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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 = 1.6022×10^{-19} C
- 1 eV = 1.6022×10^{-19} J
- m_e = 9.1094×10^{-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 = 6.02×10^{23} 1/mol
- R = 8.31 J/(molK)
- k_B = 1.38×10^{-23} J/K
- σ = 5.67×10^{-8} W/(m^{2}K^4)
- b = 2.90×10^{-3} m·K

$\boxed{2\ pt}$ 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 1420 m.

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

1. **A**◯ 3.61×10^{-1} **B**◯ 4.08×10^{-1} **C**◯ 4.61×10^{-1}
    D◯ 5.21×10^{-1} **E**◯ 5.88×10^{-1} **F**◯ 6.65×10^{-1}
    G◯ 7.51×10^{-1} **H**◯ 8.49×10^{-1}

$\boxed{2\ pt}$ In the kitchen of the spaceship the chef sets the oven timer for 2.40 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**◯ 2.70   **B**◯ 3.16   **C**◯ 3.70   **D**◯ 4.33
    E◯ 5.07   **F**◯ 5.93   **G**◯ 6.94   **H**◯ 8.12

$\boxed{4\ pt}$ 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)

3. **A**◯ 3.28×10^{-1} **B**◯ 6.56×10^{-1} **C**◯ 1.97
    D◯ 2.62   **E**◯ 3.61   **F**◯ 3.94
    G◯ 4.26   **H**◯ 6.00

$\boxed{2\ pt}$ Imagine Bob lives on the earth at rest. Clara is traveling past the earth with a velocity of 9600 m/s. If a meteor moving in the same direction passes Clara, Bob sees the meteor velocity to be 15000 m/s. What is the magnitude of the velocity of the meteor seen by Clara?

(in m/s)

4. **A**◯ 3.46×10^3 **B**◯ 4.32×10^3 **C**◯ 5.40×10^3
    D◯ 6.75×10^3 **E**◯ 8.44×10^3 **F**◯ 1.05×10^4
    G◯ 1.32×10^4 **H**◯ 1.65×10^4

$\boxed{2\ pt}$ Now assume that Clara's speed is 1.47×10^8 m/s and the meteor speed is 1.95×10^8 m/s. What is the magnitude of the velocity of the meteor that Clara sees now?

(in m/s*)*

5. **A**⚪ 7.04×10^7 **B**⚪ 7.96×10^7 **C**⚪ 8.99×10^7

D⚪ 1.02×10^8 **E**⚪ 1.15×10^8 **F**⚪ 1.30×10^8

G⚪ 1.47×10^8 **H**⚪ 1.66×10^8

$\boxed{2\ pt}$ Suppose that a photon of light is passing Clara instead of a meteor. Bob measures the photon speed to be c, the speed of light. What speed does Clara measure?
(in m/s*)*

6. **A**⚪ 1.70×10^8 **B**⚪ 2.26×10^8 **C**⚪ 3.00×10^8

D⚪ 3.99×10^8 **E**⚪ 5.31×10^8 **F**⚪ 7.06×10^8

G⚪ 9.39×10^8 **H**⚪ 1.25×10^9

$\boxed{2\ pt}$ The rest mass of the electron is 0.511 MeV/c². In other words $m_0 c^2 = 0.511$ MeV for the electron. What is the kinetic energy of an electron, when its speed is v = 0.869c?
(in MeV*)*

7. **A**⚪ 3.92×10^{-1} **B**⚪ 5.22×10^{-1} **C**⚪ 6.94×10^{-1}

D⚪ 9.23×10^{-1} **E**⚪ 1.23 **F**⚪ 1.63

G⚪ 2.17 **H**⚪ 2.89

$\boxed{2\ pt}$ At what speed is the total relativistic energy of an electron equal to 5.68 MeV? (Give the speed in terms of the speed of the light with at least five significant figures.)

8. **A**⚪ 0.99539 **B**⚪ 0.99553 **C**⚪ 0.99581

D⚪ 0.99594 **E**⚪ 0.99621 **F**⚪ 0.99635

G⚪ 0.99663 **H**⚪ 0.99691

$\boxed{2\ pt}$ Particle X has a speed of 0.890 **c** and a momentum of 7.31×10^{-19} kgm/s. What is the mass of the particle?
(in kg*)*

