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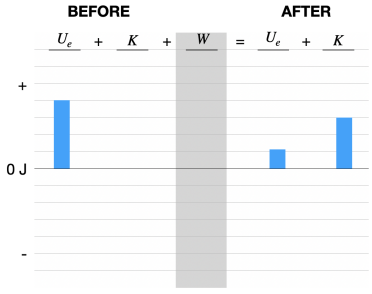
All questions on the test are multiple choice. Choose only one answer for each question, and fill it out on your bubblesheet (scantron). Each question is worth 4 points.

1. In a vacuum, a metal sphere with a negative electric charge $-Q$ briefly touches a smaller, electrically neutral (uncharged) sphere. Afterward, the two spheres repel each other. After the spheres touch, the charge of the ***smaller*** sphere is

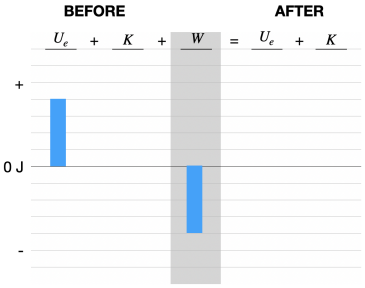
   A. zero
   B. less than Q but greater than zero
   C. equal to Q
   D. less than $-Q$ but greater than zero
   E. equal to $-Q$

2. A negative particle is released from rest near a negatively charged plate. Which of the following bar charts could represent the energy of a particle-plate system, where the initial state is just after the particle is released and the final state is after the particle has travelled a meter from the plate?

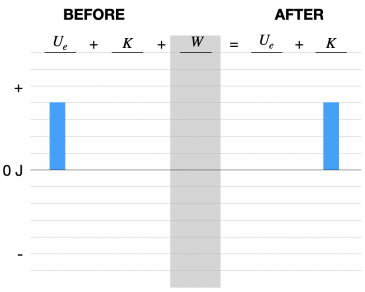
I.



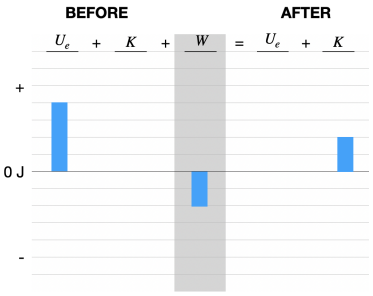
II.



III.



IV.



   A. I only
   B. III only
   C. I, II and III
   D. I and III
   E. All of them could work

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3. Two small, electrically charged spheres each have a positive charge Q. When they are separated by a distance d, the electrostatic force between them has a magnitude F. Which of the following options would result in an electrostatic force of magnitude $4F$ between the spheres?

   A. Decreasing the separation distance to $d/4$

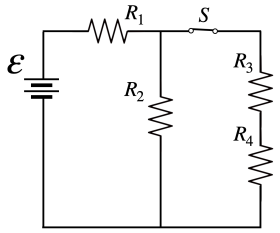
   B. Decreasing the separation distance to $d/2$

   C. Increasing the charge on *both* spheres to $2Q$ and decreasing the separation distance to $d/2$

   D. Increasing the charge on *one* sphere to $2Q$ and decreasing the separation distance to $d/4$

   E. None of these

4. The circuit shown contains a battery and four resistors, whose resistances are shown below. Initially, the switch S is closed.



Resistor	Resistance
R_1	15 Ω
R_2	60 Ω
R_3	10 Ω
R_4	20 Ω

   Which of the following correctly ranks the magnitude I of the current through each resistor?

