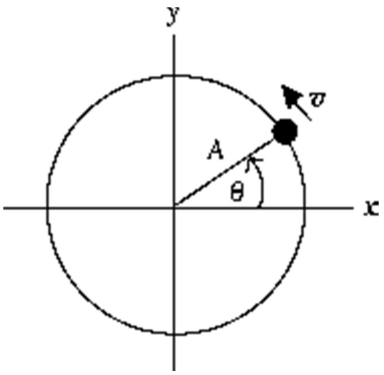
A) 0.25 s
B) 0.392 s
C) 1.57 s
D) 4.0 s
E) 25.2 s

30. A pendulum is oscillating with a total mechanical energy E_0. When the pendulum is at its maximum displacement, the kinetic energy K and the potential energy U are

A) $K = \frac{1}{\sqrt{2}} E_0;\ U = \frac{1}{2} E_0$
B) $K = 0;\ U = E_0$
C) $K = E_0;\ U = E_0$
D) $K = E_0;\ U = 0$
E) $K = E_0;\ U = \frac{1}{2} E_0$

31. A pendulum has simple harmonic motion provided that
    A) its bob is not too heavy.
    B) the supporting string is not too long.
    C) the arc through which it swings is not too small.
    D) the arc through which it swings is not too large.
    E) None of these is correct.

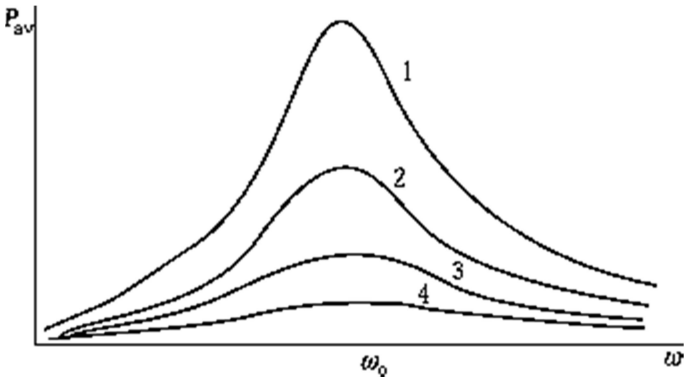
Use the following to answer question 32:



32. The object in the diagram is in circular motion. Its position at $t = 0$ was $(A, 0)$. Its frequency is f. The y component of its position is given by
    A) $y = y_0 + v_{0y}t + \frac{1}{2}at^2$
    B) $y = A \cos 2\pi ft$
    C) $y = A \sin ft$
    D) $y = A \sin 2\pi ft$
    E) $y = A \cos ft$

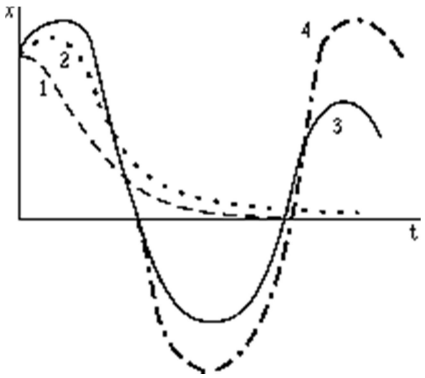
33. A particle moving in a circle of radius 15 cm makes 33.3 rev/min. If the particle starts on the positive x axis at time $t = 0$, what is the x component of the particle's velocity at time $t = 1.2$ s?
    A) 45 cm/s
    B) –3.8 cm/s
    C) 26 cm/s
    D) –45 cm/s
    E) 13 cm/s

Use the following to answer question 34:



34. The graph shows the average power delivered to an oscillating system as a function of the driving frequency. According to these data
    A) the resonant frequency is greater than ω_o.
    B) the system corresponding to curve 1 has the smallest quality factor.
    C) the system corresponding to curve 4 has the smallest quality factor.
    D) the resonant frequency is less than ω_o.
    E) None of these is correct.

Use the following to answer question 35:



35. The graph shows the displacement of an oscillator as a function of time. The oscillator that is critically damped is
    A) 1
    B) 2
    C) 3
    D) 4
    E) 1, 2, 3, and 4

A damped oscillator has a decay time constant τ. After time $t = \tau$ has passed, the fraction of the amount of energy remaining is

A) 0.25
B) 0.37
C) 0.5
D) 0.67
E) 0.75

37. A thin test tube is partially filled with lead pellets so that it floats vertically in a fluid. Use Archimedes' Principle to calculate that if displaced slightly from its equilibrium position the test tube will undergo SHM in the vertical direction and derive how the time period is related to the density of the fluid.
A) T proportional to ρ(liquid)
B) T proportional to $\rho(\text{liquid})^{1/2}$
C) T proportional to $\rho(\text{liquid})^{2}$
D) T proportional to $\rho(\text{liquid})^{-2}$
E) T proportional to $\rho(\text{liquid})^{-1/2}$

38. A 0.5-kg mass is suspended from a massless spring that has a force constant of 79 N/m. The mass is displaced 0.1m down from its equilibrium position and released. If the downward direction is negative, the displacement of the mass as a function of time is given by
A) $y = 0.1\cos(158t - \pi)$
B) $y = 0.2\cos(158t - \pi)$
C) $y = 0.1\cos(12.6t - \pi)$
D) $y = 0.2\cos(12.6t + \pi)$
E) $y = 0.1\cos(2t + \pi)$

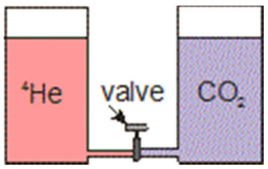
39. A body of mass 0.50 kg moves in simple harmonic motion with a period of 1.5 s and an amplitude of 20 mm. Which of the following equations correctly represents this motion?
A) $x = 40\cos(t/1.5)$ mm
B) $x = 40\cos(2\pi t/1.5)$ mm
C) $x = 20\sin(t/1.5)$ mm
D) $x = 20\sin(1.5\pi t)$ mm
E) $x = 20\sin(2\pi t/1.5)$ mm

40. The shattering of a crystal glass by an intense sound is an example of
A) resonance.
B) a Q factor.
C) critical damping.
D) an exponential decrease.
E) overdamping.

41. You can double both the pressure and the volume of an ideal gas if you change the temperature of the gas by
A) reducing it to one-quarter of its original value.
B) doubling it.
C) reducing it to one-half of its original value.
D) quadrupling it.
E) doing none of these

42. A room measures 3 m × 4 m × 2 m and is at 15°C and 1 atm. Assuming that it only has the two diatomic gases, N_2 and O_2, how much heat is needed to increase the temperature to 25°C? (Ignore the loss in air as the temperature heats up.)
A) 8.4×10^4 J
B) 1.3×10^5 J
C) 1.7×10^5 J
D) 2.1×10^5 J
E) none of the above

43. Two cylinders are connected by a small tube which has a needle valve in the middle. One cylinder contains ^{4}He gas, and the other cylinder contains CO_2 gas. The gases are at the same temperature, pressure and volume. The lids that seal the gases in are free to move up or down. When the valve is opened, what happens to the volume in each cylinder?



A) The volumes do not change.
B) The CO_2 volume decreases and the ^{4}He increases.
C) The CO_2 volume increases and the ^{4}He decreases.
D) What happens depends on the initial temperature.
E) What happens depends on the initial pressure.

44. The oxygen (molar mass = 32 g/mol) and nitrogen (molar mass = 28 g/mol) molecules in this room have equal average
A) kinetic energies, but the oxygen molecules are faster.
B) kinetic energies, but the oxygen molecules are slower.
C) kinetic energies and speeds.
D) speeds, but the oxygen molecules have a higher average kinetic energy.
E) speeds, but the oxygen molecules have a lower average kinetic energy.

45. A temperature difference of 5 C° is the same as a difference of
    A) 41 F°
    B) 14 F°
    C) 9 F°
    D) 5 F°
    E) –15 F°

46. A temperature of 14°F is equivalent to
    A) –10°C
    B) 7.77°C
    C) 25.5°C
    D) 26.7°C
    E) 47.7°C

47. A constant-volume gas thermometer reads 6.66 kPa at the triple point of water. What is the pressure reading at the normal boiling point of water?
    A) 2.44 kPa
    B) 18.2 kPa
    C) 9.10 kPa
    D) 11.8 kPa
    E) 4.87 kPa

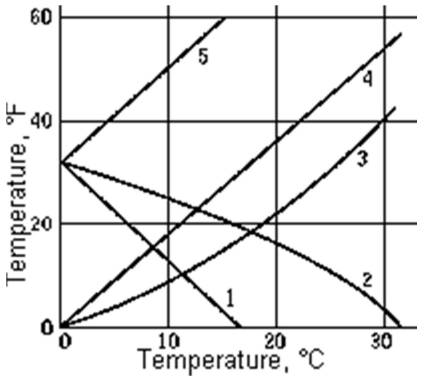
48. The air in a balloon occupies a volume of 0.10 m^3 when at a temperature of 27°C and a pressure of 1.2 atm. What is the balloon's volume at 7°C and 1.0 atm? (The amount of gas remains constant.)
    A) 0.022 m^3
    B) 0.078 m^3
    C) 0.089 m^3
    D) 0.11 m^3
    E) 0.13 m^3

49. The temperature of the air on a hot day when the temperature is 108°F is
    A) 10°C
    B) 110°C
    C) 32 K
    D) 315 K
    E) 420 K

50. A gas thermometer could measure temperature change by measuring the change in
    A) density at constant volume.
    B) specific heat at constant volume.
    C) pressure at constant volume.
    D) volume at constant temperature.
    E) mass at constant volume.

51. Inside a sphere of radius 12 cm are 8.0×10^{23} gas molecules at a temperature of 50°C. What pressure do the gas molecules exert on the inside of the sphere?
A) 650×10^3 Pa
B) 370×10^3 Pa
C) 76.0×10^3 Pa
D) 160×10^3 Pa
E) 490×10^3 Pa

52. Normal human body temperature is 98.6ºF. What is the corresponding Celsius temperature?
A) 54.8ºC
B) 72.6ºC
C) 40.0ºC
D) 37.0ºC
E) 35.5ºC

53.


Which curve correctly represents the relation of the temperature in degrees Fahrenheit to the temperature in degrees Celsius?
A) 1
B) 2
C) 3
D) 4
E) 5

54. The temperature in January in Winnipeg, Manitoba, has been known to go down to –40ºC. What is this temperature on the Fahrenheit scale?
A) –40ºF
B) –104ºF
C) +9.8ºF
D) –72ºF
E) –32ºF

55. At what common Celsius temperature is the rms velocity of oxygen molecules (molar mass = 32 g/mol) double that of hydrogen molecules (molar mass = 2.0 g/mol)?
A) –50
B) zero
C) no such temperature exists
D) 2.0
E) 16

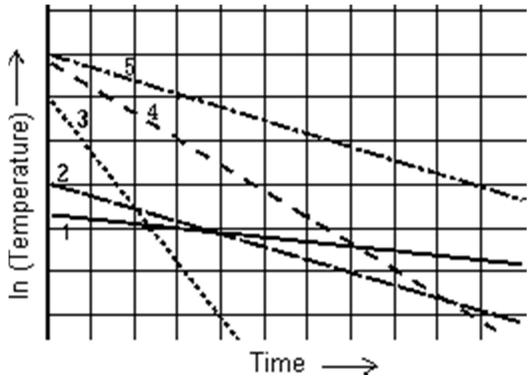
56. Which of the following is an assumption that is made in the kinetic theory of gases?
A) Molecules are not described by Newton's laws.
B) Molecules make up only a small fraction of the volume occupied by a gas.
C) Molecules collide inelastically.
D) The total number of molecules is actually very small.
E) There are forces acting on the molecules at all times.

57. Assume that helium is a perfect gas and that the volume of a cylinder containing helium is independent of temperature. A cylinder of helium at +85ºC has a pressure of 208 atm. The pressure of the helium when it is cooled to –55ºC is
A) –132 atm
B) 127 atm
C) 335 atm
D) 132 atm
E) 204 atm

58. A thermometer is constructed by filling a small glass tube with a liquid that expands linearly with temperature. The thermometer is then calibrated at 0°C and 100°C, and the scale evenly divided between the two values. Unfortunately a manufacturing defect results in the middle one-third of the tube being narrower, otherwise the tube has uniform diameter. For what range of temperatures is the reading accurate?

A) 0°C to 33°C
B) 0°C and 67°C
C) 0°C to 33°C and 67°C to 100°C
D) 67°C to 100°C
E) At no point does this thermometer gives the right reading except at 0°C and 100°C.

59.

