1 pt
Instructions:

The exam has 19 problems in three parts. The students in section 10 are required to do the first and second parts while the students in section 11 are required to do the second and third parts. Any problems done in a part that is not required of your section will count for extra credit. Good luck with the exam!

Part one (Section 10 must do these for credit, section 11 may work them for extra credit):

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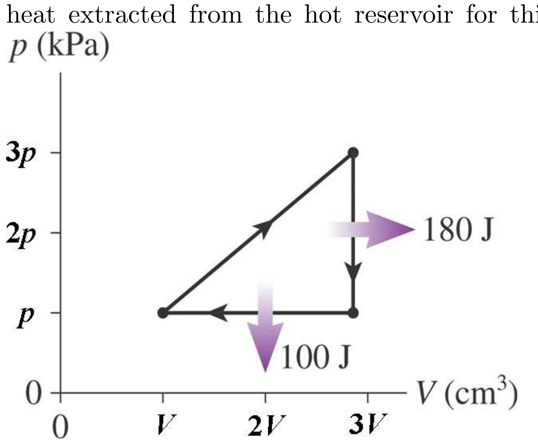
1 pt The pV diagram is shown for a heat engine. The heat flow for two of the stages is shown in the figure. The horizontal axis is scaled in units of V = 400 cm^3 and the vertical axis is scaled in units of p = 200 kPa. Find the heat extracted from the hot reservoir for this heat engine.



(in J*)*

2.A◯ 330.8 **B**◯ 440.0 **C**◯ 585.2
D◯ 778.3 **E**◯ 1035.2

1 pt Find the efficiency of the heat engine.

3.A◯ 0.116 **B**◯ 0.155 **C**◯ 0.206 **D**◯ 0.273
E◯ 0.364

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1 pt A Carnot refrigerator with coefficient of performance K is run backwards as a Carnot heat engine. What is the heat engine's efficiency η in terms of the refrigerator's K value?

4. A◯ $\eta = 1/K$
B◯ $\eta = 1/(K+1)$
C◯ $\eta = K/(K+1)$
D◯ $\eta = (K-1)/2$
E◯ $\eta = 1/(K-1)$

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1 pt A hollow cylinder is rolling without slipping on a flat surface. Due to its motion, it has translational and rotational kinetic energy. What percentage of its total kinetic energy is due to rotational kinetic energy? *(in* `percent`*)*

5.A◯ 28.6 **B**◯ 30.0 **C**◯ 33.3 **D**◯ 45.7
E◯ 50.0

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1 pt
Part two (Sections 10 and 11 must do these for credit):

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1 pt A diver is 76 m deep in a mountain lake, where the temperature at this depth is 9°C. While he is down there, the air bubbles that he exhales have a diameter of 1.9 cm. The bubbles rise to the surface of the lake, where the ambient temperature is 21°C. What is the diameter of the air bubbles when they reach the surface of the lake? You may assume that the bubbles are in thermal equilibrium with the water surrounding them. *(in* `cm`*)*

7.A◯ 2.09 **B**◯ 2.44 **C**◯ 2.86 **D**◯ 3.34
E◯ 3.91

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1 pt At a dull formal banquet one evening, you get served a watery flavorless soup with little meatballs floating on the surface. You decide to amuse yourself by adding more and more salt to the soup, thus increasing the density of the soup. What will the meatballs do?

8. A◯ they will sink to the bottom of the soup bowl
B◯ they will float lower in the liquid, but not sink to the bottom
C◯ they will stay at the same level in the liquid
D◯ they will float higher in the liquid

1 pt The after-dinner speech is especially boring, so you continue to look for amusement. When the speech begins, you add several ice cubes from your drink to your soup, and you note the liquid level in the bowl. At the end of the long speech, all of the ice has melted. Compared to the liquid level after you initially added the ice cubes, the liquid level in the bowl is now:

9. **A**◯ higher
B◯ the same height
C◯ lower

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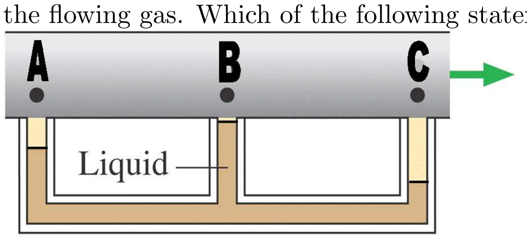
1 pt Gas is flowing through a horizontal pipe, but you cannot see inside the pipe to know how the inner diameter changes. Your only indication of what is going on is the vertical columns of liquid that are connected to the pipe with the flowing gas. Which of the following statements are true?