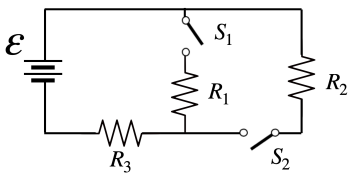
   A. $I_3 > I_1 > I_4 > I_2$

   B. $I_1 > (I_3 = I_4) > I_2$

   C. $(I_3 = I_4) > (I_1 = I_2)$

   D. $I_1 > (I_2 = I_3) > I_4$

5. Students are doing experiments using the circuit shown above. They open or close switches S_1 and S_2 and can measure the current in any of the resistors. Which of the following sets of switch positions and current measurements would provide evidence to verify Kirchhoff's junction rule?



	S_1	S_2	Current Measurements
A.	Open	Open	R_1
B.	Open	Closed	R_1 and R_2
C.	Closed	Open	R_1 and R_2
D.	Open	Closed	R_2 and R_3
E.	Closed	Closed	R_1. R_2, and R_3

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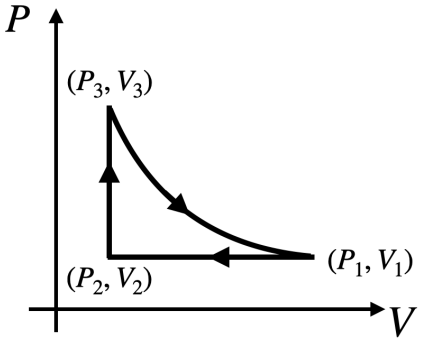
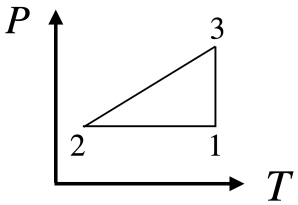
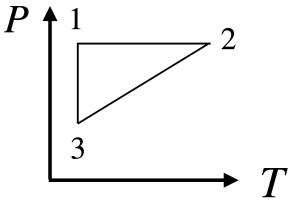
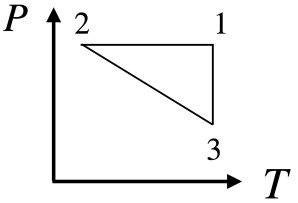
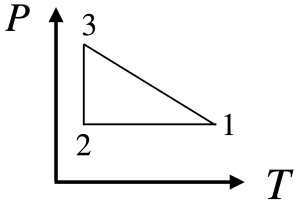
6. Which of the following pressure vs. temperature graphs best describes the cycle shown?



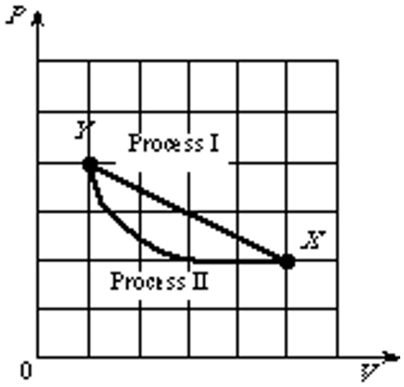
A.


B.


C.


D.


7. A sample of one mole of an ideal gas is confined to a container with a movable piston. The PV diagram shows the initial state of the sample, represented by point X, and the final state, represented by point Y. Also shown are two different processes that can be used to take the gas sample from X to Y. (Both Process I and Process II start at state X and end at state Y.) Which of the statements below, I through V, are CORRECT?



I. The heat is transferred out of the gas in both processes.

II. The heat is transferred into the gas in both processes.

III. The heat is transferred into the gas in one of the processes and out of the gas in the other.

IV. The amount of heat transfer in Process I is the same as it is in Process II.

V. The amount of heat transfer in Process I is NOT the same as it is in Process II.

A. I and IV

B. II and IV

C. III and IV

D. I and V

E. II and V

F. III and V

8. One mole of an ideal gas is compressed isothermally in an ideal engine. During the compression, N J of work is done on the gas and no work is done by the gas. Which of the following statements is true?