9. **A**⚪ 2.828×10^{-28} **B**⚪ 4.100×10^{-28}

C⚪ 5.945×10^{-28} **D**⚪ 8.621×10^{-28}

E⚪ 1.250×10^{-27} **F**⚪ 1.812×10^{-27}

G⚪ 2.628×10^{-27} **H**⚪ 3.811×10^{-27}

$\boxed{2\ pt}$ What is the rest energy of the particle?
(in J*)*

10. **A**⚪ 2.949×10^{-11} **B**⚪ 3.686×10^{-11}

C⚪ 4.608×10^{-11} **D**⚪ 5.760×10^{-11}

E⚪ 7.200×10^{-11} **F**⚪ 9.000×10^{-11}

G⚪ 1.125×10^{-10} **H**⚪ 1.406×10^{-10}

$\boxed{2\ pt}$ What is the kinetic energy of the particle?
(in J*)*

11. **A**⚪ 2.815×10^{-11} **B**⚪ 3.519×10^{-11}

C⚪ 4.399×10^{-11} **D**⚪ 5.498×10^{-11}

E⚪ 6.873×10^{-11} **F**⚪ 8.591×10^{-11}

G⚪ 1.074×10^{-10} **H**⚪ 1.342×10^{-10}

$\boxed{2\ pt}$ What is the total energy of the particle?
(in J*)*

12. **A**⚪ 5.582×10^{-11} **B**⚪ 8.093×10^{-11}

C⚪ 1.174×10^{-10} **D**⚪ 1.702×10^{-10}

E⚪ 2.467×10^{-10} **F**⚪ 3.578×10^{-10}

G⚪ 5.188×10^{-10} **H**⚪ 7.522×10^{-10}

$\boxed{2\ pt}$ 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 515 nm instead of the regular 400 nm. In terms of the speed of the light, what is the radial speed of the quasar with respect to Earth?

13. **A**⚪ 0.105 **B**⚪ 0.140 **C**⚪ 0.186 **D**⚪ 0.247

E⚪ 0.329 **F**⚪ 0.438 **G**⚪ 0.582 **H**⚪ 0.774

$3\ pt$ What is the pressure of 1.47 moles of Nitrogen gas in a 6.63 liter container, if the temperature of the gas is 34.5 °C?
(in `atm`*)*

14. **A**◯ 5.60 **B**◯ 6.99 **C**◯ 8.74 **D**◯ 10.93

E◯ 13.66 **F**◯ 17.08 **G**◯ 21.35 **H**◯ 26.68

$2\ pt$ What is the RMS speed of Helium atoms when the temperature of the Helium gas is 371.0 K? (Possibly useful constants: the atomic mass of Helium is 4.00 AMU, the Atomic Mass Unit is: $1\ \text{AMU} = 1.66 \times 10^{-27}$ kg, Boltzmann's constant is: $k_B = 1.38 \times 10^{-23}$ J/K.)
(in `m/s`*)*

15. **A**◯ 3.99×10^2 **B**◯ 4.98×10^2 **C**◯ 6.23×10^2

D◯ 7.79×10^2 **E**◯ 9.73×10^2 **F**◯ 1.22×10^3

G◯ 1.52×10^3 **H**◯ 1.90×10^3

$2\ pt$ What would be the RMS speed, if the temperature of the Helium gas was doubled?
(in `m/s`*)*

16. **A**◯ 1.68×10^3 **B**◯ 1.90×10^3 **C**◯ 2.15×10^3

D◯ 2.43×10^3 **E**◯ 2.75×10^3 **F**◯ 3.10×10^3

G◯ 3.51×10^3 **H**◯ 3.96×10^3

$2\ pt$ 5 kg of lead shot at 96.7° C are poured into 5 kg of water at 20.0° C. Find the final temperature (in °C) of the mixture. Use $c_{\text{water}} = 4187$ J/kg °C and $c_{\text{lead}} = 128$ J/kg °C.

17. **A**◯ 5.04 **B**◯ 7.31 **C**◯ 1.06×10^1

D◯ 1.54×10^1 **E**◯ 2.23×10^1 **F**◯ 3.23×10^1

G◯ 4.68×10^1 **H**◯ 6.79×10^1

$3\ pt$ The height of the Eiffel tower is 321 m during the Summer when the temperature is 22.5 °C. What is the magnitude of the change in the height of the tower, when the temperature cools down to -16.4 °C during the Winter? The coefficient of linear expansion of the tower's material is 1.11×10^{-5} 1/C°.
(in `cm`*)*

18. **A**◯ 5.89 **B**◯ 6.66 **C**◯ 7.52

D◯ 8.50 **E**◯ 9.61 **F**◯ 1.09×10^1

G◯ 1.23×10^1 **H**◯ 1.39×10^1

$2\ pt$ The temperature of an oven is kept constant at 920.0 K. A hole with a diameter of 22.0 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`*)*

