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Yuan,

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Keep this exam **CLOSED** until advised by the instructor.

50 minute long closed book exam.

Fill out the bubble sheet: **last name**, first initial, **student number**. Leave the section, code, form and signature areas empty.

One, two-sided handwritten 8.5 by 11 help sheet is allowed.

When done, hand in your **test** and your **bubble sheet**.

Thank you and good luck!

Posssibly useful constants:

- c = 299,792,458. m/s
- e = 1.6022 $\times$ 10^{-19} C
- 1 eV = 1.6022 $\times$ 10^{-19} J
- m_e = 9.1094 $\times$ 10^{-31} kg
- $m_e c^2$ = 0.511 MeV
- ρ_{water} = 1000 kg/m^3 = 1 kg/l = 1 g/cm^3
- c_{water} = 4.1868 kJ/(kg°C) = 1 kcal/(kg°C)
- 1 cal = 4.1868 J
- 1 atm = 101.3 kPa = 760 mmHg
- N_A = 6.02$\times$$10^{23}$ 1/mol
- R = 8.31 J/(molK)
- k_B = 1.38$\times$$10^{-23}$ J/K
- σ = 5.67$\times$$10^{-8}$ W/(m^2K^4)
- b = 2.90$\times$$10^{-3}$ m·K

4 pt The mean lifetime of muons in their rest frame is 2.20 μs. Now consider a muon traveling through the Earth's atmosphere at a speed of 0.994 **c**. What is the mean distance traveled before it decays?
(in `km`*)*

1. **A**◯ 2.16×10^{-1} **B**◯ 3.28×10^{-1} **C**◯ 6.56×10^{-1}
D◯ 2.62 **E**◯ 4.26 **F**◯ 6.00
G◯ 1.77×10^{1} **H**◯ 1.90×10^{1}

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2 pt Imagine that a relativistic train travels past your lecture room at a speed of 0.952 **c**. The passengers of the train claim that when they measure the length of the train using standard meter bars found on the train, the length comes out to be 95.8 m. What would be the length of the train in the frame of the lecture room, if you measured it?
(in `m`*)*

2. **A**◯ 1.39×10^{1} **B**◯ 2.02×10^{1} **C**◯ 2.93×10^{1}
D◯ 4.25×10^{1} **E**◯ 6.17×10^{1} **F**◯ 8.94×10^{1}
G◯ 1.30×10^{2} **H**◯ 1.88×10^{2}

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2 pt How long would a regular 50 minute long class in the lecture room last for the passengers of the train, if they measured it while sitting on the train?
(in `min`*)*

3. **A**◯ 1.21×10^{1} **B**◯ 1.76×10^{1} **C**◯ 2.55×10^{1}
D◯ 3.70×10^{1} **E**◯ 5.36×10^{1} **F**◯ 7.77×10^{1}
G◯ 1.13×10^{2} **H**◯ 1.63×10^{2}

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3 pt Dr. Nefario and the minions finally managed to build an antimatter weapon. They have developed an efficient and economic method to produce significant quantities of antimatter and they also solved the problem of the long term confinement of antimatter. The whole weapon fits in a large suitcase. If the device contains 5.55 grams of antimatter, then how much energy would this device yield upon detonation?
(in `TJ`*)*

4. **A**◯ 3.28×10^{2} **B**◯ 4.75×10^{2} **C**◯ 6.89×10^{2}
D◯ 9.99×10^{2} **E**◯ 1.45×10^{3} **F**◯ 2.10×10^{3}
G◯ 3.05×10^{3} **H**◯ 4.42×10^{3}

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3 pt The height of the Eiffel tower is 321 m during the Summer when the temperature is 26.5 °C. What is the magnitude of the change in the height of the tower, when the temperature cools down to -14.4 °C during the Winter? The coefficient of linear expansion of the tower's material is 1.18×10^{-5} 1/C°.
(in `cm`*)*

5. **A**◯ 1.24×10^{1} **B**◯ 1.55×10^{1} **C**◯ 1.94×10^{1}
D◯ 2.42×10^{1} **E**◯ 3.03×10^{1} **F**◯ 3.78×10^{1}
G◯ 4.73×10^{1} **H**◯ 5.91×10^{1}

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3 pt What is the pressure of 2.02 moles of Nitrogen gas in a 7.73 liter container, if the temperature of the gas is 34.3 °C?
(in `atm`*)*

6. **A**◯ 1.58 **B**◯ 2.11 **C**◯ 2.80 **D**◯ 3.73
E◯ 4.96 **F**◯ 6.59 **G**◯ 8.77 **H**◯ 11.66

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3 pt A gas bottle contains 7.34×10^{23} Methane molecules at a temperature of 362 K. What is the thermal energy of the gas?
(in `J`*)*

7. **A**◯ 8.04×10^{3} **B**◯ 9.41×10^{3} **C**◯ 1.10×10^{4}
D◯ 1.29×10^{4} **E**◯ 1.51×10^{4} **F**◯ 1.76×10^{4}
G◯ 2.06×10^{4} **H**◯ 2.41×10^{4}

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3 pt On average how much energy is stored by ONE degree of freedom for ONE single molecule?
(in `J`*)*

8. **A**◯ 6.00×10^{-22} **B**◯ 7.99×10^{-22}
C◯ 1.06×10^{-21} **D**◯ 1.41×10^{-21}
E◯ 1.88×10^{-21} **F**◯ 2.50×10^{-21}
G◯ 3.32×10^{-21} **H**◯ 4.42×10^{-21}

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10 pt Constant amount of ideal gas is kept inside a cylinder by a piston. Then the piston compresses the gas **adiabatically**. Compare the initial (i) and the final (f) physical quantities of the gas to each other.