A. By the 1st law, more than N J of energy must leave the gas through cooling.

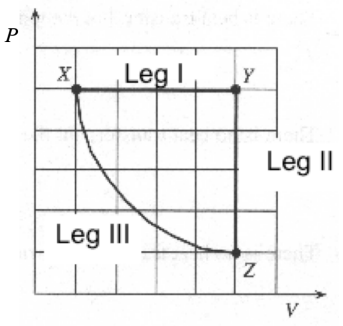
B. By the 1st law, exactly N J of energy leaves the gas through cooling.

C. The compression is isothermal so there is no heating or cooling.

D. By the 1st law, exactly N J of energy enters the gas through heating.

E. By the 1st law, more than N J of energy must enter the gas through heating.

9. One mole of an ideal gas is confined to a container with a movable piston. The P-V diagram shown describes a cyclic process made up of three legs: I, II and II in the figure. The cycle goes $X - Y - Z - X$...



Compare the net energy transferred to the gas through heating/cooling with the net amount of work done by/on the gas in one cycle ($X - Y - Z - X$):

A. You need to know the pressures and volumes in order to determine which amount of energy transfer is bigger.

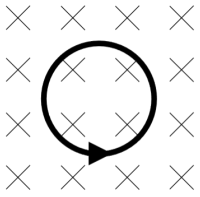
B. The net quantity of energy transferred to the gas through heating/cooling is greater than the net work done by/on the gas.

C. The net quantity of energy transferred to the gas through heating/cooling is less than the net work done by/on the gas.

D. The net quantity of energy transferred to the gas through heating/cooling is the same amount as the net work done by/on the gas.

E. The net quantity of energy transferred to the gas through heating/cooling can be greater than or less than the net work done by/on the gas, depending on the temperatures.

10. A charged particle moves counterclockwise in a circle at a steady speed due to a uniform magnetic field, as shown. Consider a particle with the same mass moving at the same speed, but it is moving in the clockwise direction. Which of the following could be true for the clockwise moving particle?



A. The magnetic field points to the right.

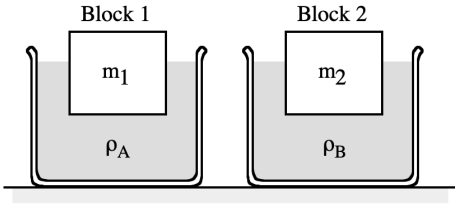
B. The charge of the particle is opposite to that of the counterclockwise moving particle.

C. The charge of the particle is opposite to that of the counterclockwise moving particle, and the magnetic field points to the right.

D. The charge of the particle is opposite to that of the counterclockwise moving particle, and the magnetic field points out of the page.

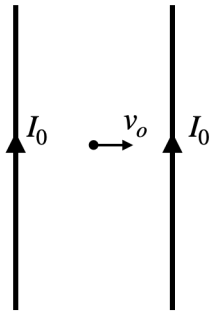
E. None of these could be true.

11. In both cases shown in the diagram, a block is floating at rest in a liquid. Both blocks have the same volume, and both have 60% of their volume below the surface. The masses of the blocks are not the same. Find the density ρ_A in terms of ρ_B, m_1, and m_2.



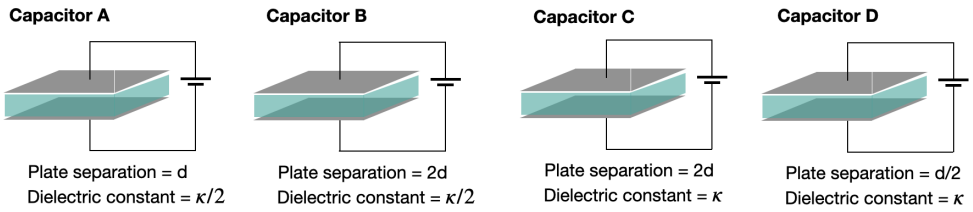
A. $\rho_A = \rho_B(m_1/m_2)$
B. $\rho_A = \rho_B(m_2/m_1)$
C. $\rho_A = \rho_B(m_2 - m_1)/(m_2 + m_1)$
D. $\rho_A = 0.6\rho_B$
E. $\rho_A = \rho_B$

12. A negatively charged particle moving with speed v_o is located halfway between two current carrying wires as shown. In which direction is the force on the particle at the moment it is in the middle?