▷ the diameter of the pipe is larger at point A than at point C
10. **A**◯ True **B**◯ False

▷ the gas speed is slowest at point B
11. **A**◯ True **B**◯ False

▷ for the gas at points C and B the volume flow rate is the same
12. **A**◯ True **B**◯ False

▷ the diameter of the pipe is largest at point B
13. **A**◯ True **B**◯ False

▷ the pressure in the pipe is highest at point C
14. **A**◯ True **B**◯ False

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1 pt A lead bullet (mass = 29 g) is shot from a rifle at a temperature of 51°C and travels at a speed of 550 m/s until it hits a large block of ice at 0°C and comes to rest within it. How much ice will melt? *(in* g*)*

15.**A**◯ 7.01 **B**◯ 8.77 **C**◯ 10.96 **D**◯ 13.70 **E**◯ 17.12

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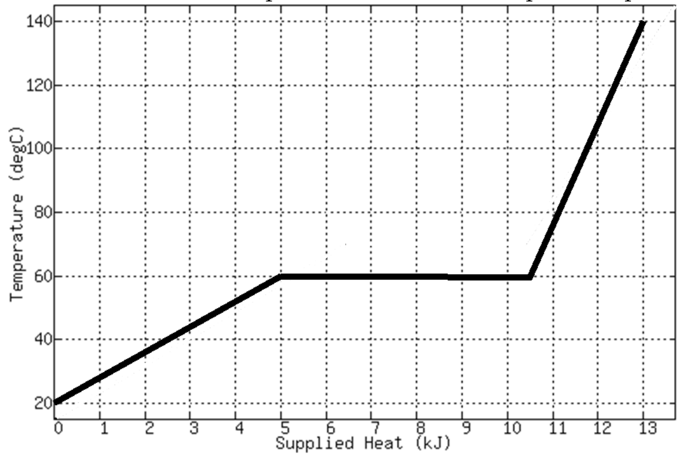
1 pt The graph below shows the temperature vs. supplied heat for a liquid that is heated from 20°C up through evaporation. The mass of the liquid is 65 grams. Note that the x-axis (supplied heat) is in units of kJ. At what temperature does the liquid evaporate?



16. **A**◯ 140°C
B◯ 90°C
C◯ 60°C
D◯ 40°C
E◯ cannot be determined from information given

1 pt What is the latent heat of vaporization for this substance? *(in* J/kg*)*

17.**A**◯ 6.18×10^4 **B**◯ 7.23×10^4 **C**◯ 8.46×10^4 **D**◯ 9.90×10^4 **E**◯ 1.16×10^5

1 pt What is the specific heat of the liquid phase of this substance? *(in* J/(kg*K)*)*

18.**A**◯ 1923 **B**◯ 2404 **C**◯ 3005 **D**◯ 3756 **E**◯ 4695

Material	Density (kg/m^3)
wood	600
water	1000
aluminum	2700
steel	7800
lead	11300
gold	19300

1 pt Several solid blocks made of different materials (wood, aluminum, steel, lead and gold) are placed in a tub of water. The densities of these materials are given above. All of the blocks have the same volume. The blocks are released and allowed to reach some equilibrium position (that is, some may sink and some may float). Which of the following statements are true?