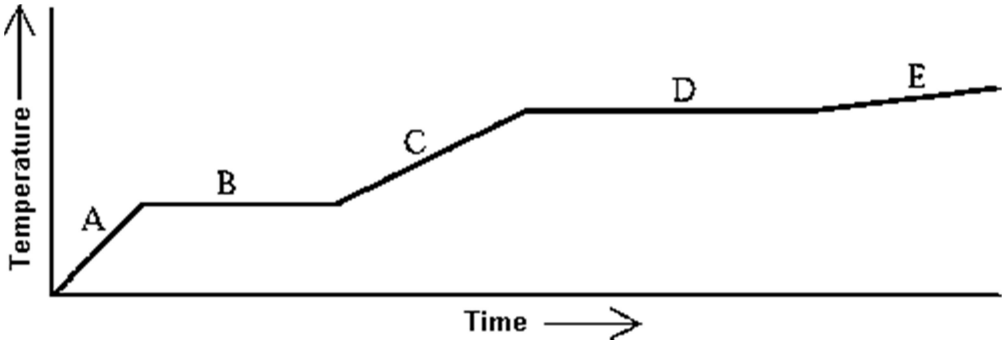


The graph shows the natural logarithm of the temperature of various thermometers as a function of time. The thermometer that cools at the slowest rate is

A) 1
B) 2
C) 3
D) 4
E) 5

60. If it is known that two bodies are in thermal equilibrium, one can conclude that
A) they must be in thermal equilibrium with a third body.
B) there must be a net heat flow between them.
C) the bodies must be at different temperatures.
D) some shared physical property must be changing.
E) they must be at the same temperature.

Use the following to answer question 61:

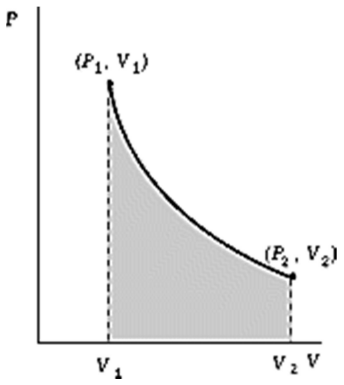


61. Heat is added to a substance at a constant rate. The substance starts as a solid and is melted; the liquid is heated and vaporized; finally, the vapor is heated. This process is shown in the graph. The latent heat of fusion can be found by
    A) multiplying the length of B (in seconds) by the rate at which heat is added, anddividing by the mass of the substance.
    B) multiplying the length of D (in seconds) by the rate at which heat is added, and dividing by the mass of the substance.
    C) multiplying the slope of A by the rate at which heat is added, and dividing by the mass of the substance.
    D) multiplying the slope of C by the rate at which heat is added, and dividing by the mass of the substance.
    E) multiplying the slope of E by the rate at which heat is added, and dividing by the mass of the substance.

62. A lake with 8.0×10^9 kg of water, which has a specific heat of 4180 J/kg · C°, warms from 10 to 15°C. The amount of heat transferred to the lake is
    A) 2.5×10^3 J
    B) 1.7×10^{14} J
    C) 4.0×10^{15} J
    D) 1.7×10^{16} J
    E) 2.8×10^{16} J

63. An ideal gas is heated so that it expands at constant pressure. The gas does work *W*. What heat is added to the gas?
    A) *W*
    B) –*W*
    C) zero
    D) more than *W*
    E) less than *W*

Use the following to answer question 64:

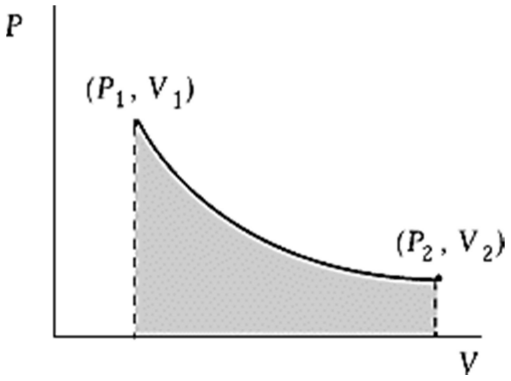


64. One mole of an ideal gas ($\gamma = 5/3$) expands adiabatically and quasistatically from a pressure $P_1 = 6$ atm and a temperature of 50ºC to a pressure $P_2 = 4$ atm. How much work is done by the gas during this process? $R = 8.314$ J/mol·K = 8.206 L·atm/mol·K.
A) 50.3 kJ
B) 56.2 kJ
C) 95.9 kJ
D) 131 kJ
E) 158 kJ

65. The pressure of a mass of air at 20°C is halved adiabatically. If the ratio of C_p to C_v for air is 1.41, calculate the resulting temperature.
A) 240°C
B) 85.0°C
C) –33.0°C
D) –126°C
E) 16.0°C

66. The difference in the molar heat capacity at constant P and constant V is (assume ideal gas).
A) equal to R for monotomic gas.
B) equal to 2R for diatomic gas.
C) equal to NR for polyatomic gas, where N is the number of atoms in a polyatomic molecules.
D) equal to R for all gases.
E) A and D

Use the following to answer questions 67-68:



67. An ideal gas initially at 100ºC and pressure P_1 = 250 kPa occupies a volume V_1 = 4.5 L. It undergoes a quasistatic, isothermal expansion until its pressure is reduced to 150 kPa. How much does the internal energy of the gas change during this process? R = 8.314 J/mol·K = 8.206 L·atm/mol·K.
A) 116 J
B) 320 J
C) 575 J
D) 640 J
E) The internal energy does not change during this process.

68. An ideal gas initially at 50ºC and pressure P_1 = 100 kPa occupies a volume V_1 = 3 L. It undergoes a quasi-static, isothermal expansion until its pressure is reduced to 50 kPa. How much work was done by the gas during this process? R = 8.314 J/mol·K = 8.206 L·atm/mol·K.
A) 116 J
B) 208 J
C) 256 J
D) 304 J
E) 416 J

69. If 100 g of steam at 100°C were mixed with 10 kg of ice at –100°C, find the final temperature of the mixture assuming no heat losses to the surroundings.
A) –85°C
B) –65°C
C) 0°C
D) –15°C
E) – 43°C

70. A system has a heat capacity of 100 J. This means
A) it is possible to extract the 100 J of heat and convert it to work.
B) it is possible to transfer the 100 J of heat to the environment.
C) some of the heat capacity can be converted to work.
D) some of the heat capacity can be transferred to another system if there is a temperature difference.
E) C and D

71. Calculate the speed of sound in hydrogen gas (H_2) at 20°C given the ratio of C_p to C_v is 1.41. (Molar mass of H_2 = 2 g/mol.)
A) 1850 m/s
B) 1150 m/s
C) 342 m/s
D) 1310 m/s
E) 41 m/s

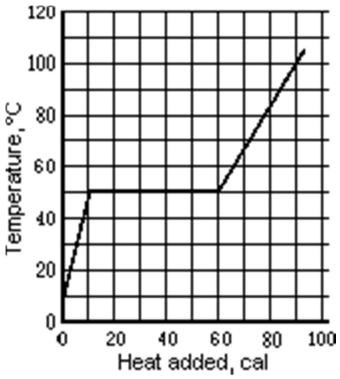
72. A 2.0-kg mass of iron (specific heat = 0.12 kcal/kg · C°) at a temperature of 430°C is dropped into 48 kg of water. The water is initially at a temperature of 10°C. With no heat losses to the surroundings, the equilibrium temperature of the iron and water is approximately
A) 12°C
B) 18°C
C) 19°C
D) 30°C
E) 33°C

73. The pressure of a gas in an isobaric expansion remains constant. In such an expansion,
A) no work is done.
B) work is done by the gas.
C) work is done on the gas.
D) "isobaric" and "expansion" are contradictory terms.
E) work is or is not done depending on whether the temperature of the gas changes.

74. In a system composed of gas contained in a cylinder fitted with a piston, an adiabatic expansion causes the temperature of the gas to drop because
A) heat is given up by the system when the piston moves.
B) the pressure of the gas remains constant.
C) work is done on the system as the gas expands.
D) work done by the system is entirely at the expense of its internal energy.
E) heat is absorbed by the piston when it does work.

75. "The specific heat of an ideal gas at constant pressure C_p is greater than the specific heat of a gas at constant volume C_v." Which of the following describes this statement?
A) The statement is true because there is always more gas at constant pressure.
**B) The statement is true because, to raise the temperature of a gas at constant pressure,
work must be done by the gas.**
C) The statement is true because, to raise the temperature of a gas at constant volume, work must be done by the gas.
D) The statement is not true; $C_v > C_p$.
E) The statement is not true; $C_p = C_v$.

Use the following to answer question 76:

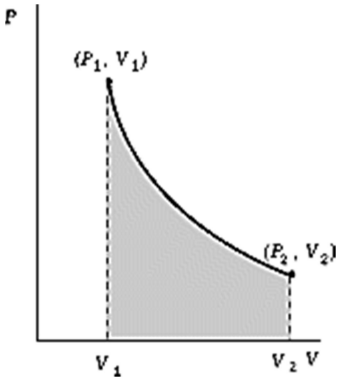


76. The graph shows the temperature of a 1.0-g sample of material as heat is added to it. The material is initially a solid at 10ºC. The pressure remains constant, and there is no chemical change. The specific heat of the solid phase is
    A) 0.6 cal/g · Cº
    B) 0.25 cal/g · Cº
    C) 1.6 cal/g · Cº
    D) 1.7 cal/g · Cº
    E) None of these is correct.

77. A small lake has a surface area of 10000 m^2. Assuming that the average depth of the lake is 2 m, how much heat is released when the average temperature of the water in the lake drops by 1C°?
    A) 8.36×10^{10} J
    B) 8.36×10^{7} J
    C) 2.0×10^{8} J
    D) 2.0×10^{11} J
    E) 8.36×10^{3} J

78. At a particular point on a *PV* diagram, the magnitude of the slope of a curve that represents an adiabatic process is
    A) zero.
    B) infinite.
    C) the same as that of an isotherm through the same point.
    D) less than that of an isotherm through the same point.
    E) greater than that of an isotherm through the same point.

Use the following to answer question 79:

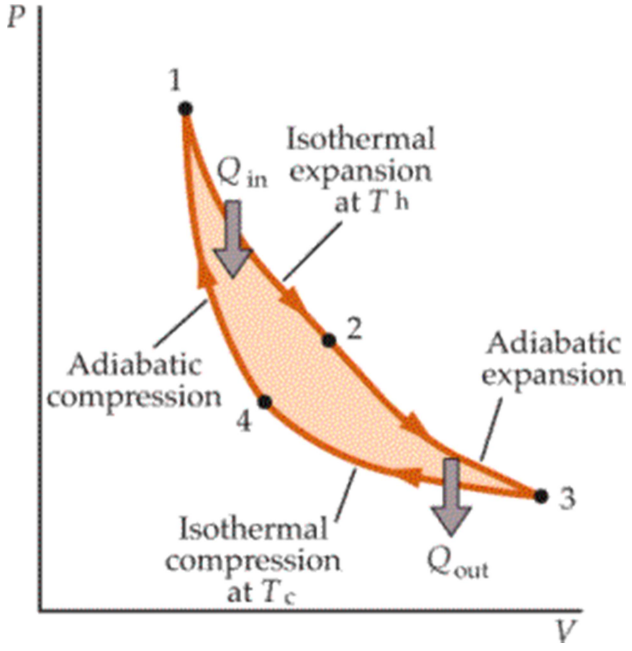


79. An ideal gas initially at 50ºC and pressure P_1 = 100 kPa occupies a volume V_1 = 3 L. It undergoes a quasistatic, isothermal expansion until its pressure is reduced to 50 kPa. How much heat enters the gas during this process? R = 8.314 J/mol·K = 8.206 L·atm/mol·K.
A) 116 J
B) 208 J
C) 256 J
D) 304 J
E) 416 J

80. A balloon contains gas at a pressure 1.2 atm (1 atm = 101.3 kPa) and has a volume of 0.10m^3. More gas is pumped into the balloon at constant pressure until the volume is doubled. How much work is done by the pump?
A) 12 J
B) 24 kJ
C) 24 J
D) 12 kJ
E) 6.1 kJ

81. A steam engine operates between a high and low temperature of 550°C and 180°C. If the steam engine operates at 40% of its theoretical maximum efficiency and does work at a rate of 1000 W, calculate how much heat is discharged per hour.
A) 0.8 MJ/hr
B) 2.8 MJ/hr
C) 3.4 MJ/hr
D) 16 MJ/hr
E) 12 MJ/hr

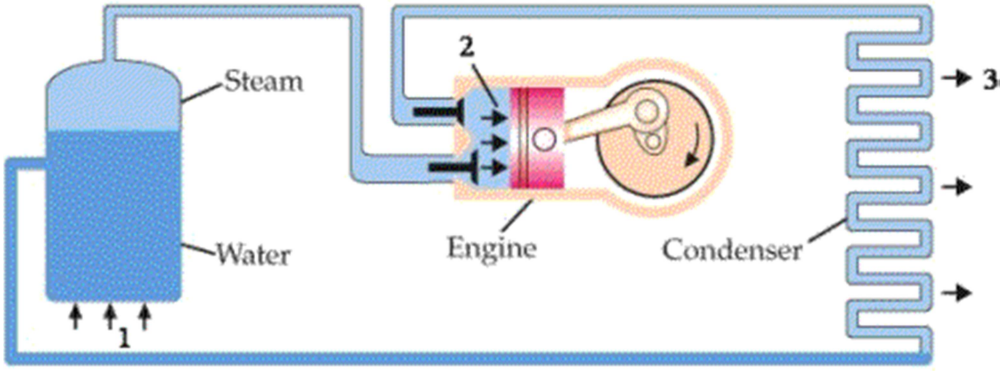
82.



