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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

1 pt A spaceship is 1600 m long when it is at rest. When it is traveling at a certain constant speed its length is measured by external observers and it is found to be 500 m.

What is the speed of the spaceship in terms of the speed of light?

1. **A**◯ 9.50×10^{-1} **B**◯ 1.11 **C**◯ 1.30
D◯ 1.52 **E**◯ 1.78 **F**◯ 2.08
G◯ 2.44 **H**◯ 2.85

1 pt In the kitchen of the spaceship the chef sets the oven timer for 1.15 hours to make roast beef. How much time does the roast beef spend in the oven when measured by external observers at rest?
(in `h`*)*

2. **A**◯ 3.96×10^{-1} **B**◯ 5.74×10^{-1} **C**◯ 8.32×10^{-1}
D◯ 1.21 **E**◯ 1.75 **F**◯ 2.54
G◯ 3.68 **H**◯ 5.34

1 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 0.996 **c**. What is the mean distance traveled before it decays?
(in `km`*)*

3. **A**◯ 1.64×10^{-1} **B**◯ 2.17×10^{-1} **C**◯ 3.29×10^{-1}
D◯ 6.57×10^{-1} **E**◯ 3.29 **F**◯ 3.62
G◯ 7.36 **H**◯ 2.04×10^{1}

1 pt Imagine Mel lives on the earth at rest. Sara is traveling past the earth with a velocity of 10000 m/s. If a meteor moving in the same direction passes Sara, Mel sees the meteor velocity to be 15200 m/s. What is the magnitude of the velocity of the meteor seen by Sara?

(in `m/s`*)*

4. **A**◯ 3.91×10^{3} **B**◯ 5.20×10^{3} **C**◯ 6.92×10^{3}
D◯ 9.20×10^{3} **E**◯ 1.22×10^{4} **F**◯ 1.63×10^{4}
G◯ 2.16×10^{4} **H**◯ 2.88×10^{4}

1 pt Now assume that Sara's speed is 1.39×10^{8} m/s and the meteor speed is 1.83×10^{8} m/s. What is the magnitude of the velocity of the meteor that Sara sees now?

(in `m/s`*)*

5. **A**◯ 6.13×10^{7} **B**◯ 6.93×10^{7} **C**◯ 7.83×10^{7}
D◯ 8.85×10^{7} **E**◯ 1.00×10^{8} **F**◯ 1.13×10^{8}
G◯ 1.28×10^{8} **H**◯ 1.44×10^{8}

1 pt Suppose that a photon of light is passing Sara instead of a meteor. Mel measures the photon speed to be c, the speed of light. What speed does Sara measure?
(in `m/s`*)*

6. **A**◯ 3.00×10^{8} **B**◯ 3.75×10^{8} **C**◯ 4.69×10^{8}
D◯ 5.86×10^{8} **E**◯ 7.32×10^{8} **F**◯ 9.16×10^{8}
G◯ 1.14×10^{9} **H**◯ 1.43×10^{9}

1 pt The rest mass of the electron is 0.511 MeV/c^2. In other words $m_0c^2 = 0.511$ MeV for the electron. What is the kinetic energy of an electron, when its speed is v = 0.831c?
(in `MeV`*)*

7. **A**◯ 1.94×10^{-1} **B**◯ 2.81×10^{-1} **C**◯ 4.08×10^{-1}
D◯ 5.91×10^{-1} **E**◯ 8.57×10^{-1} **F**◯ 1.24
G◯ 1.80 **H**◯ 2.61

1 pt At what speed is the total relativistic energy of an electron equal to 5.79 MeV? (Give the speed in terms of the speed of the light with at least five significant figures.)

8. **A**◯ 0.99513 **B**◯ 0.99555 **C**◯ 0.99583
D◯ 0.99597 **E**◯ 0.99610 **F**◯ 0.99623
G◯ 0.99651 **H**◯ 0.99693

1 pt Particle X has a speed of 0.740 **c** and a momentum of 4.62×10^{-19} kgm/s. What is the mass of the particle? *(in* `kg`*)*

9. **A**◯ 4.588×10^{-28} **B**◯ 5.734×10^{-28} **C**◯ 7.168×10^{-28} **D**◯ 8.960×10^{-28} **E**◯ 1.120×10^{-27} **F**◯ 1.400×10^{-27} **G**◯ 1.750×10^{-27} **H**◯ 2.187×10^{-27}

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1 pt What is the rest energy of the particle? *(in* `J`*)*

10. **A**◯ 5.747×10^{-11} **B**◯ 6.724×10^{-11} **C**◯ 7.867×10^{-11} **D**◯ 9.204×10^{-11} **E**◯ 1.077×10^{-10} **F**◯ 1.260×10^{-10} **G**◯ 1.474×10^{-10} **H**◯ 1.725×10^{-10}

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1 pt What is the kinetic energy of the particle? *(in* `J`*)*

11. **A**◯ 6.599×10^{-12} **B**◯ 9.568×10^{-12} **C**◯ 1.387×10^{-11} **D**◯ 2.012×10^{-11} **E**◯ 2.917×10^{-11} **F**◯ 4.230×10^{-11} **G**◯ 6.133×10^{-11} **H**◯ 8.893×10^{-11}