▷ The metal blocks all experience an equal buoyant force
19. **A**◯ True **B**◯ False

▷ The steel block displaces more water than the wood block
20. **A**◯ True **B**◯ False

▷ The gold block has the smallest mass
21. **A**◯ True **B**◯ False

▷ The steel block experiences a smaller buoyant force than the wood block
22. **A**◯ True **B**◯ False

▷ The wood block experiences the greatest buoyant force
23. **A**◯ True **B**◯ False

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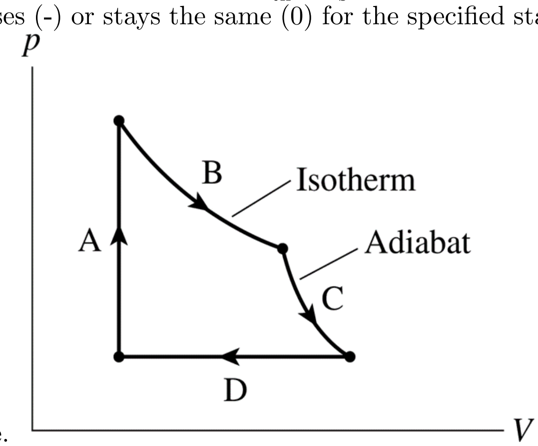
1 pt A typical pV cycle is shown in the figure. State whether the indicated quantity (ΔE_{th}, W_s or Q) increases (+), decreases (-) or stays the same (0) for the specified stage of the cycle.



▷ ΔE_{th} during Stage A
24. **A**◯ increases (+) **B**◯ decreases (-)
C◯ stays the same (0)

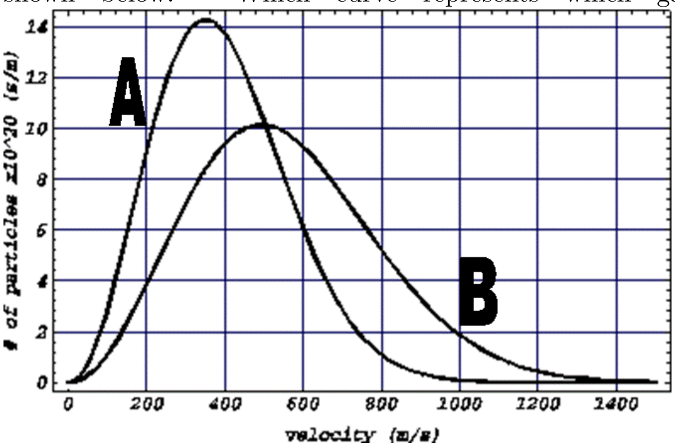
▷ W_s during Stage D
25. **A**◯ increases (+) **B**◯ decreases (-)
C◯ stays the same (0)

▷ ΔE_{th} during Stage B
26. **A**◯ increases (+) **B**◯ decreases (-)
C◯ stays the same (0)

▷ Q during Stage B
27. **A**◯ increases (+) **B**◯ decreases (-)
C◯ stays the same (0)

▷ ΔE_{th} during Stage C
28. **A**◯ increases (+) **B**◯ decreases (-)
C◯ stays the same (0)

1 pt The velocity distributions for 1 mole of neon and 1 mole of argon at the same temperature are shown below. Which curve represents which gas?



29. **A**◯ curve A is argon
B◯ curve A is neon

1 pt If the rms speed of the argon atoms is 420 m/s based on the above distribution, what is the rms speed of the neon atoms? *(in* `m/s`*)*

30.**A**◯ 242 **B**◯ 302 **C**◯ 378 **D**◯ 472 **E**◯ 590

1 pt What is the temperature of the gas? *(in* `K`*)*

31.**A**◯ 212 **B**◯ 282 **C**◯ 375 **D**◯ 499 **E**◯ 664

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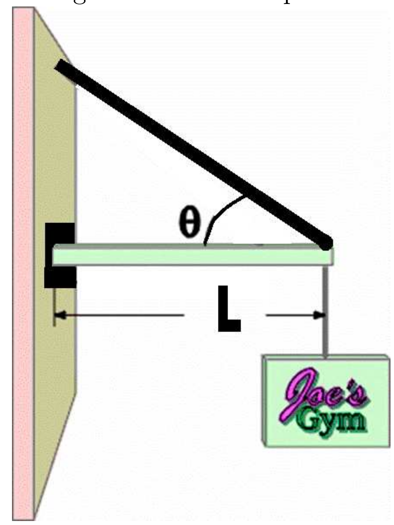
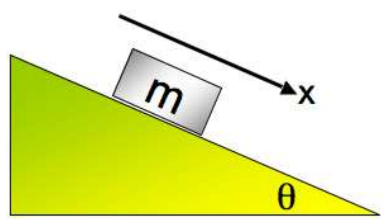
1 pt A sign for Joe's Gym is hanging from the end of a horizontal beam, which itself is suspended by a cable attached to the wall. The beam has length L and mass M. The sign has mass m. Which of the following is the correct expression for



the tension in the cable?