The schematic diagram above illustrates a Carnot engine. Which two paths of the cycle is work done by the gas?

A) 1→2, 2→3
B) 2→3, 3→4
C) 3→4, 4→1
D) 4→1, 1→2
E) only 1→2

83. The diagram below is a schematic of a heat engine. The three quantities, Q_H, Q_L, and W are represented, respectively, by



A) 1, 2, 3
B) 1, 3, 2
C) 2, 3, 1
D) 3, 1, 2
E) 3, 2, 1

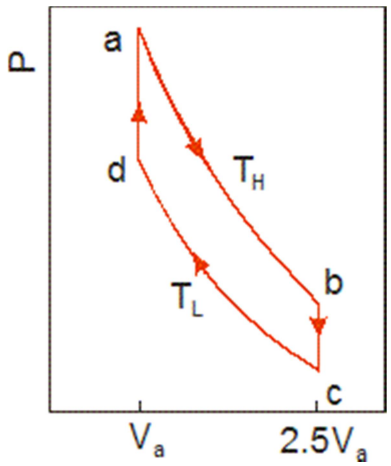
84. For which of the following is COP the abbreviation?
A) Clausius or Planck
B) cycle of pressure
C) coefficients of pressure
D) Carnot ordered performance
E) coefficient of performance

85. A heat engine operating between the temperatures T_1 and T_2 takes in Q_1 calories at temperature T_1 and gives up Q_2 calories at temperature T_2. The efficiency of this heat engine is
A) $(Q_1 - Q_2)/Q_2$
B) $(Q_1 - Q_2)/Q_1$
C) $(T_2 - T_1)/T_2$
D) $Q_2/(Q_1 - Q_2)$
E) $T_1/(T_1 - T_2)$

86. What is the maximum possible efficiency of a steam engine operating between a high and low temperature of 550°C and 180°C?
A) 45%
B) 67%
C) 55%
D) 33%
E) 82%

87. Two refrigerators, one with a COP of 4.0 and another with a COP of 5.0, both extract 400 kJ of heat from the cold reservoir (food). Calculate the difference in energy they exhaust to the hot reservoir and hence the room.
A) 320 kJ
B) 80 kJ
C) 125 kJ
D) 100 kJ
E) 20 kJ

Use the following to answer question 88:



An ideal heat engine uses 0.01 mol of gas and operates between a hot reservoir at $T_H = 400$ K and cold reservoir at $T_L = 300$ K, in a cycle from a→b→c→d→a. From a→b the gas undergoes an isothermal expansion, changing its volume from V_a to $2.5V_a$. From b→c, the pressure is reduced at a constant volume. From c→d, the gas undergoes an isothermal compression, and from d→a, the pressure is increased at a constant volume until the gas is back at the original condition at a.

88. How much heat is absorbed in going from a→b?
    A) 30.5 J
    B) 7.62 J
    C) 22.9 J
    D) 8.31 J
    E) 0.917 J

89. If a steam engine operates at half of its theoretical maximum efficiency (e_{max}) and does work at a rate of W J/s, calculate how much heat is discharged per second.
    A) $W(1 - e_{max}/2) / 2e_{max}$
    B) $2W(1 - e_{max}) / e_{max}$
    C) $W(1 - e_{max}) / e_{max}$
    D) $W(2 - 2e_{max}/2) / (e_{max}/2)$
    E) $2W(1 - e_{max}/2) / e_{max}$

90. The change in the entropy of the universe due to an operating Carnot engine
    A) is zero.
    B) must be positive.
    C) must be negative.
    D) could be positive or negative.
    E) is meaningless to consider, because a Carnot engine has no connection to entropy.

91. Three moles of a gas at $T = 250$ K expand quasi-statically and adiabatically from an initial volume of 30 L to a final volume of 60 L. The change in entropy of the gas during this expansion is ($R = 8.314$ J/mol·K)
A) 17.3 J/K
B) 18.6 J/K
C) –17.4 J/K
D) 19.5 J/K
E) zero

92. We wish to increase the efficiency of an ideal heat engine from 25% to 35%. If the initial temperature of the hot reservoir is 650°C, to what temperature would this need to be increased assuming the exhaust temperature remains the same?
A) 1065°C
B) 910°C
C) 1019°C
D) 973°C
E) 792°C

93. The Carnot cycle consists of
A) a quasistatic isothermal absorption of heat from a hot reservoir.
B) a quasistatic adiabatic expansion to a lower temperature.
C) a quasistatic isothermal exhaustion of heat to a cold reservoir.
D) a quasistatic adiabatic compression to the initial state of the system.
E) All of these are correct.

94. One mole of an ideal gas undergoes a reversible isothermal expansion from a volume of 1 L to a volume of 2 L. The change in entropy of the gas in terms of the universal gas constant R is
A) $R/2$
B) $2R$
C) $R \ln(2)$
D) $R \ln(\frac{1}{2})$
E) None of these is correct.

95. The maximum theoretical thermal efficiency of a steam engine that is supplied steam at a temperature of 600ºC and exhausts it at a temperature of 200ºC is
A) 33.3%
B) 45.8%
C) 66.7%
D) 77.1%
E) 84.6%

96. Entropy is related to probability. An isolated system moves toward
A) a highly ordered state of low probability and high entropy.
B) a highly ordered state of high probability and high entropy.
C) a state of low order, high probability, and high entropy.
D) a state of low order, low probability, and high entropy.
E) a state of low order, high probability, and low entropy.

97. The Carnot efficiency for a heat engine operating between the temperatures of 227ºC and 27ºC is
A) 20%
B) 25%
C) 40%
D) 88%
E) 100%

98. A Carnot engine operating between reservoir temperatures of 340ºC and 40ºC has an efficiency of
A) 37.5%
B) 49.0%
C) 60.0%
D) 62.5%
E) 88.2%

99. A heat pump with COP = 5 uses electrical energy W to heat a house. How much heat is pumped into the house?
A) W
B) $5W$
C) $6W$
D) $4W$
E) $1.2W$

100. A block of mass m = 0.2 kg slides across a rough horizontal surface with coefficient of kinetic friction $\mu_k = 0.5$. What is the change in entropy after the block has moved a distance of 1 m? The temperature of the block and surrounding is 22°C.
A) 4.5×10^{-2} J/K
B) 3.3×10^{-3} J/K
C) 6.7×10^{-3} J/K
D) 9.0×10^{-3} J/K
E) zero

101. If the absolute temperature of an object is doubled, the rate at which it radiates thermal energy
A) doubles.
B) increases by a factor of 4.
C) increases by a factor of 8.
D) increases by a factor of 16.
E) increases by a factor of 32.

102. If the absolute temperature of the filament of a lamp were doubled, the energy radiated per second by the filament would
A) remain the same.
B) increase by a factor of 2.
C) increase by a factor of 4.
D) increase by a factor of 8.
E) increase by a factor of 16.

103. The coefficient of linear expansion for a certain metal is α. The coefficient of area expansion for a square plate made of the same metal is approximately
A) α
B) $\alpha/2$
C) α^2
D) $\sqrt{\alpha}$
E) 2α

104. The wall of a house consists of three layers: a wooden outer wall with an *R* factor of 1.0, a 3-in layer of fiberglass insulation with an *R* factor of 11, and a gypsum-board inner wall with an *R* factor of 0.33 (all *R* factors are in $h \cdot ft^2 \cdot F^o/Btu$). When the temperature is 68°F inside the house and – 4.0°F outside, what is the rate of heat loss through an 8-ft by 15-ft section of this wall?
A) 700 Btu/h
B) 780 Btu/h
C) 5.8 Btu/h
D) 130 Btu/h
E) 350 Btu/h

105. A sheet of metal has a star shaped hole. What happens to the distance, d, when the temperature of the sheet is increased?
A) does not change
B) always increases
C) always decreases
D) unable to tell
E) depends on the thickness of the metal sheet.

106. If a piece of iron is exposed to the sun, its temperature rises until
A) it is hot enough to reflect all the energy that strikes it.
B) the heat absorbed exceeds its thermal capacity.
C) the heat absorbed equals its thermal capacity.
D) it loses and gains heat at the same rate.
E) its temperature equals the temperature of its surroundings.

107. A solid sphere at temperature T radiates energy at a rate of R J/s. If the radius of the sphere were doubled (its temperature remains at T), then the rate of radiating energy would go up by a factor of
A) stays the same
B) 2
C) 4
D) 8
E) 16

108. You have cut a hole in the middle of a large sheet of metal. When the sheet is heated, the area of the hole
A) does not change.
B) always increases.
C) always decreases.
D) increases if the hole is not in the exact center of the sheet.
E) decreases only if the hole is in the exact center of the sheet.

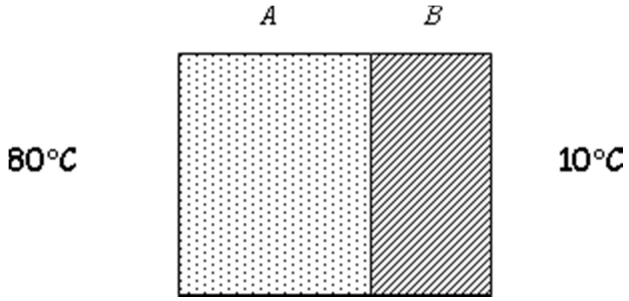
109. The gas tank of your car can hold 60 L of gasoline. Do you get more gasoline in terms of the number of moles when you fill your tank when the gasoline is cold or hot? The coefficient of volume expansion for gasoline = 930×10^{-6}/K and that of steel is 33×10^{-6}/K.
A) Gasoline is sold by volume so it does not make any difference.
B) Gasoline expands when the temperature increases, so you get more when it is hot.
C) Gasoline expands when the temperature increases, so you get less when it is hot.
D) Both gasoline and the tank expand so they cancel each other out.
E) It depends on whether it is regular or premium gasoline.

110. The length of an object varies with temperature according to

$$L = 6 + 2T + 5T^2$$

The coefficient of linear expansion of this object is
A) $2 + 10T$
B) $2/L$
C) $10T/L$
D) T/L
E) $(2 + 10T)/L$

111.



You are testing thermal conduction through a composite material made up of two layers, *A* and *B*. Layer *A* is twice as thick as layer *B*, and the thermal conductivity of material *A* is three times higher than that of material *B*. If the temperature on the outside surface of *A* is 80°C, and the temperature on the outside surface of *B* is 10°C, find the temperature at the interface of the two materials once a steady state of heat flow has been established.

A) 44°C
B) 52°C
C) 70°C
D) 12°C
E) 47°C

112. An object at temperature 227°C radiates energy at a net rate of *R* J/s. By what factor would the net rate of energy loss increase if the same object were at a temperature of 427°C? Assume the surrounding temperature is 0°C.

A) 4.1
B) 3.8
C) 12.5
D) 8.3
E) 6.7

113. Earth receives approximately 1.7×10^{17} J of energy from the sun each second through a process called

A) conduction.
B) convection.
C) radiation.
D) sublimation.
E) evaporation.

114. The axes on a phase diagram are

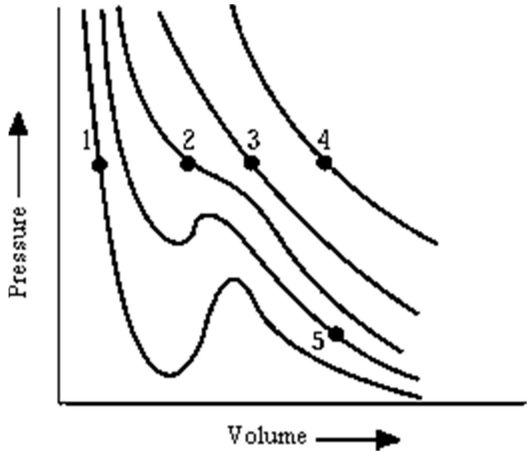
A) temperature and volume.
B) pressure and volume.
C) isotherms and pressure.
D) temperature and pressure.
E) solid, liquid, and vapor.

115. The triple point of a substance gas is
A) the temperature above which the gas cannot be liquefied.
B) the temperature at which solid, liquid, and gas coexist.
C) the temperature below which the gas cannot exist as a liquid.
D) the temperature at which the gas has a maximum volume.
E) the temperature above which there is not distinction between liquid and solid.