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1 pt What is the total energy of the particle? *(in* `J`*)*

12. **A**◯ 7.963×10^{-11} **B**◯ 8.998×10^{-11} **C**◯ 1.017×10^{-10} **D**◯ 1.149×10^{-10} **E**◯ 1.298×10^{-10} **F**◯ 1.467×10^{-10} **G**◯ 1.658×10^{-10} **H**◯ 1.873×10^{-10}

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1 pt When studying the optical spectrum of a very distant quasar (quasi stellar object), they have found that a certain spectral line appeared at a wavelength of 653 nm instead of the regular 461 nm. In terms of the speed of the light, what is the radial speed of the quasar with respect to Earth?

13. **A**◯ 0.268 **B**◯ 0.335 **C**◯ 0.418 **D**◯ 0.523 **E**◯ 0.654 **F**◯ 0.817 **G**◯ 1.022 **H**◯ 1.277

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1 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 2.21 grams of antimatter, then how much energy would this device yield upon detonation? *(in* `TJ`*)*

14. **A**◯ 2.04×10^{2} **B**◯ 2.55×10^{2} **C**◯ 3.18×10^{2} **D**◯ 3.98×10^{2} **E**◯ 4.97×10^{2} **F**◯ 6.22×10^{2} **G**◯ 7.77×10^{2} **H**◯ 9.71×10^{2}

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1 pt What is the pressure of 2.11 moles of Nitrogen gas in a 5.99 liter container, if the temperature of the gas is 38.1 °C? *(in* `atm`*)*

15. **A**◯ 6.76 **B**◯ 8.99 **C**◯ 11.96 **D**◯ 15.91 **E**◯ 21.16 **F**◯ 28.14 **G**◯ 37.43 **H**◯ 49.78

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1 pt What is the RMS speed of Helium atoms when the temperature of the Helium gas is 379.0 K? (Possibly useful constants: the atomic mass of Helium is 4.00 AMU, the Atomic Mass Unit is: 1 AMU = 1.66×10^{-27} kg, Boltzmann's constant is: $k_B = 1.38 \times 10^{-23}$ J/K.) *(in* `m/s`*)*

16. **A**◯ 9.60×10^{2} **B**◯ 1.12×10^{3} **C**◯ 1.31×10^{3} **D**◯ 1.54×10^{3} **E**◯ 1.80×10^{3} **F**◯ 2.10×10^{3} **G**◯ 2.46×10^{3} **H**◯ 2.88×10^{3}

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1 pt What would be the RMS speed, if the temperature of the Helium gas was doubled? *(in* `m/s`*)*

17. **A**◯ 1.39×10^{3} **B**◯ 1.74×10^{3} **C**◯ 2.17×10^{3} **D**◯ 2.72×10^{3} **E**◯ 3.40×10^{3} **F**◯ 4.25×10^{3} **G**◯ 5.31×10^{3} **H**◯ 6.63×10^{3}

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1 pt 3 kg of lead shot at 94.9° C are poured into 3 kg of water at 26.5° C. Find the final temperature (in °C) of the mixture. Use $c_{water} = 4187$ J/kg °C and $c_{lead} = 128$ J/kg °C.

18. **A**◯ 9.12 **B**◯ 1.21×10^{1} **C**◯ 1.61×10^{1} **D**◯ 2.15×10^{1} **E**◯ 2.85×10^{1} **F**◯ 3.79×10^{1} **G**◯ 5.05×10^{1} **H**◯ 6.71×10^{1}

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1 pt The height of the Eiffel tower is 321 m during the Summer when the temperature is 26.3 °C. What is the magnitude of the change in the height of the tower, when the temperature cools down to -20.5 °C during the Winter? The coefficient of linear expansion of the tower's material is 1.15×10^{-5} 1/C°.
(in `cm`*)*

19. **A**◯ 5.52 **B**◯ 7.34 **C**◯ 9.77
D◯ 1.30×10^{1} **E**◯ 1.73×10^{1} **F**◯ 2.30×10^{1}
G◯ 3.06×10^{1} **H**◯ 4.06×10^{1}

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1 pt The temperature of an oven is kept constant at 975.0 K. A hole with a diameter of 25.0 mm is drilled in the wall of the oven. How much power is emitted by this hole? Hint: consider the hole as a black body.
(in `W`*)*

20. **A**◯ 3.42 **B**◯ 4.54 **C**◯ 6.04
D◯ 8.04 **E**◯ 1.07×10^{1} **F**◯ 1.42×10^{1}
G◯ 1.89×10^{1} **H**◯ 2.52×10^{1}

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1 pt What is the wavelength for which the radiant energy is maximum?
(in `nm`*)*

21. **A**◯ 2.54×10^{3} **B**◯ 2.97×10^{3} **C**◯ 3.48×10^{3}
D◯ 4.07×10^{3} **E**◯ 4.76×10^{3} **F**◯ 5.57×10^{3}
G◯ 6.52×10^{3} **H**◯ 7.62×10^{3}