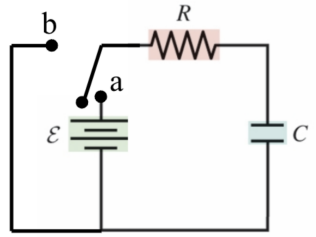
A. Upwards
B. Downwards
C. Out of the page
D. Into the page
E. The force is zero

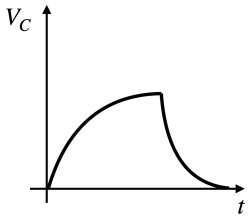
13. Four capacitors, shown below, are all connected to identical batteries. They have the same area, but different plate separations and are made with different dielectrics. How does the capacitance of the different capacitors compare?

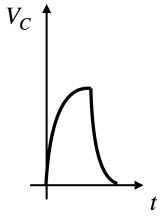


A. $C_C < C_B < C_A = C_D$
B. $C_D < C_B < C_A = C_C$
C. $C_B < C_C = C_A < C_D$
D. $C_C = C_B < C_A < C_D$
E. $C_C = C_D > C_B > C_A$

14. The potential across a capacitor in an RC circuit is measured as the capacitor is charged (with the switch in position a) and then discharged (with the switch in position b). The potential as a function of time is shown below, at the left. One change is made to the circuit, and then the potential is measured again. The potential as a function of time for this second circuit is shown below, at the right.







Which of the following changes could have resulted in the new potential function shown?

A. The resistor was exchanged with one that has half the cross-sectional area, and is otherwise the same.

B. The capacitor was exchanged with one that has half the dielectric strength, and is otherwise the same.

C. A second battery was added in series.

D. The resistor was changed to one with resistance $2R$ and the capacitor was changed to one with capacitance $C/2$.

E. None of these would work.

15. A piston moves slowly outward as a gas expands such that the gas inside the piston does not change temperature. What must be true about the work done on the gas by the piston, W, and heat transferred from the surroundings to the gas, Q?

A. Q is positive, W is positive

B. Q is positive, W is negative

C. Q is negative, W is positive

D. Q is negative, W is negative

E. We cannot know because we do not know how the thermal energy changes.

16. A cheetah is running down a grassy hill, decreasing the gravitational potential energy of the cheetah-Earth system by 6000 J, and gains 2000 J of kinetic energy. If the cheetah uses 1000 J of chemical energy during this journey, how much does the thermal eenrgy of the system increase?

A. 8000 J

B. 7000 J

C. 5000 J

D. 3000 J

E. None of these.

17. You have a large clay block and you want to divide it into two pieces such that when the two pieces are added to a container of water, one of the pieces floats and the other piece sinks. Which of the following should you do?

    A. Make sure that one piece has less mass than the other, so that its weight is smaller and it will float.

    B. Make sure that one piece has more volume than the other, so that the buoyant force on it is larger and it will float.

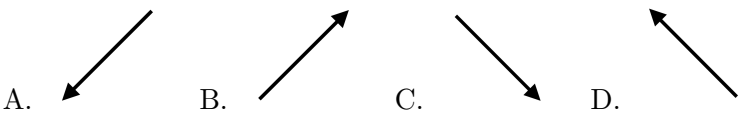
    C. Make sure that one piece has less material than the other so that it has a lower density and will float.

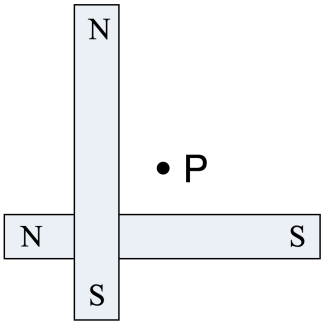
    D. You cannot divide the block into two pieces that behave differently, since the density of the two pieces will always be the same.