19. **A**◯ 7.42 **B**◯ 8.38 **C**◯ 9.47

D◯ 1.07×10^1 **E**◯ 1.21×10^1 **F**◯ 1.37×10^1

G◯ 1.54×10^1 **H**◯ 1.74×10^1

$2\ pt$ What is the wavelength for which the radiant energy is maximum?
(in `nm`*)*

20. **A**◯ 1.93×10^3 **B**◯ 2.18×10^3 **C**◯ 2.47×10^3

D◯ 2.79×10^3 **E**◯ 3.15×10^3 **F**◯ 3.56×10^3

G◯ 4.02×10^3 **H**◯ 4.55×10^3

$2\ pt$ A gas bottle contains 4.20×10^{23} Oxygen molecules at a temperature of 393.0 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`*)*

21. **A**◯ 3.22×10^3 **B**◯ 4.28×10^3 **C**◯ 5.70×10^3

D◯ 7.58×10^3 **E**◯ 1.01×10^4 **F**◯ 1.34×10^4

G◯ 1.78×10^4 **H**◯ 2.37×10^4

$2\ pt$ How much energy is stored in ONE degree of freedom for the whole system?
(in `J`*)*

22. **A**◯ 7.90×10^2 **B**◯ 8.92×10^2 **C**◯ 1.01×10^3

D◯ 1.14×10^3 **E**◯ 1.29×10^3 **F**◯ 1.45×10^3

G◯ 1.64×10^3 **H**◯ 1.86×10^3

$2\ pt$ What is the average energy of a single molecule?
(in `J`*)*

23. **A**◯ 9.91×10^{-21} **B**◯ 1.16×10^{-20}

C◯ 1.36×10^{-20} **D**◯ 1.59×10^{-20}

E◯ 1.86×10^{-20} **F**◯ 2.17×10^{-20}

G◯ 2.54×10^{-20} **H**◯ 2.97×10^{-20}

$\boxed{2\ pt}$ On average how much energy is stored by ONE degree of freedom for ONE single molecule?
(in J*)*

24. **A**◯ 1.45×10^{-21} **B**◯ 1.69×10^{-21}
  C◯ 1.98×10^{-21} **D**◯ 2.32×10^{-21}
  E◯ 2.71×10^{-21} **F**◯ 3.17×10^{-21}
  G◯ 3.71×10^{-21} **H**◯ 4.34×10^{-21}

$\boxed{2\ pt}$ 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 entropy S_f is ... S_i.
25. **A**◯ equal to   **B**◯ less than
  C◯ greater than

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

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

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

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

$\boxed{3\ pt}$ 2.58 mol of an ideal gas expands reversibly and isothermally at 391 K until its volume is increased by a factor of 4.24. What is the increase in entropy of the gas?
(in J/K*)*

30. **A**◯ 2.26×10^1 **B**◯ 2.65×10^1 **C**◯ 3.10×10^1
  D◯ 3.62×10^1 **E**◯ 4.24×10^1 **F**◯ 4.96×10^1
  G◯ 5.80×10^1 **H**◯ 6.79×10^1

$\boxed{3\ pt}$ How much heat did the gas absorb?
(in J*)*

31. **A**◯ 8.85×10^3 **B**◯ 1.04×10^4 **C**◯ 1.21×10^4
  D◯ 1.42×10^4 **E**◯ 1.66×10^4 **F**◯ 1.94×10^4
  G◯ 2.27×10^4 **H**◯ 2.65×10^4

$\boxed{3\ pt}$ A Stirling-engine is used in the heat-pump mode to heat a house. The engine maintains a temperature of 20.7 °C inside the house. The temperature of the Earth loop is 10.9 °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?

32. **A**◯ 1.17×10^1 **B**◯ 1.37×10^1 **C**◯ 1.60×10^1
  D◯ 1.87×10^1 **E**◯ 2.19×10^1 **F**◯ 2.56×10^1
  G◯ 3.00×10^1 **H**◯ 3.51×10^1

$\boxed{2\ pt}$ If the power of the electric motor driving the heat pump is 188 W, then what is the rate at which heat is delivered to the house?
(in W*)*

33. **A**◯ 1.28×10^3 **B**◯ 1.85×10^3 **C**◯ 2.68×10^3
  D◯ 3.89×10^3 **E**◯ 5.64×10^3 **F**◯ 8.17×10^3
  G◯ 1.19×10^4 **H**◯ 1.72×10^4