32. **A**◯ (mg/2-Mg/2)/tanθ
B◯ (mg+Mg/2)/sinθ
C◯ (mg+Mg)·cosθ
D◯ (mg+Mg/2)·sinθ
E◯ (mg-Mg/2)/sinθ



A block of mass m is sliding down an incline with a coefficient of kinetic friction μ_k.

1 pt If it starts at a certain height, which one of the following statements is true?

33. **A**◯ The time it takes to arrive at the bottom is independent of the mass of the block.
B◯ The larger the mass of the block, the sooner it will arrive at the bottom.
C◯ The larger the mass of the block, the longer it will take for it to arrive at the bottom.

1 pt Which one of the following equations describes its motion in x-direction?

34. A◯ $\frac{d^2x}{dt^2} = mg\sin\theta - \mu_k\cos\theta$

B◯ $\frac{d^2x}{dt^2} = g\cos\theta - g\mu_k\sin\theta$

C◯ $\frac{d^2x}{dt^2} = g(\sin\theta - \mu_k\cos\theta)$

D◯ $\frac{d^2x}{dt^2} = g(\sin\theta + \mu_k\cos\theta)$

E◯ $m\frac{d^2x}{dt^2} = mg\sin\theta - \mu_k\cos\theta$

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1 pt Which of the following statements are true regarding force and torque?

35. A◯ The net force being zero does not imply that the net torque must be zero.
B◯ Both the net force and the net torque on an object must always be zero.
C◯ If the net force on an object is zero, the net torque must also be zero.
D◯ If the net torque on an object is zero, the net force must also be zero.
E◯ Neither the net force nor the net torque on an object is ever zero.

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1 pt Due never A 64.3 kg adult sits at one end of a 11.4 m board, on the other end of which sits his 29.9 kg child. How far away from the adult should the pivot be placed so the board (ignore its mass) is balanced?
(in m*)*

36.A◯ 1.19 **B**◯ 1.72 **C**◯ 2.50 **D**◯ 3.62
E◯ 5.25

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1 pt Imagine that a puck is tied to a string and then placed on a horizontal frictionless air hockey table. The other end of the string is attached to the surface of the table. You set the puck in circular motion by giving it a sideways push with your hand, and then letting go. Thus, the puck moves in a horizontal circle on the surface of the table. Assume that the puck has mass m and the string has length L, and you may ignore effects of air resistance. Which of the following statements are true about this case?

▹ There are a total of 4 forces acting on the puck
37. A◯ True **B**◯ False

▹ The centripetal force is supplied by gravity
38. A◯ True **B**◯ False

▹ The magnitude of the normal force of the table does not depend on the speed of the puck
39. A◯ True **B**◯ False

▹ The magnitude of the centripetal force depends upon the speed of the puck
40. A◯ True **B**◯ False

▹ The direction of the centripetal force is inward, towards the center of the circle
41. A◯ True **B**◯ False

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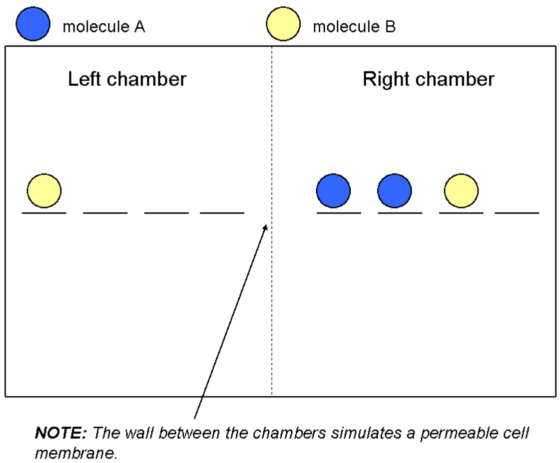
1 pt
Part three (Section 11 must do these for credit, section 10 may work them for extra credit):



1 pt

Consider two types of molecules A and B. Assume you have a container consisting of two chambers in which molecules are allowed to pass ***freely*** between chambers. Given that you have two of each type of molecule in your container, and each molecule can have four independent positions in either the left chamber or right chamber, how many ***distinct*** states are there if one only distinguishes states based on the number and type of molecule in each chamber?