116. The coefficient of linear expansion for most materials
A) is much less than 1 K^{-1}.
B) is much greater than 1 K^{-1}.
C) is approximately 1 K^{-1}.
D) can be less than, greater than, or about equal to 1 K^{-1}.
E) is described by none of these.

117. If the absolute temperature of an object is tripled, the rate at which it radiates thermal energy
A) triples.
B) increases by a factor of 9.
C) increases by a factor of 27.
D) increases by a factor of 81.
E) depends on whether the absolute temperature is above or below zero.

118.



The graph shows isotherms of a gas plotted from van der Waal's equation. At which point is a mixture of liquid and vapor likely to be found?
A) 1
B) 2
C) 3
D) 4
E) 5

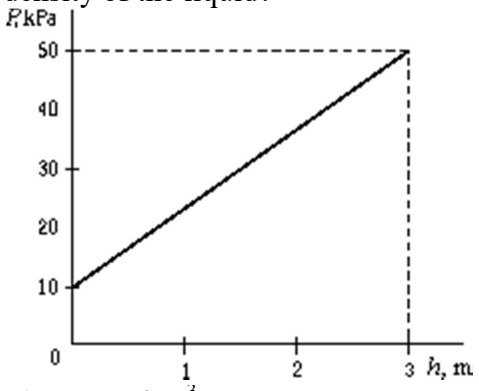
119. A square hole, 30 cm on each edge, is cut in the center of a square aluminum plate 1 m on a side. The coefficient of linear expansion of aluminum is $2.4 \times 10^{-5}/C^{o}$. If the plate is heated 25 ºC above the starting temperature, the area of the hole
A) increases by 1.1 cm^2.
B) increases by 0.54 cm^2.
C) increases by 0.00060 cm^2.
D) decreases by 0.54 cm^2.
E) decreases by 0.00060 cm^2.

120. If the temperature on the warmer side of a wall is doubled, the rate at which heat is conducted through the wall
A) doubles.
B) increases by a factor of 4.
C) decreases by a factor of 4.
D) is cut in half.
E) increases but the rate cannot be determined.

121. A small sphere of wood with a density $\rho = 0.40\ g/cm^3$ is held at rest well under the surface of a pool of water. The magnitude of the initial acceleration of the sphere when it is released is
A) 15 m/s^2
B) 9.8 m/s^2
C) 33 m/s^2
D) 23 m/s^2
E) 3.4 m/s^2

122. A small portion of an incompressible liquid in steady flow through a pipe of variable cross section, if friction is negligible, has at each point throughout its path a constant
A) kinetic energy.
B) velocity.
C) potential energy.
D) total energy.
E) momentum.

123. Pressure as a function of depth for a certain liquid is plotted on the graph. What is the density of the liquid?



A) 1.76 g/cm^3
B) 1.36 g/cm^3
C) 0.340 g/cm^3
D) 1.70 g/cm^3
E) 3.27 g/cm^3

124. When Bernoulli's equation is written in the form

$$P/\rho + \frac{1}{2}v^2 + U = C,$$

the constant C represents the
A) energy per unit mass.
B) energy per unit volume.
C) net work done by outside forces.
D) power supplied by outside sources.
E) mass flow per unit time.

125. A horizontal pipe narrows from a diameter of 10 to 5 cm. For a nonviscous fluid flowing from the larger diameter to the smaller,
A) the velocity and pressure both increase.
B) the velocity increases and the pressure decreases.
C) the velocity decreases and the pressure increases.
D) the velocity and pressure both decrease.
E) either the velocity or the pressure changes but not both.

126. A block of ice 30.5 cm thick floating in fresh water just supports a man weighing 801 N. If the specific gravity of ice is 0.917, the smallest area the block can have is
A) 3.25 m^2
B) 3.57 m^2
C) 2.88 m^2
D) 1.45 m^2
E) 0.269 m^2

127. The force exerted by a stationary liquid on an inclined rectangular surface at rest in the liquid

A) acts normally to the surface.
B) is exerted equally at all points on the surface.
C) acts parallel to the surface.
D) is independent of the density of the liquid.
E) varies inversely as the depth.

128. A 2.5-kg object is attached to a spring of force constant $k = 4.5$ kN/m. The spring is stretched 10 cm from equilibrium and released. What is the kinetic energy of themass–spring system when the mass is 5.0 cm from its equilibrium position?

A) 5.6 J
B) 11 J
C) 17 J
D) 14 J
E) 42 J

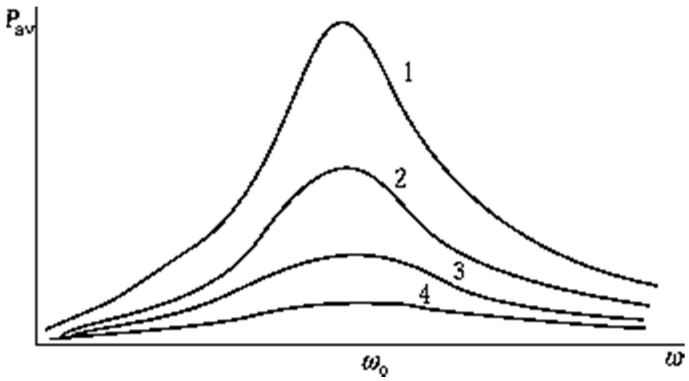
129. The differential equation for a damped oscillator is

$$-kx - b\frac{dx}{dt} = m\frac{d^2x}{dt^2}$$

If the damping is not too large, the time constant for the motion of this oscillator is determined by the

A) spring constant k and the mass m of the system.
B) spring constant k and the damping coefficient b of the system.
C) mass *m* and the damping coefficient *b* of the system.
D) initial displacement of the system.
E) initial velocity of the system.

Use the following to answer question 10:



130. The graph shows the average power delivered to an oscillating system as a function of the driving frequency. According to these data
A) the resonant frequency is greater than ω_o.
B) the system corresponding to curve 1 has the largest quality factor.
C) the system corresponding to curve 4 has the largest quality factor.
D) the resonant frequency is less than ω_o.
E) None of these is correct.

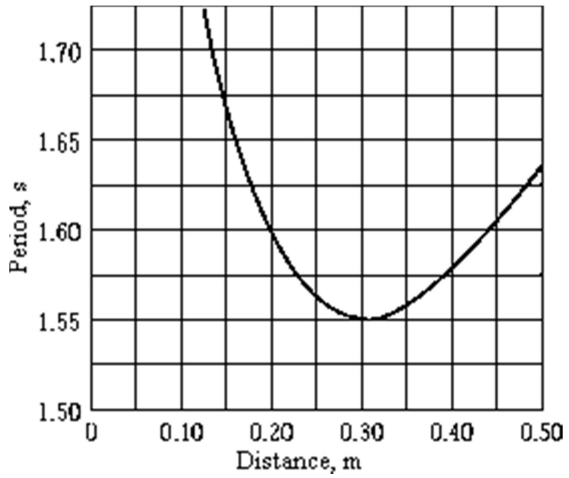
131. A mass on a spring oscillates with an amplitude of 5.0 cm. What is the position of the mass when the kinetic and potential energies are equal?
A) There is not enough information provided to answer this question.
B) 1.2 cm
C) 2.5 cm
D) 3.5 cm
E) 3.8 cm

132. The equation of a body in simple harmonic motion is

$$y = 8.0 \cos(20t + \frac{1}{4}\pi)$$

where y is in centimeters and t is in seconds. The frequency of the oscillations is
A) $\pi/10$ Hz
B) $\pi/4$ Hz
C) $10/\pi$ Hz
D) 8 Hz
E) 20 Hz

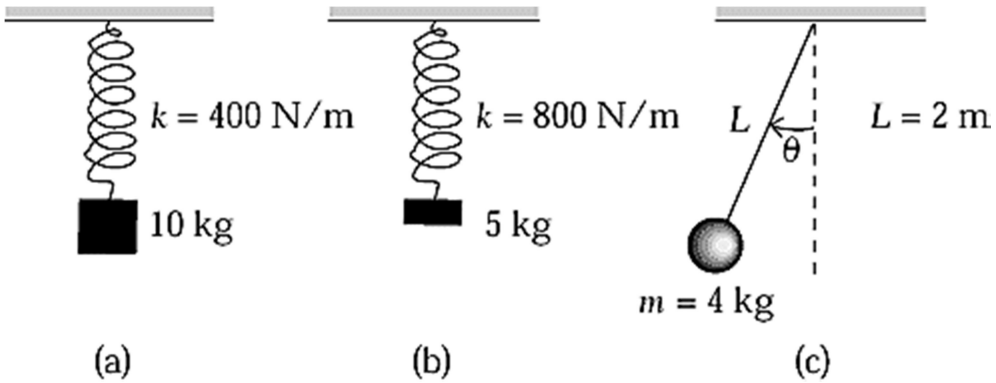
133.



The graph is a plot of the period of a physical pendulum versus the distance from the pivot point to the center of mass. If the physical pendulum is suspended 44 cm from the center of mass, a simple pendulum that would have the same period would have a length of approximately

A) 19 cm
B) 30 cm
C) 44 cm
D) 49 cm
E) 63 cm

134.



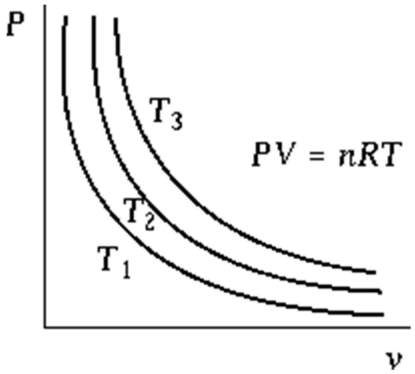
The order, from highest to lowest, of the *frequencies* of the oscillatory systems shown in the figure is

A) a, b, c
B) b, a, c
C) c, b, a
D) c, a, b
E) a, c, b

135. A thermometer is constructed by filling a small glass tube with a liquid that expands linearly with temperature. The thermometer is then calibrated at 0°C and 100°C, and the scale evenly divided between the two values. Unfortunately a manufacturing defect results in the middle one-third of the tube being narrower, otherwise the tube has uniform diameter. For what range of temperatures is the reading accurate?

A) 0°C to 33°C
B) 0°C and 67°C
C) 0°C to 33°C and 67°C to 100°C
D) 67°C to 100°C
E) At no point does this thermometer gives the right reading except at 0°C and 100°C.

136.



The isotherm that corresponds to the lowest temperature is the one labeled
A) T_1
B) T_2
C) T_3
D) The isotherms correspond to the same temperature.
E) None of these is correct.

137. A hailstorm causes an average pressure of 1.4 N/m^2 on the 200-m^2 flat roof of a house. The hailstones, each of mass 7.0×10^{-3} kg, have an average velocity of 10 m/s perpendicular to the roof and rebound after hitting the roof with the same speed. How many hailstones hit the roof each second?

A) 4000
B) 2000
C) 1000
D) 10
E) 800

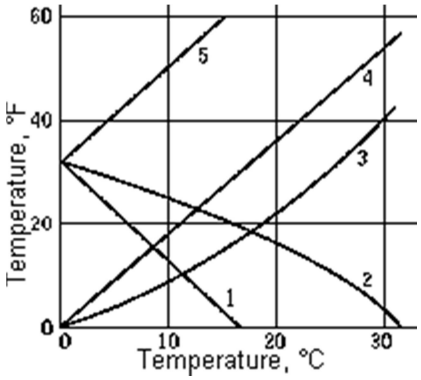
138. A room measures 3 m × 4 m × 2 m and is at 15°C and 1 atm. When the temperature is increased to 25°C, the number of molecules that escaped from the room is, assuming that the pressure stays at 1 atm

A) 6.1×10^{26}
B) 2.1×10^{25}
C) 2.9×10^{26}
D) 1.2×10^{28}
E) 7.04×10^{27}

139. The air around us has 78% nitrogen and 21% oxygen. If the pressure is 1 atm, the pressure due to oxygen is

A) 0.21 atm
B) 0.78 atm
C) 1 atm
D) 0.5 atm
E) 0.67 atm

140.



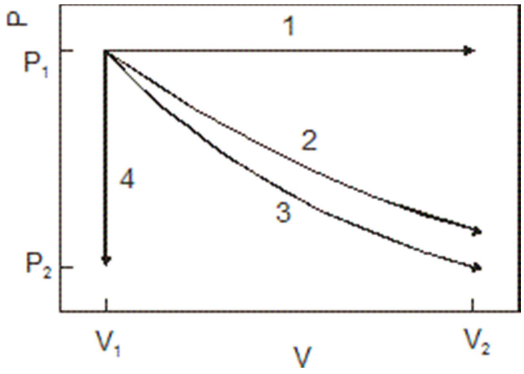
Which curve correctly represents the relation of the temperature in degrees Fahrenheit to the temperature in degrees Celsius?