18. A sealed cylindrical pump contains one mole of an ideal gas, and is thermally insulated from its surroundings. The piston fits tightly so that no gas escapes, and friction is negligible between the piston and the cylinder walls. The gas expands. Which of the following ***could be*** the signs of the the heat added to the gas, the work done on the gas, the temperature change of the gas, and the pressure change of the gas?

	Q	W	ΔT	ΔP
A.	$-$	0	$-$	$+$
B.	$+$	$+$	$+$	0
C.	0	$-$	$+$	$+$
D.	0	$+$	0	$-$
E.	0	$-$	$-$	$-$

19. Two magnets are arranged as shown in the figure. What direction is the magnetic field at point P?





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20. In a cyclic process, a real heat engine takes in 400 J at a 900 K reservoir and deposits 200 J into a 300 K reservoir. What is the absolute value of the TOTAL entropy change of the two reservoirs?

A. (10/9) J/K
B. (2/3) J/K
C. (2/9) J/K
D. (5/9) J/K
E. (4/9) J/K

21. Water flows through a pipe as it gets wider. You measure that the speed of the water at the wider end is 1/4 the speed of the water at the more narrow end. How do the diameters of the ends of the pipe compare, if d_n is the diameter of the narrow end and d_w is the diameter of the wider end?

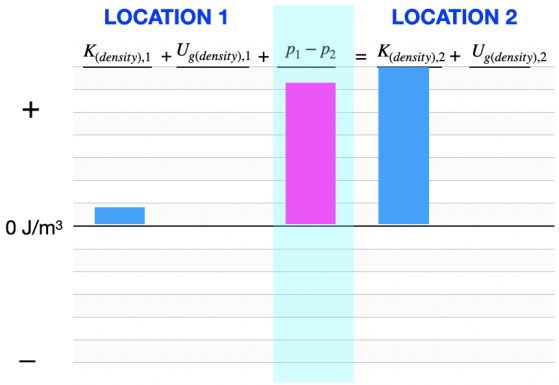
A. $d_w = 4d_n$
B. $d_w = 16d_n$
C. $d_w = 2d_n$
D. $d_w = d_n/2$
E. $d_w = d_n/4$

22. Because the plaque buildup, the radius of an artery in a person's heart decreases by 40%. Determine the ratio of the present flow rate to the original flow rate if the pressure across the artery, its length, and the viscosity of blood are unchanged. **[Sections A and C may not have gotten to this material! We know that, and please don't stress about being able to do this problem for the final.]**

A. $Q = 0.60Q_0$
B. $Q = 0.13Q_0$
C. $Q = Q_0/0.60$
D. $Q = Q_0/0.13$

23. Water travels through a pipe. Let the cross-sectional area be represented by A and the elevation by y. Which of the following corresponds to the Bernoulli energy bar chart shown?

A. $A_1 > A_2$ and $y_1 > y_2$
B. $A_1 < A_2$ and $y_1 > y_2$
C. $A_1 > A_2$ and $y_1 < y_2$
D. $A_1 < A_2$ and $y_1 < y_2$
E. $A_1 > A_2$ and $y_1 = y_2$



The following situation applies to questions 24 and 25:
A heat engine operating between 727 K and 127 K takes in 2000 J from the hot reservoir and exhausts 800 J to the cold reservoir.

24. If the temperature of the cooler reservoir is increased, will the maximum possible efficiency of the engine...

    A. increase

    B. decrease

    C. remain the same

    D. We do not have enough information to know.

25. If the temperatures of the hot reservoir and cold reservoir are both increased by the same amount, with no change to Q_{hot} or Q_{cold}, will the entropy change of the system...

    A. increase

    B. decrease

    C. remain the same

    D. We do not have enough information to know.