43.A◯ 9.0 **B**◯ 13.1 **C**◯ 18.9 **D**◯ 27.4 **E**◯ 39.8

1 pt What is the most likely state? (**EXAMPLE RESPONSE** LAABRA stands for 2 A molecules and 1 B molecule in the left chamber and 1 A molecule in the right chamber. Answer **MUST** be in all capital letters.)

44. *Leave blank on scoring form*

1 pt What is one of the two most unlikely states?

45. *Leave blank on scoring form*

1 pt What is the probability that when one observes the state of the container, it is seen to be in the most likely state?

46.A◯ 0.1755 **B**◯ 0.2194 **C**◯ 0.2743 **D**◯ 0.3429 **E**◯ 0.4286

1 pt What's the probability that when a coin is flipped it is heads?

47.A◯ 0.3916 **B**◯ 0.4425 **C**◯ 0.5000 **D**◯ 0.5650 **E**◯ 0.6384

1 pt Let a state be defined as the number of heads and tails. How many different states are there when **2** coins are flipped?

48.A◯ 3 **B**◯ 4.3500 **C**◯ 6.3075 **D**◯ 9.1459 **E**◯ 13.2615

1 pt If one flips **2** coins how many combinations are there when both are heads? >

49.A◯ 0.8547 **B**◯ 1 **C**◯ 1.1700 **D**◯ 1.3689 **E**◯ 1.6016

> both are tails? >

50.A◯ 0.4096 **B**◯ 0.5120 **C**◯ 0.6400 **D**◯ 0.8000 **E**◯ 1

> one heads and one tails? >

51.A◯ 2 **B**◯ 2.2600 **C**◯ 2.5538 **D**◯ 2.8858 **E**◯ 3.2609

1 pt When **2** coins are flipped what is the total number of combinations? >

52.A◯ 2.9221 **B**◯ 3.4188 **C**◯ 4 **D**◯ 4.6800 **E**◯ 5.4756

1 pt If one flips **2** coins what is the probability that both are heads? >

53.A◯ 0.1826 **B**◯ 0.2137 **C**◯ 0.2500
D◯ 0.2925 **E**◯ 0.3422

> both are tails? >

54.A◯ 0.2500 **B**◯ 0.2825 **C**◯ 0.3192
D◯ 0.3607 **E**◯ 0.4076

> one heads and one tails? >

55.A◯ 0.1640 **B**◯ 0.2378 **C**◯ 0.3448
D◯ 0.5000 **E**◯ 0.7250

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1 pt Bacteria use swimming to seek out places where food is more plentiful, *i.e.* where the concentration of food molecules is larger. Imagine that the bacterium is in a region of low food concentration. For the bacterium to profit from swimming to a region with more food, it has to get there before diffusion of food molecules makes the concentrations in the two regions the same. For an *E. coli* swimming at a speed of 26 μm/s , how far will the bacterium swim in 2 seconds? *(in* `um`*)*

56.A◯ 22.10 **B**◯ 29.40 **C**◯ 39.10 **D**◯ 52.00
E◯ 69.16

1 pt If the diffusion constant (D) of a typical food molecule is 1 μm^2/ms, how far will the food diffuse in 2 seconds? *(in* `um`*)*

57.A◯ 63.25 **B**◯ 74.00 **C**◯ 86.58
D◯ 101.29 **E**◯ 118.52

1 pt Now we will find the distance that the bacterium needs to swim before it outruns its food. What time will the distance swum be the same as the distance that the food diffuses? *(in* `s`*)*

58.A◯ 2.96×10^{-3} **B**◯ 3.34×10^{-3} **C**◯ 3.78×10^{-3}
D◯ 4.27×10^{-3} **E**◯ 4.82×10^{-3}

1 pt How far will the bacterium swim in that time? *(in* `um`*)*

59.A◯ 4.11×10^{-2} **B**◯ 4.80×10^{-2} **C**◯ 5.62×10^{-2}
D◯ 6.57×10^{-2} **E**◯ 7.69×10^{-2}