A) 1
B) 2
C) 3
D) 4
E) 5

141. A temperature of 14ºF is equivalent to
A) –10ºC
B) 7.77ºC
C) 25.5ºC
D) 26.7ºC
E) 47.7ºC

142. A liquid is irregularly stirred in a well-insulated container and thereby undergoes a rise in temperature. Regarding the liquid as a system, you can say that
A) heat has been transferred.
B) the rise in temperature indicates work done by the system.
C) the internal energy has been unchanged.
D) the work done by the system equals the work done on the system.
E) there is a positive change in internal energy.

143.



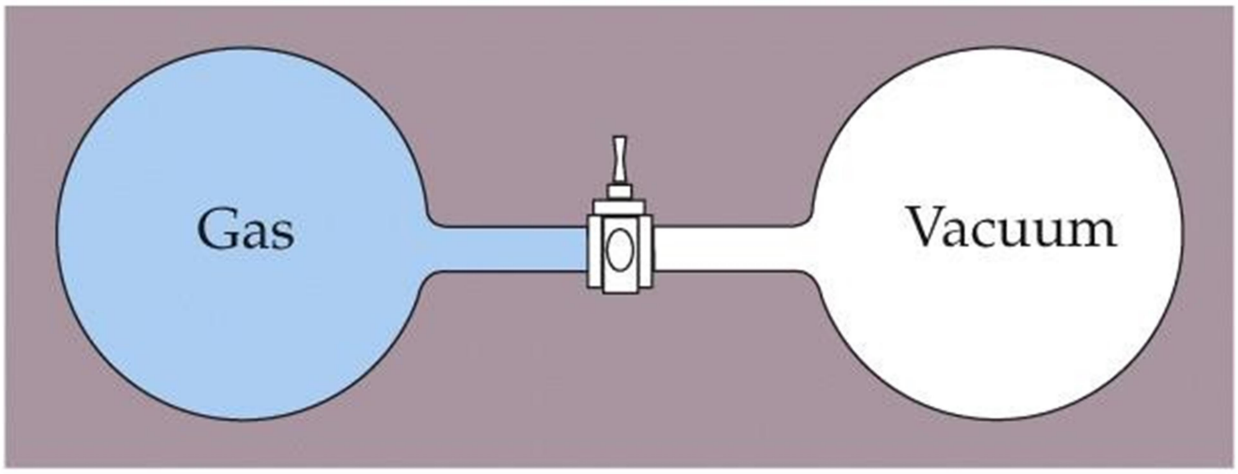
The diagram above show the state of an ideal gas going from (V_1, P_1) to a final state. Which path best represents an isothermal expansion?
A) 1
B) 2
C) 3
D) 4
E) none of the paths

144. A state variable is one that allows other variables to be determined using a relationship. Which of the following variables are state variables?
A) P, V, and T
B) Internal energy, U
C) W and Q
D) A and B
E) A, B, and C

145. An ideal gas with an initial volume of 3 L at a pressure of 2 atm is compressed adiabatically until it has a volume of 2 L; then it is cooled at constant volume until its temperature drops to its initial value. The final pressure is
A) $\frac{3}{4}$ atm
B) 2 atm
C) 3 atm
D) 4/3 atm
E) 6 atm

146. "The specific heat of an ideal gas at constant pressure C_p is greater than the specific heat of a gas at constant volume C_v." Which of the following describes this statement?
A) The statement is true because there is always more gas at constant pressure.
B) The statement is true because, to raise the temperature of a gas at constant pressure, work must be done by the gas.
C) The statement is true because, to raise the temperature of a gas at constant volume, work must be done by the gas.
D) The statement is not true; $C_v > C_p$.
E) The statement is not true; $C_p = C_v$.

147. Two containers of equal volume are connected by a stopcock as shown below. One container is filled with a gas at a pressure of 1 atm and temperature of 293 K while the other container is evacuated so that it is under vacuum. The containers are thermally isolated from the surrounding so no heat enters or escaped from the system. The stopcock is then opened allowing the gas from one container to fill the other. What is the final temperature of the gas after it has come to equilibrium?



A) 136.5 K
B) 273 K
C) 293 K
D) 195 K
E) undetermined

148. A system is said to go through an adiabatic process if, throughout the process,
A) it maintains a constant ratio of pressure to temperature.
B) it remains at a constant temperature.
C) it loses no heat to its surroundings and gains none from them.
D) its total energy increases.
E) it does no work on its surroundings.

149. An electric power plant generates 100 MW of power at an efficiency of 35%. At what rate must water be circulated pass the condenser if the change in water temperature is not to exceed 10ºC?
A) 2400 kg/s
B) 6800 kg/s
C) 3400 kg/s
D) 11300 kg/s
E) 4400 kg/s

We wish to increase the efficiency of an ideal heat engine from 25% to 35%. If the initial temperature of the hot reservoir is 650°C, to what temperature would this need tobe increased assuming the exhaust temperature remains the same?

A) 1065°C
B) 910°C
C) 1019°C
D) 973°C
E) 792°C

151. A refrigerator extracts 25 kJ from a cold reservoir and rejects 35 kJ to a hot reservoir. What is the coefficient of performance of this refrigerator?
A) 2.5
B) 3.5
C) 1.4
D) 5.0
E) 4.0

152. A steam engine with a boiler temperature of 227ºC and an exhaust temperature of 27ºC has a maximum efficiency of approximately
A) 67%
B) 88%
C) 14%
D) 12%
E) 40%

153. One mole of an ideal gas undergoes a reversible isothermal expansion from a volume of 1 L to a volume of 2 L. The change in entropy of the gas in terms of the universal gas constant R is
A) $R/2$
B) $2R$
C) $R \ln(2)$
D) $R \ln(\frac{1}{2})$
E) None of these is correct.

154. A quantity of heat is removed from a hot reservoir at absolute temperature T and then is added to a cold reservoir at absolute temperature $T/2$. The cold reservoir experiences an entropy increase S. What is the change in the entropy of the universe?
A) S
B) zero
C) $-S$
D) $2S$
E) $S/2$

155. What is the maximum possible efficiency of a steam engine operating between a high and low temperature of 550°C and 180°C?
A) 45%
B) 67%
C) 55%
D) 33%
E) 82%

156. You are trying to decide what the change in heat loss would be if you put a 100 cm × 150 cm and 5-mm thick glass window in an outside wall. The thickness of the wall is 15 cm. If the thermal conductivities of the glass and wall are 0.90 W/m·K and 0.15 W/m·K respectively, calculate the difference in heat loss through thermal conductivity with and without the window when the outside temperature is –10°C and the inside temperature is 15°C.
A) 1.34×10^3 J/s
B) 6.7×10^3 J/s
C) 5.53×10^3 J/s
D) 6.75×10^3 J/s
E) none of the above

157. If the temperature on the warmer side of a wall is doubled, the rate at which heat is conducted through the wall
A) doubles.
B) increases by a factor of 4.
C) decreases by a factor of 4.
D) is cut in half.
E) increases but the rate cannot be determined.

158. Two types of wall separate a refrigerated room from the rest of a building. Wall 1 has half the thermal conductivity of wall 2. Wall 2 is half as thick as wall 1. The two walls have the same area. The rate of heat flow through wall 2 compared with the rate of heat flow through wall 1 is
A) four times greater.
B) twice as great.
C) the same.
D) half as great.
E) one-quarter as great.

159. Which of the following statements about electromagnetic radiation is NOT true?
A) Electromagnetic radiation occurs for all objects at all temperatures.
B) Electromagnetic radiation can travel in vacuum.
C) Electromagnetic radiation can travel through glass.
D) A medium is needed for electromagnetic radiation.
E) Electromagnetic radiation transfers energy.

160. If the temperature is 30ºC and the dew point is 10ºC, what is the relative humidity? (use the accompanying table)

Vapor Pressure of Water versus Temperature

t, ºC	*P*, mmHg	*P*, kPa
0	4.581	0.611
10	9.209	1.23
15	12.653	1.69
20	17.535	2.34
30	31.827	4.24
40	55.335	7.38
50	92.55	12.3
60	149	19.9
70	233.8	31.2
80	355	47.4
90	526	70.1
100	760	101.3
110	1074	143.3
120	1489	198.5
130	2026	270.1

A) 53%
B) 71%
C) 29%
D) 3.4%
E) 33%

161. A solid sphere at temperature T radiates energy at a rate of R J/s. If the radius of the sphere were doubled (its temperature remains at T), then the rate of radiating energy would go up by a factor of
A) stays the same
B) 2
C) 4
D) 8
E) 16

162. A common trick to open the lid of a jar that is stuck is to put the lid under hot running water. Suppose the diameter of the lid of a jar of strawberry jam is 6 cm, by how much does the circumference change if the temperature is increased by 30°C? Assume the lid is made of steel.

A) 2.0×10^{-3} cm
B) 3.1×10^{-3} cm
C) 4.1×10^{-3} cm
D) 6.2×10^{-3} cm
E) 5.2×10^{-3} cm

163. Mountaineers say that you cannot hardboil an egg on the top of Mount Rainier. This is true because

A) the air is too cold to boil water.
B) the air pressure is too low for stoves to burn.
C) boiling water is not hot enough to hardboil the egg.
D) the oxygen content of the air is too low.
E) eggs always break in their backpacks.

164. A scuba tank of volume 40 L is filled with 200 moles of compressed air at a pressure of 100 atm. What is the value of an^2/V^2 due to O_2?

A) 1.52 atm
B) 34.6 atm
C) 21.6 atm
D) 3.23 atm
E) 10.4 atm

165. Earth receives approximately 1.7×10^{17} J of energy from the sun each second through a process called

A) conduction.
B) convection.
C) radiation.
D) sublimation.
E) evaporation.

166. The coefficient of linear expansion of the steel in a certain bridge is $1.10 \times 10^{-5}/C^{o}$. If at a minimum winter temperature of –30ºC the bridge is 30.5 m long, at the summer maximum of 40ºC its length is increased about

A) 2.54 cm
B) 2.54 mm
C) 0.254 mm
D) 25.4 μm
E) 2.54 μm

167. A clock pendulum made of aluminum, which has a coefficient of linear expansion of 24 $\times 10^{-6}$/K, has a period of exactly 1 s at 20ºC. Before a homeowner leaves town for one week, he turns the thermostat down to 10ºC. When he returns, the clock is
A) fast by about 73 s.

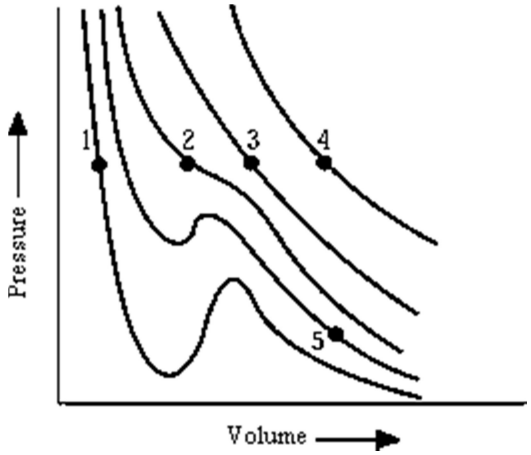
B) fast by about 7.6 min.
C) exactly on time.
D) slow by about 7.6 min.
E) slow by about 73 s.

168. If the thickness of a uniform wall is halved, the rate at which heat is conducted through the wall is
A) doubled.
B) increased by a factor of four.
C) decreased by a factor of four.
D) cut in half.
E) unchanged.

169. The wall of a house consists of three layers: a wooden outer wall with an *R* factor of 1.0, a 3-in layer of fiberglass insulation with an *R* factor of 11, and a gypsum-board inner wall with an *R* factor of 0.33 (all *R* factors are in $h \cdot ft^2 \cdot F^o/Btu$). When the temperature is 68ºF inside the house and – 4.0ºF outside, what is the rate of heat loss through an 8-ft by 15-ft section of this wall?
A) 700 Btu/h
B) 780 Btu/h
C) 5.8 Btu/h
D) 130 Btu/h
E) 350 Btu/h

170. The gas tank of your car can hold 60 L of gasoline. Do you get more gasoline in terms of the number of moles when you fill your tank when the gasoline is cold or hot? The coefficient of volume expansion for gasoline = 930×10^{-6}/K and that of steel is 33×10^{-6}/K.
A) Gasoline is sold by volume so it does not make any difference.
B) Gasoline expands when the temperature increases, so you get more when it is hot.
C) Gasoline expands when the temperature increases, so you get less when it is hot.
D) Both gasoline and the tank expand so they cancel each other out.
E) It depends on whether it is regular or premium gasoline.