▷ The volume V_f is ... V_i.
9. **A**◯ equal to **B**◯ less than **C**◯ greater than

▷ The pressure p_f is ... p_i.
10. **A**◯ equal to **B**◯ less than **C**◯ greater than

▷ The entropy S_f is ... S_i.
11. **A**◯ equal to **B**◯ less than **C**◯ greater than

▷ The temperature T_f is ... T_i.
12. **A**◯ equal to **B**◯ less than **C**◯ greater than

▷ The internal energy U_f is ... U_i.
13. **A**◯ equal to **B**◯ less than **C**◯ greater than

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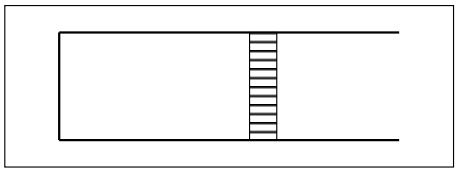
2 pt A cylinder contains 1.69 mol of Nitrogen gas at Standard Temperature and Pressure. A frictionless and massless piston keeps the gas inside the cylinder.



The cyclinder and the piston conducts heat very well. What is the temperature of the gas after it absorbs 5.83 kJ heat from the environment? (The Standard Temperature is 273 K, the Standard Pressure is 101.3 kPa and the volume of 1 mol gas at STP is 22.4 l.)
(in `K`*)*

14. **A**◯ 4.21×10^{1} **B**◯ 6.11×10^{1} **C**◯ 8.86×10^{1}
D◯ 1.28×10^{2} **E**◯ 1.86×10^{2} **F**◯ 2.70×10^{2}
G◯ 3.92×10^{2} **H**◯ 5.68×10^{2}

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2 pt What is the increase in volume of the gas?
(in `m^3`*)*

15. **A**◯ 6.99×10^{-3} **B**◯ 9.30×10^{-3} **C**◯ 1.24×10^{-2}
D◯ 1.64×10^{-2} **E**◯ 2.19×10^{-2} **F**◯ 2.91×10^{-2}
G◯ 3.87×10^{-2} **H**◯ 5.15×10^{-2}

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2 pt How much work did the gas perform?
(in `kJ`*)*

16. **A**◯ 1.04 **B**◯ 1.22 **C**◯ 1.42 **D**◯ 1.67
E◯ 1.95 **F**◯ 2.28 **G**◯ 2.67 **H**◯ 3.12

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3 pt 2.74 mol of an ideal gas expands reversibly and isothermally at 445 K until its volume is increased by a factor of 3.72. What is the increase in entropy of the gas?
(in J/K*)*

17. **A**◯ 9.81 **B**◯ 1.42×10^1 **C**◯ 2.06×10^1
D◯ 2.99×10^1 **E**◯ 4.34×10^1 **F**◯ 6.29×10^1
G◯ 9.12×10^1 **H**◯ 1.32×10^2

3 pt How much heat did the gas absorb?
(in J*)*

18. **A**◯ 9.23×10^3 **B**◯ 1.04×10^4 **C**◯ 1.18×10^4
D◯ 1.33×10^4 **E**◯ 1.50×10^4 **F**◯ 1.70×10^4
G◯ 1.92×10^4 **H**◯ 2.17×10^4

3 pt A Stirling-engine is used in the heat-pump mode to heat a house. The engine maintains a temperature of 21.9 °C inside the house. The temperature of the Earth loop is 14.1 °C. (The Earth loop buried deep under the ground is the cold reservoir of this heat pump.) What is the coefficient of performance of this heat pump?

19. **A**◯ 2.96×10^1 **B**◯ 3.35×10^1 **C**◯ 3.78×10^1
D◯ 4.27×10^1 **E**◯ 4.83×10^1 **F**◯ 5.46×10^1
G◯ 6.17×10^1 **H**◯ 6.97×10^1

2 pt If the power of the electric motor driving the heat pump is 175 W, then what is the rate at which heat is delivered to the house?
(in W*)*

20. **A**◯ 2.81×10^3 **B**◯ 3.18×10^3 **C**◯ 3.59×10^3
D◯ 4.06×10^3 **E**◯ 4.59×10^3 **F**◯ 5.18×10^3
G◯ 5.86×10^3 **H**◯ 6.62×10^3