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1 pt A gas bottle contains 7.23×10^{23} Hydrogen molecules at a temperature of 324.0 K. What is the thermal energy of the gas? (You might need to know Boltzmann's constant: $k_B = 1.38 \times 10^{-23}$ J/K.)
(in `J`*)*

22. **A**◯ 4.39×10^{3} **B**◯ 4.96×10^{3} **C**◯ 5.60×10^{3}
D◯ 6.33×10^{3} **E**◯ 7.16×10^{3} **F**◯ 8.09×10^{3}
G◯ 9.14×10^{3} **H**◯ 1.03×10^{4}

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1 pt How much energy is stored in ONE degree of freedom for the whole system?
(in `J`*)*

23. **A**◯ 5.17×10^{2} **B**◯ 6.87×10^{2} **C**◯ 9.14×10^{2}
D◯ 1.22×10^{3} **E**◯ 1.62×10^{3} **F**◯ 2.15×10^{3}
G◯ 2.86×10^{3} **H**◯ 3.80×10^{3}

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1 pt What is the average energy of a single molecule?
(in `J`*)*

24. **A**◯ 5.73×10^{-21} **B**◯ 7.16×10^{-21}
C◯ 8.95×10^{-21} **D**◯ 1.12×10^{-20}
E◯ 1.40×10^{-20} **F**◯ 1.75×10^{-20}
G◯ 2.18×10^{-20} **H**◯ 2.73×10^{-20}

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

25. **A**◯ 8.72×10^{-22} **B**◯ 1.02×10^{-21}
C◯ 1.19×10^{-21} **D**◯ 1.40×10^{-21}
E◯ 1.63×10^{-21} **F**◯ 1.91×10^{-21}
G◯ 2.24×10^{-21} **H**◯ 2.62×10^{-21}

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1 pt Constant amount of ideal gas is kept inside a cylinder by a piston. The piston is locked in to position, it is not allowed to move. The gas is then heated up. Compare the initial (i) and the final (f) physical quantities of the gas to each other.

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

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

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

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

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

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1 pt 2.31 mol of an ideal gas expands reversibly and isothermally at 413 K until its volume is increased by a factor of 4.20. What is the increase in entropy of the gas?
(in `J/K`*)*

31. **A**◯ 2.96 **B**◯ 4.30 **C**◯ 6.23
D◯ 9.04 **E**◯ 1.31×10^1 **F**◯ 1.90×10^1
G◯ 2.75×10^1 **H**◯ 3.99×10^1

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

32. **A**◯ 7.28×10^3 **B**◯ 9.10×10^3 **C**◯ 1.14×10^4
D◯ 1.42×10^4 **E**◯ 1.78×10^4 **F**◯ 2.22×10^4
G◯ 2.78×10^4 **H**◯ 3.47×10^4

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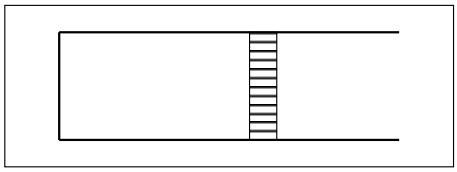
1 pt A cylinder contains 1.94 mol of Nitrogen gas at Standard Temperature and Pressure. A frictionless and massless piston keeps the gas inside the cylinder.



The cyclinder and the piston conducts heat very well. What is the temperature of the gas after it absorbs 4.86 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`*)*

33. **A**◯ 1.95×10^2 **B**◯ 2.20×10^2 **C**◯ 2.49×10^2
D◯ 2.81×10^2 **E**◯ 3.18×10^2 **F**◯ 3.59×10^2
G◯ 4.06×10^2 **H**◯ 4.59×10^2

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

34. **A**◯ 3.29×10^{-3} **B**◯ 4.38×10^{-3} **C**◯ 5.83×10^{-3}
D◯ 7.75×10^{-3} **E**◯ 1.03×10^{-2} **F**◯ 1.37×10^{-2}
G◯ 1.82×10^{-2} **H**◯ 2.42×10^{-2}

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

35. **A**◯ 7.41×10^{-1} **B**◯ 8.67×10^{-1} **C**◯ 1.01
D◯ 1.19 **E**◯ 1.39 **F**◯ 1.62
G◯ 1.90 **H**◯ 2.22

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1 pt A Stirling-engine is used in the heat-pump mode to heat a house. The engine maintains a temperature of 23.7 °C inside the house. The temperature of the Earth loop is 11.5 °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?

36. **A**◯ 7.78 **B**◯ 1.03×10^1 **C**◯ 1.38×10^1
D◯ 1.83×10^1 **E**◯ 2.43×10^1 **F**◯ 3.24×10^1
G◯ 4.30×10^1 **H**◯ 5.72×10^1

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1 pt If the power of the electric motor driving the heat pump is 182 W, then what is the rate at which heat is delivered to the house?
(in `W`*)*

37. **A**◯ 3.92×10^3 **B**◯ 4.43×10^3 **C**◯ 5.00×10^3
D◯ 5.65×10^3 **E**◯ 6.39×10^3 **F**◯ 7.22×10^3
G◯ 8.16×10^3 **H**◯ 9.22×10^3