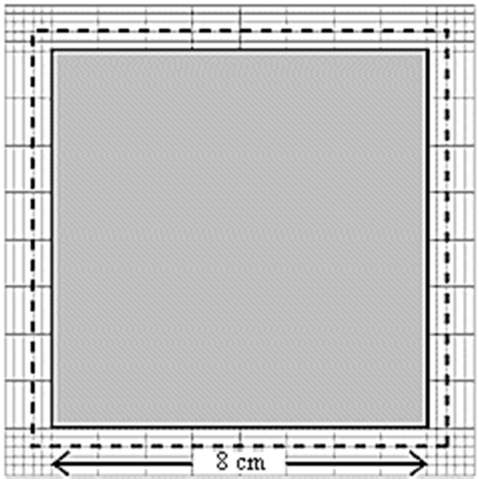
171.



The graph shows isotherms of a gas plotted from van der Waal's equation. At which point is a mixture of liquid and vapor likely to be found?

A) 1
B) 2
C) 3
D) 4
E) 5

172.



A change in temperature of 100º C causes a square plate to expand as shown in the figure. The coefficient of linear expansion of the plate is approximately

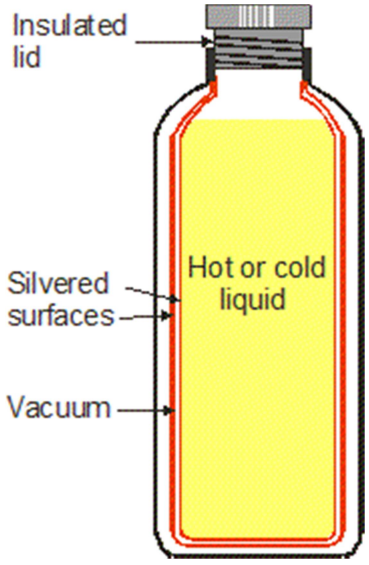
A) 0.0020/Cº
B) 0.0010/Cº
C) 0.0005/Cº
D) 0.0040/Cº
E) 0.0017/Cº

173. If the absolute temperature of the filament of a lamp were doubled, the energy radiated per second by the filament would

A) remain the same.
B) increase by a factor of 2.
C) increase by a factor of 4.
D) increase by a factor of 8.

E) increase by a factor of 16.

174. A thermo keeps a hot drink hot and a cold drink cold for a long time. Shown below is a cut-away section of a thermo with the important features labeled. The reason for the silvered double-wall vacuum chamber is



A) the silvered surfaces reflect any radiation while the vacuum suppresses heat losses by convection and heat conductivity.

B) people like silvery thing so it is a marketing tool. The vacuum keeps the container clean.

C) the silvered surfaces suppresses heat conduction and convection and the vacuum prevents radiated heat.

D) because putting silvery surface is easy to manufacture, and while they are at it, might as well put a vacuum in between.

E) none of the above

175. Two types of wall separate a refrigerated room from the rest of a building. Wall 1 has half the thermal conductivity of wall 2. Wall 2 is half as thick as wall 1. The two walls have the same area. The rate of heat flow through wall 2 compared with the rate of heat flow through wall 1 is

A) four times greater.

B) twice as great.

C) the same.

D) half as great.

E) one-quarter as great.

176. A solid sphere at temperature T radiates energy at a rate of R J/s. If the radius of the sphere were doubled (its temperature remains at T), then the rate of radiating energy would go up by a factor of

A) stays the same

B) 2

C) 4

D) 8
E) 16

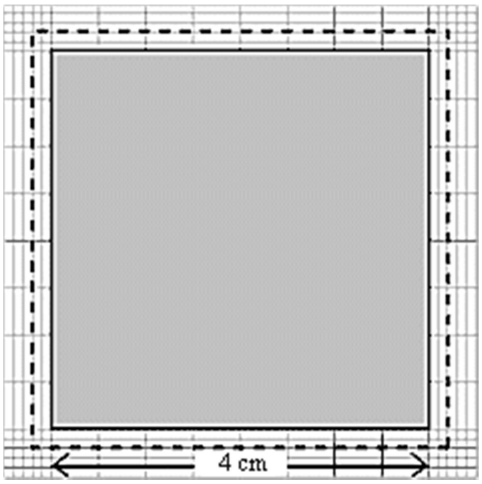
177. A sheet of metal has a star shaped hole. What happens to the distance, d, when the temperature of the sheet is increased?
A) does not change
B) always increases
C) always decreases
D) unable to tell
E) depends on the thickness of the metal sheet.

The length of an object varies with temperature according to

$$L = 6 + 2T + 5T^2$$

The coefficient of linear expansion of this object is
A) $2 + 10T$
B) $2/L$
C) $10T/L$
D) T/L
E) $(2 + 10T)/L$

179.



A change in temperature of 100° C causes a square plate to expand as shown in the figure. The coefficient of linear expansion of the plate is approximately
A) 0.0020/C°
B) 0.0010/C°
C) 0.0005/C°
D) 0.0040/C°
E) 0.0017/C°

180. A well-known technique for achieving a very tight fit between two components is to "expand by heating and then cool to shrink fit." For example, an aluminum ring of inner

radius 5.98 cm needs to be firmly bonded to a cylindrical shaft of radius 6.00 cm (Measurements are at 20°C). Calculate the minimum temperature to which the aluminum ring needs to be heated before it can be slipped over the shaft for fitting. (Coefficient of linear expansion for Al = 24×10^{-6}/K.)

A) 140°C
B) 850°C
C) 120°C
D) 160°C
E) 180°C

181. If α is the coefficient of linear expansion of a material at 0ºC, the volume thermal-expansion coefficient of this material at 0ºC is

A) ~α
B) ~3α
C) $\sim\alpha^3$
D) $\sim\alpha^{1/3}$
E) None of these is correct.

182. An object at temperature 227°C radiates energy at a net rate of *R* J/s. By what factor would the net rate of energy loss increase if the same object were at a temperature of 427°C? Assume the surrounding temperature is 0°C.

A) 4.1
B) 3.8
C) 12.5
D) 8.3
E) 6.7

183. If the temperature on the warmer side of a wall is doubled, the rate at which heat is conducted through the wall

A) doubles.
B) increases by a factor of 4.
C) decreases by a factor of 4.
D) is cut in half.
E) increases but the rate cannot be determined.

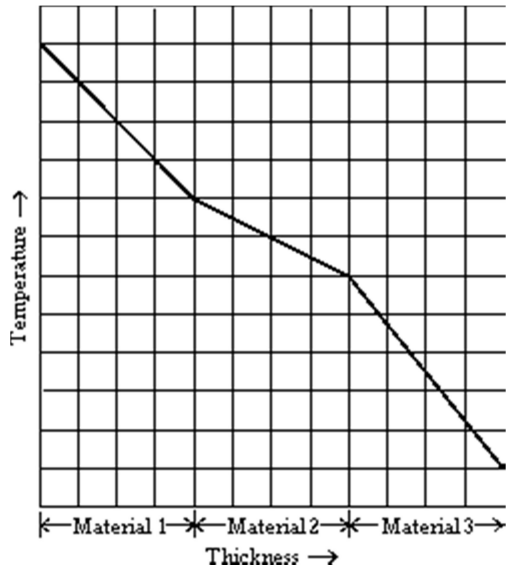
184. You have cut a hole in the middle of a large sheet of metal. When the sheet is heated, the area of the hole

A) does not change.
B) always increases.
C) always decreases.
D) increases if the hole is not in the exact center of the sheet.
E) decreases only if the hole is in the exact center of the sheet.

185. If the thickness of a uniform wall is doubled, the rate at which heat is conducted through the wall is

A) doubled.
B) increased by a factor of four.
C) decreased by a factor of four.
D) cut in half.
E) unchanged.

186.



The graph shows temperature as a function of thickness in three adjacent slabs of material of equal thickness. Assuming the heat transfer through the compound slabs is in a steady state, what can you say of these materials?

A) material 1 is the best insulator
B) material 2 is the best insulator
C) material 3 is the best insulator
D) all are equally good insulators
E) It is impossible to determine which is the best insulator.

187. If a piece of iron is exposed to the sun, its temperature rises until
A) it is hot enough to reflect all the energy that strikes it.
B) the heat absorbed exceeds its thermal capacity.
C) the heat absorbed equals its thermal capacity.
D) it loses and gains heat at the same rate.
E) its temperature equals the temperature of its surroundings.

188. A certain blackbody radiates 100 W at a temperature of 2000 K. How much power would this body radiate at 3000 K?
A) 150 W
B) 225 W
C) 338 W
D) 506 W
E) 759 W

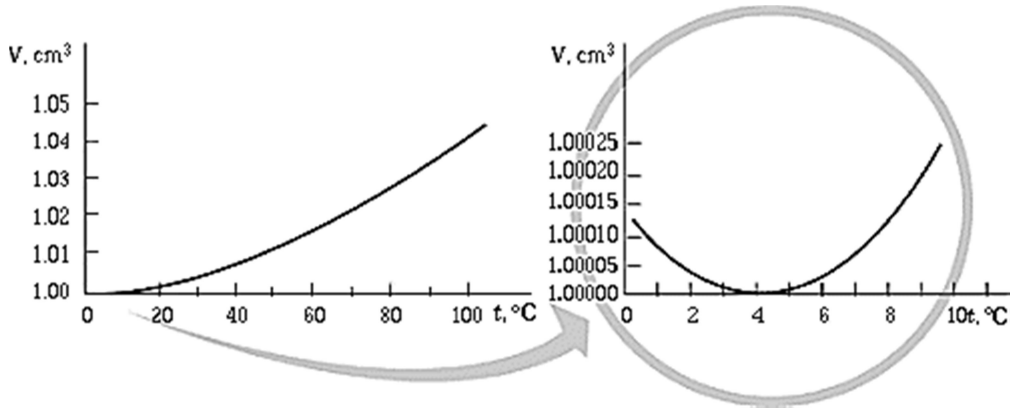
189. The coefficient of thermal expansion of water at 20ºC is 0.207×10^{-3} K^{-1}. A thin glass tube contains a 75.0 cm column of water at 20ºC. If the thermal expansion of the glass tube is negligible, by how much does the length of the column of water expand when it is heated to 80ºC?
A) 3.1 mm
B) 9.3 mm
C) 12.4 mm
D) 4.1 mm
E) 28 mm

190. The main process by which heat is transferred to your home when it is heated by solar energy is
A) conduction.
B) convection.

C) radiation.
D) latent heat transfer.
E) insulation.

191. The critical temperature of any gas is
A) the temperature above which the gas cannot be liquefied.
B) the temperature at which solid, liquid, and gas coexist.
C) the temperature below which the gas cannot exist as a liquid.
D) the temperature at which the gas has a maximum volume.
E) 374ºC.

192.



The graph shows the volume occupied by 1 g of water as a function of temperature. The graph shows that
A) for temperatures greater than 4ºC, the volume decreases with temperature.
B) the volume of the water is a minimum at 4ºC.
C) for temperatures less than 4ºC, the volume increases as the temperature decreases.
D) for temperatures greater than 4ºC, water becomes denser as it cools.
E) All of these statements are true.

193. A heat engine with an output of 300 W has an efficiency of 25% and works at 10 cycles/s. How much heat is absorbed (Q_h) and how much rejected (Q_c) in each cycle?
A) $Q_h = 150$ J, $Q_c = 120$ J
B) $Q_h = 1500$ J, $Q_c = 1200$ J
C) $Q_h = 40$ J, $Q_c = 10$ J
D) $Q_h = 120$ J, $Q_c = 90$ J
E) $Q_h = 1200$ J, $Q_c = 900$ J

194. For which of the following is COP the abbreviation?
A) Clausius or Planck
B) cycle of pressure
C) coefficients of pressure
D) Carnot ordered performance
E) coefficient of performance

195. What is the entropy change when 4 kg of water at 0°C is frozen into 4 kg of ice at 0°C?
A) 4.9 kJ/K
B) an infinite change
C) –4.9 kJ/K
D) 1340 kJ/K
E) –33 kJ/K

196. Two refrigerators, one with a COP of 4.0 and another with a COP of 5.0, both extract 400 kJ of heat from the cold reservoir (food). Calculate the difference in energy they exhaust to the hot reservoir and hence the room.

A) 320 kJ
B) 80 kJ
C) 125 kJ
D) 100 kJ
E) 20 kJ

197 A box contains 10 red and 10 white marbles. The box is then given a good shake. What is the probability that all the 10 red marbles will be at the bottom of the box?
A) 1/1024
B) 1/2048
C) 1/512
D) 1/2
E) zero

198 A Carnot heat engine absorbs heat Q from a hot reservoir at 127ºC and exhausts heat to a cold reservoir at 27ºC. How much heat is exhausted to the cold reservoir?
A) Q
B) $27Q/127$
C) $127Q/27$
D) $3Q/4$
E) $4Q/3$

199. An ideal heat pump is used to pump head from the outside air at –5ºC to the hot-air supply for the heating fan in a house, which is at 35ºC. How much work is required to pump
1.5 kJ of heat into the house?
A) 0.165 kJ
B) 0.195 kJ
C) 0.205 kJ
D) 0.212 kJ
E) 0.224 kJ

200. What is the maximum possible coefficient of performance of a heat pump that is capable of maintaining the interior of a house at 23ºC when the temperature outside is –30ºC?
A) 4.59
B) 3.27
C) 4.87
D) 2.63
E) 5.21

201. A substance undergoes a series of reversible processes that bring it back to its initial state. In this cycle, heat Q_x is absorbed by the substance and heat Q_y is rejected. The net amount of work performed by the substance is
A) $Q_y - Q_x$
B) $Q_x - Q_y$
C) $(Q_y - Q_x)/Q_y$
D) $(Q_x - Q_y)/Q_x$
E) $(Q_x - Q_y)/Q_y$

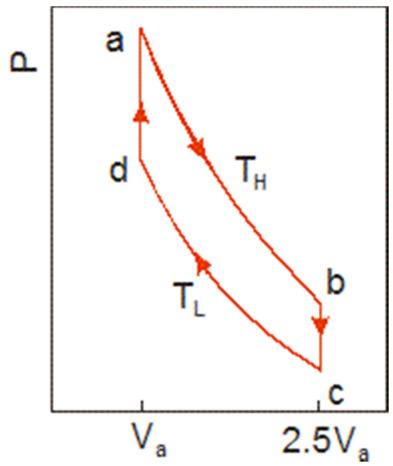
202. When you make ice cubes, the entropy of the water
A) decreases.
B) remains unchanged.
C) increases.
D) is unchanged as the water cools but decreases as the water freezes.
E) decreases while the water is cooling but does not change as it turns to ice.

203. What is the maximum possible coefficient of performance of a heat pump that is capable of maintaining the interior of a house at +20ºC when the temperature outside is –40ºC?
A) 2.0
B) 5.2
C) 12
D) 4.9
E) 3.9

204. A refrigerator extracts heat Q from a cold reservoir. The heat exhausted to a hot reservoir
A) is Q.
B) must be greater than Q.
C) must be less than Q.
D) could be greater than Q.
E) is zero.

205. A refrigerator with a coefficient of performance 5.0 removes 25 kJ of heat from a cold reservoir. If this refrigerator is reversible and is run backward as a heat engine, what would be the efficiency of the heat engine?
A) 50%
B) 80%
C) 83%
D) 17%
E) 20%

Use the following to answer question 44:



An ideal heat engine uses 0.01 mol of gas and operates between a hot reservoir at $T_H = 400$ K and cold reservoir at $T_L = 300$ K, in a cycle from a→b→c→d→a. From a→b the gas undergoes an isothermal expansion, changing its volume from V_a to $2.5V_a$. From b→c, the pressure is reduced at a constant volume. From c→d, the gas undergoes an isothermal compression, and from d→a, the pressure is increased at a constant volume until the gas is back at the original condition at a.

206. How much heat is absorbed in going from a→b?
A) 30.5 J
B) 7.62 J
C) 22.9 J
D) 8.31 J

E) 0.917 J

207. What is the maximum possible efficiency of a steam engine operating between a high and low temperature of 550°C and 180°C?
A) 45%
B) 67%
C) 55%
D) 33%
E) 82%

208. A heat pump with COP = 5 uses electrical energy W to heat a house. How much heat is pumped into the house?
A) W
B) $5W$
C) $6W$
D) $4W$
E) $1.2W$

209. In a nuclear power plant, heat is taken from the reactor core at 300ºC, work is done to drive an electric generator, and heat is rejected to the environment at 40ºC. What is the maximum possible thermal efficiency of this system?
A) 13%
B) 27%
C) 45%
D) 55%
E) 87%

210. A refrigerator has a coefficient of performance 5.0. How much heat is exhausted to the hot reservoir when 200 kJ of heat are removed from the cold reservoir?
A) 50 kJ
B) 150 kJ
C) 200 kJ
D) 240 kJ
E) Not enough information is given to answer this question.

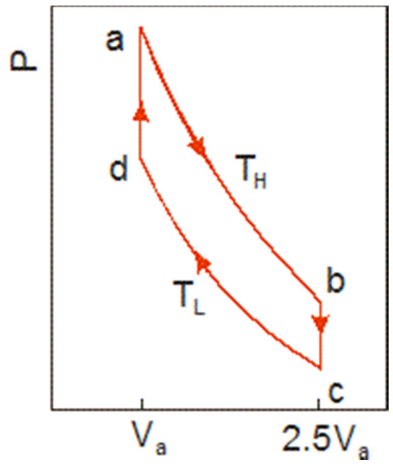
211. A heat engine absorbs 70 kcal of heat from a hot reservoir and exhausts 50 kcal to a cold reservoir each cycle. Its efficiency is
A) 20%
B) 24%
C) 29%
D) 33%
E) 37%

212. If a steam engine operates at half of its theoretical maximum efficiency (e_{max}) and does work at a rate of W J/s, calculate how much heat is discharged per second.
A) $W(1 - e_{max}/2) / 2e_{max}$
B) $2W(1 - e_{max}) / e_{max}$
C) $W(1 - e_{max}) / e_{max}$
D) $W(2 - 2e_{max}/2) / (e_{max}/2)$
E) $2W(1 - e_{max}/2) / e_{max}$

213. The Carnot efficiency for a heat engine operating between the temperatures of 227ºC and 27ºC is
A) 20%
B) 25%
C) 40%
D) 88%

E) 100%

Use the following to answer question 52:



An ideal heat engine uses 0.01 mol of gas and operates between a hot reservoir at $T_H = 400$ K and cold reservoir at $T_L = 300$ K, in a cycle from a→b→c→d→a. From a→b the gas undergoes an isothermal expansion, changing its volume from V_a to $2.5V_a$. From b→c, the pressure is reduced at a constant volume. From c→d, the gas undergoes an isothermal compression, and from d→a, the pressure is increased at a constant volume until the gas is back at the original condition at a.

214. If the engine operates at 50 cycles per second, the power output is
    A) 381 W
    B) 45.8 W
    C) 1145 W
    D) 415 W
    E) 1525 W

215. The construction of a heat engine operating between temperatures T_1 and T_2, and having an efficiency greater than that of a Carnot engine operating between the same two temperatures, would constitute a violation of
    A) the law of the conservation of energy.
    B) the first law of thermodynamics.
    C) the second law of thermodynamics.
    D) Boyle's law.
    E) None of these is correct.

216. A heat engine exhausts heat Q to a cold reservoir. The amount of work done by the Engine
    A) is Q.
    B) must be greater than Q.
    C) must be less than Q.
    D) could be greater than Q.
    E) is zero.

217. A quantity of heat is removed from a hot reservoir at absolute temperature T and then is added to a cold reservoir at absolute temperature $T/2$. The cold reservoir experiences an entropy increase S. What is the change in the entropy of the universe?
    A) S
    B) Zero
    C) $-S$

D) 2*S*
E) *S*/2

218. A thermodynamic system is taken in equilibrium steps from State I to State II. The quantities by which the process can be characterized are

1 internal energy,
2 entropy,
3 temperature,
4 work, and
5 heat.

Of these quantities, those that are independent of path are
A) 1, 2, and 3.
B) 2, 3, and 4.
C) 3, 4, and 5.
D) 1, 3, and 5.
E) 2, 3, and 5.

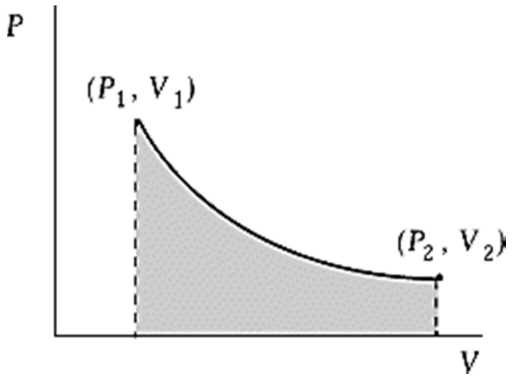
219. An engine operating in a cycle would violate the second law of thermodynamics if it
A) changed all the heat from a source to mechanical work.
B) changed all of its mechanical work to heat.
C) were irreversible.
D) operated between two isotherms and two adiabats.
E) were less efficient than a Carnot engine.

220. A heat engine absorbs heat Q from a hot reservoir. The amount of work done by the Engine
A) is Q.
B) must be greater than Q.
C) must be less than Q.
D) could be greater than Q.
E) is zero.

221. A steam engine operates between a high and low temperature of 550°C and 180°C. If the steam engine operates at 40% of its theoretical maximum efficiency and does work at a rate of 1000 W, calculate how much heat is discharged per hour.
A) 0.8 MJ/hr
B) 2.8 MJ/hr
C) 3.4 MJ/hr
D) 16 MJ/hr
E) 12 MJ/hr

222. A block of mass m = 0.2 kg slides across a rough horizontal surface with coefficient of kinetic friction $\mu_k = 0.5$. What is the change in entropy after the block has moved a distance of 1 m? The temperature of the block and surrounding is 22°C.
A) 4.5×10^{-2} J/K
B) 3.3×10^{-3} J/K
C) 6.7×10^{-3} J/K
D) 9.0×10^{-3} J/K
E) Zero

Use the following to answer question 61:



223. An ideal gas initially at 50ºC and pressure P_1 = 100 kPa occupies a volume V_1 = 3 L. It undergoes a quasistatic, isothermal expansion until its pressure is reduced to 50 kPa. How much does the internal energy of the gas change during this process? R = 8.314 J/mol·K = 8.206 L·atm/mol·K.
A) 116 J
B) 208 J
C) 256 J
D) 304 J
E) The internal energy does not change during this process.

224. The difference in the molar heat capacity at constant P and constant V is (assume ideal gas).
A) equal to R for monotomic gas.
B) equal to 2R for diatomic gas.
C) equal to NR for polyatomic gas, where N is the number of atoms in a polyatomic molecules.
D) equal to R for all gases.
E) A and D

225. Suppose you do 75 kJ of work on a system consisting of 10 kg of water by stirring it with a paddle wheel. During this process, 40 kcal of heat is removed. The change in the internal energy of the system is
A) –35 kJ
B) –115 kJ
C) –134 kJ
D) –242 kJ
E) –156 kJ

226. A lake with 8.0×10^9 kg of water, which has a specific heat of 4180 J/kg · Cº, warms from 10 to 15ºC. The amount of heat transferred to the lake is
A) 2.5×10^3 J
B) 1.7×10^{14} J
C) 4.0×10^{15} J
D) 1.7×10^{16} J
E) 2.8×10^{16} J

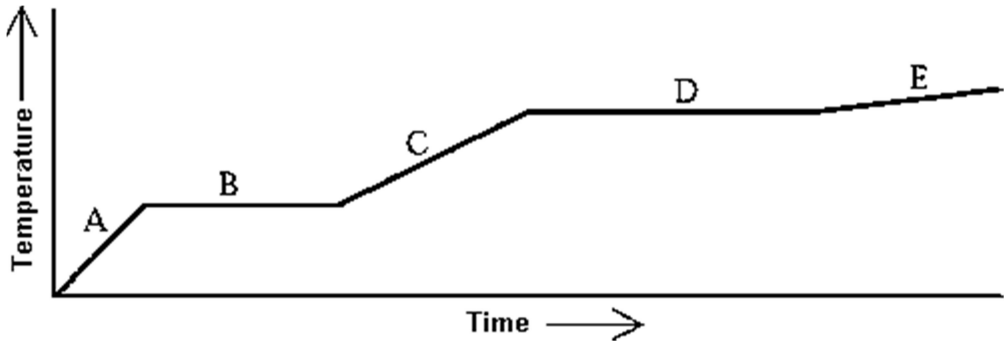
227. A system is said to go through an adiabatic process if, throughout the process,
A) it maintains a constant ratio of pressure to temperature.
B) it remains at a constant temperature.
C) it loses no heat to its surroundings and gains none from them.
D) its total energy increases.

E) it does no work on its surroundings.

228. For most metals, the heat capacity goes as $C = \gamma T + AT^3$ at low temperatures (~ 100 K), whereas insulators only has the T^3 term. Both γ and A are constants. The two terms in the expression for C suggests
A) there are at least two degrees of freedom in metals.
B) there are two independent mechanisms for heat to be absorbed or released in metals.
C) that there are two kinds of heat that are absorbed by metals.
D) that thermal energy is transferred to metals differently than insulators.
E) nothing. It just happens that way.

229. The molar specific heat of copper is 24.5 J/(mol·K). The amount of heat needed to raise 126 g of copper by 2C° is
A) 24.5 J
B) 49 J
C) 12.3 J
D) 98 J
E) 147 J

Use the following to answer question 68:



230. Heat is added to a substance at a constant rate. The substance starts as a solid and is melted; the liquid is heated and vaporized; finally, the vapor is heated. This process is shown in the graph. Which of the following statements is correct?
A) The latent heat of fusion is greater than the latent heat of vaporization.
B) The latent heat of vaporization is greater than the latent heat of fusion.
C) The latent heat of vaporization is equal to the latent heat of fusion.
D) The mass of the substance must be known before any statements about the latent heats can be made.
E) The relative sizes of the latent heats depend on the rate at which the heat is added.

231. The specific heat of a gas is
A) the same for all gases.
B) directly proportional to the absolute temperature.
C) independent of constraints imposed on it while heating.
D) a negligible quantity.
E) greater at constant pressure than at constant volume.

232. If the heat capacities of both ice and steam are 0.5 cal/g · Cº, the quantity of heat required to change 1 g of ice at –10ºC to steam at 120ºC is approximately
A) 750 cal
B) 735 cal
C) 630 cal

D) 620 cal

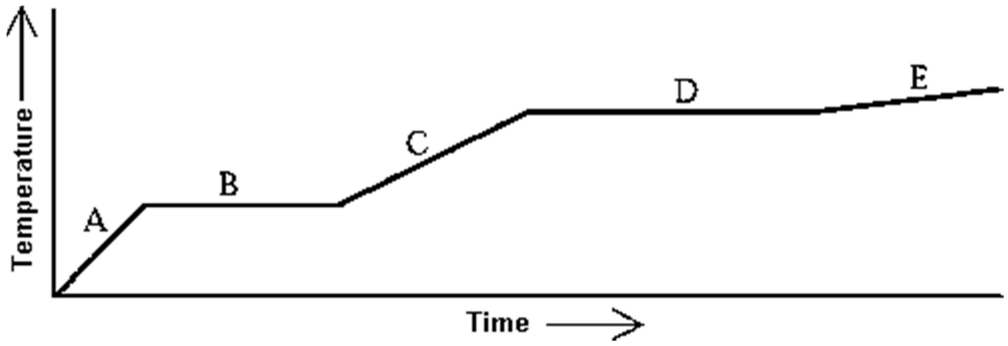
E) 555 cal

233. Two liquids, *A* and *B*, are mixed together, and the resulting temperature is 22°*C*. If liquid *A* has mass *m* and was initially at temperature 35°C, and liquid *B* has mass 3*m* and was initially at temperature 11°C, calculate the ratio of the specific heats of *A* divided by *B*.
A) 0.85
B) 2.5
C) 1.2
D) 0.45
E) 0.94

234. An ideal monatomic gas has a molar heat capacity C_{mp} at constant pressure. What is the molar heat capacity at constant volume of an ideal diatomic gas?
A) C_{mp}
B) $C_{mp} + R$
C) $C_{mp} - R$
D) $C_{mp} + 3R/2$
E) $C_{mp} - 3R/2$

235. The internal energy for a diatomic gas is given by $U = 5nRT/2$. Calculate the internal energy of a 100 g mixture of oxygen (20%) and nitrogen (80%) gas at 25°C. (The molar weight of O_2 = 32 g, and the molar weight of N_2 = 28 g.)
A) 21.6 kJ
B) 1.80 kJ
C) 12.1 kJ
D) 13.0 kJ
E) 1.10 kJ

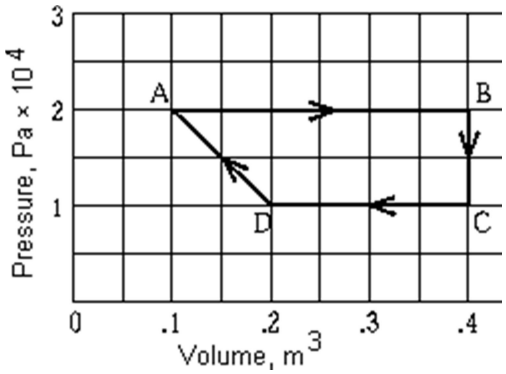
Use the following to answer question 74:



236. Heat is added to a substance at a constant rate. The substance starts as a solid and is melted; the liquid is heated and vaporized; finally, the vapor is heated. This process is shown in the graph. The specific heat of the solid can be found by
A) multiplying the length of B (in seconds) by the rate at which heat is added, and dividing by the mass of the substance.
B) multiplying the length of D (in seconds) by the rate at which heat is added, and dividing by the mass of the substance.
C) dividing the rate at which heat is added by the product of the slope of A and the mass of the substance.
D) dividing the rate at which heat is added by the product of the slope of C and the mass of the substance.
E) dividing the rate at which heat is added by the product of the slope of E and the

mass of the substance.

237.



A reversible heat engine has the *PV* graph shown. The work done during the entire cycle is

A) zero
B) 2.5 kJ
C) 6.0 kJ
D) 2.0 kJ
E) 5.0 kJ

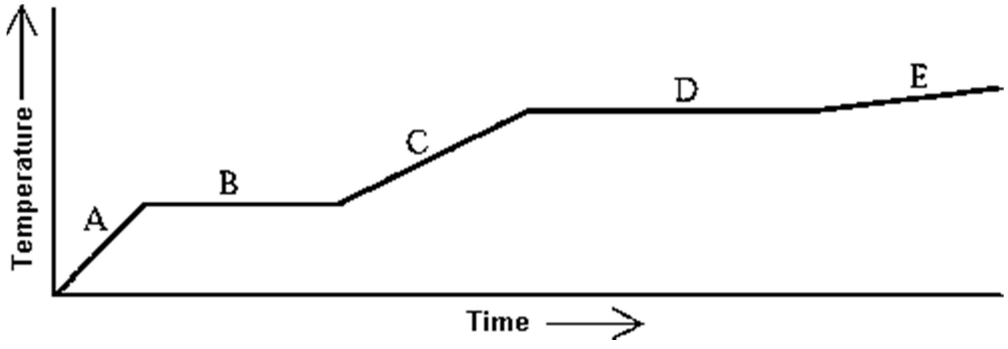
238. The specific heat of a gas at constant pressure is

A) directly proportional to the pressure.
B) inversely proportional to the pressure.
C) always greater than the specific heat at constant volume.
D) always less than the specific heat at constant volume.
E) independent of the kind of gas.

239. The pressure of a mass of air at 20°C is halved adiabatically. If the ratio of C_p to C_v for air is 1.41, calculate the resulting volume.

A) 2.66 times the original volume
B) 1.63 times the original volume
C) 2.00 times the original volume
D) 0.50 times the original volume
E) 0.61 times the original volume

Use the following to answer question 78:



240. Heat is added to a substance at a constant rate. The substance starts as a solid and is melted; the liquid is heated and vaporized; finally, the vapor is heated. This process is shown in the graph. The specific heat of the liquid can be found by

A) multiplying the length of B (in seconds) by the rate at which heat is added, and dividing by the mass of the substance.

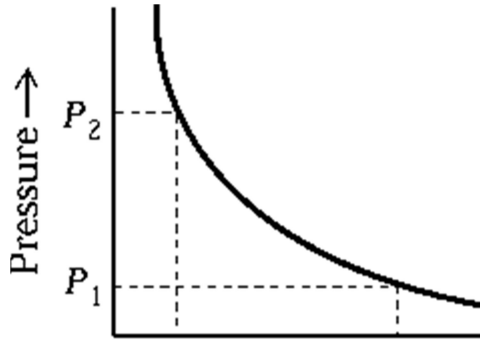
B) multiplying the length of D (in seconds) by the rate at which heat is added, anddividing by the mass of the substance.

C) dividing the rate at which heat is added by the product of the slope of A and the mass of the substance.

D) dividing the rate at which heat is added by the product of the slope of C and the mass of the substance.

E) dividing the rate at which heat is added by the product of the slope of E and the mass of the substance.

241.



The work done by a gas on a piston can be obtained from the graph, provided the abscissa represents the

A) internal energy.

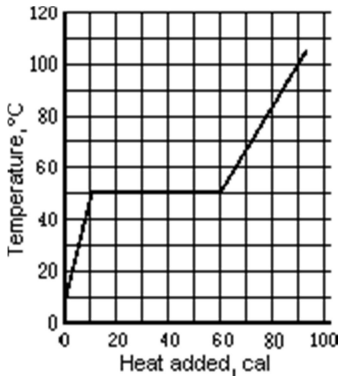
B) temperature.

C) density.

D) volume.

E) time.

Use the following to answer question 80:



242. The graph shows the temperature of a 1.0-g sample of material as heat is added to it. The material is initially a solid at 10ºC. The pressure remains constant, and there is no chemical change. The melting point temperature is

A) 10ºC

B) 100ºC

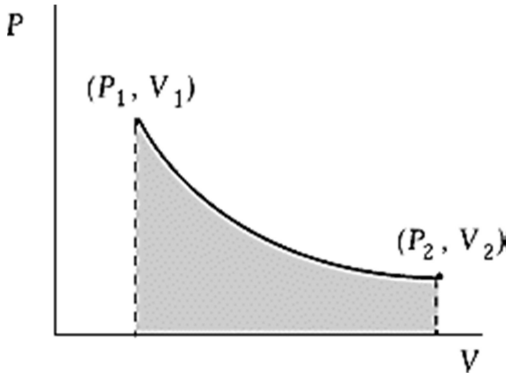
C) 60ºC

D) 73°C

E) None of these is correct.

243. An ideal gas with an initial volume of 3 L at a pressure of 2 atm is compressed adiabatically until it has a volume of 2 L; then it is cooled at constant volume until its temperature drops to its initial value. The final pressure is
A) $\frac{3}{4}$ atm
B) 2 atm
C) 3 atm
D) 4/3 atm
E) 6 atm

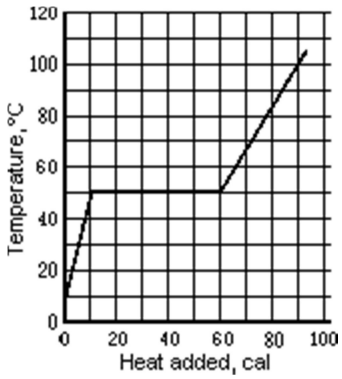
Use the following to answer question 82:



244. An ideal gas initially at 50ºC and pressure $P_1 = 250$ kPa occupies a volume $V_1 = 4.5$ L. It undergoes a quasistatic, isothermal expansion until its pressure is reduced to 150 kPa. How much work was done by the gas during this process? $R = 8.314$ J/mol·K = 8.206 L·atm/mol·K.
A) 116 J
B) 320 J
C) 575 J
D) 640 J
E) 850 J

245. Two liquids, *A* and *B*, are mixed together. Liquid *A* has mass *m* and was initially at temperature 40°C, and liquid *B* has mass 2*m* and was initially at temperature 5°C. The specific heat of liquid *A* is 1.5 times that of liquid *B*.
Calculate the final temperature of the mixture.
A) 33.5°C
B) 14.3°C
C) 17.0°C
D) 20.0°C
E) 25.7°C

Use the following to answer question 84:



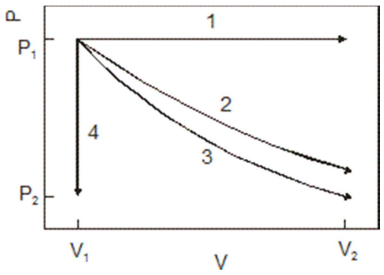
246. The graph shows the temperature of a 1.0-g sample of material as heat is added to it. The material is initially a solid at 10ºC. The pressure remains constant, and there is no chemical change. The specific heat of the solid phase is
   A) 0.6 cal/g · Cº
   B) 0.25 cal/g · Cº
   C) 1.6 cal/g · Cº
   D) 1.7 cal/g · Cº
   E) None of these is correct.

247. A state variable is one that allows other variables to be determined using a relationship. Which of the following variables are state variables?
   A) P, V, and T
   B) Internal energy, U
   C) W and Q
   D) A and B
   E) A, B, and C

248 In a certain thermodynamic process, 1000 cal of heat are added to a gas confined in a cylinder. At the same time, 1000 J of work are done by the gas as it expands. The increase in internal energy of the gas is
   A) zero
   B) 3186 J
   C) –239 J
   D) 5186 J
   E) 1239 J

249. If the heat given off by 300 g of an alloy as it cools through 50 Cº is sufficient to raise the temperature of 300 g of water from 30º to 40ºC, the specific heat of the alloy must be approximately
   A) 0.015 cal/g · Cº
   B) 0.10 cal/g · Cº
   C) 0.15 cal/g · Cº
   D) 0.20 cal/g · Cº
   E) 0.50 cal/g · Cº

250.



The diagram above show the state of an ideal gas going from (V_1,P_1) to a final state. Which path best represents adiabatic expansion?

A) 1
B) 2
C) 3
D) 4
E) none of the paths

4.8×10^5
8.0×10^4
1.6×10^5
1.1×10^4
3.6×10^5