Name: KEY

Student #

PHY215, fall 2017

Modern Physics and Thermodynamics

Exam #1, Code-Name: Covfefe
Friday, September 29, 2017: 40 points

You must work problems 1, 2, and 3 and one of either problem 4 or problem 5 which are each nominally 10 points. You must choose which is your "real" choice and indicate below. If you choose to do the other in addition, it's worth up to 5 points extra credit. You'll see for each that there is a primary point total (which adds to 10) and an "extra credit" total (which adds to 5).

Circle your primary last question:

Question 4

Question 5

Speed of Light: $c = 3 \times 10^8$ m/s
Gas Constant: $R = 8.3145$ J/mol·K

You must show all of your work.

1. (total for problem: 13 pts)

There is a sub-nuclear particle called a "kaon," K^0. (The "0" indicates that it is electrically neutral...it has charged partners as well.) It is unstable and decays most of the time into two neutral pions, π^0. If the kaon decays at rest:

a. (2 pts) How does the momentum of one pion compare to the other?

same

b. (1 pt) Draw a "before" and an "after" picture from the kaon's rest frame.

c. (5 pts) The rest energy of the kaon is 498 MeV and the rest energy of the pion is 135 MeV. What is the kinetic energy, in MeV, of one of the pions?

$$E_K = E_A + E_B$$

$$m_K c^2 = 2m_\pi c^2 + 2K_\pi$$

$$K_\pi = \frac{m_K c^2 - 2m_\pi c^2}{2}$$

$$K_\pi = \frac{498 - 2(135)}{2} = 114 \text{ MeV each}$$

d. (5 pts) What is the velocity of that pion as a fraction of the speed of light...ie., what is β_π

$$E = m_\pi c^2 + K = m_\pi \gamma c^2$$

$$\gamma = \frac{m_\pi c^2}{m_\pi c^2} + \frac{K}{m_\pi c^2} = 1 + \frac{114}{135}$$

$$\gamma = 1.84 = \frac{1}{\sqrt{1-\beta^2}}$$

$$\Rightarrow \gamma^2 = \frac{1}{1-\beta^2}$$

$$1-\beta^2 = \frac{1}{\gamma^2}$$

$$1 - \frac{1}{\gamma^2} = \beta^2 = 1 - \frac{1}{3.4}$$

$$\beta = 0.84$$

2. (3 pts)

A line of charges at rest create a static electric field in the line's rest frame. If I am moving with constant velocity parallel to that line of charge, in words, generally what field configuration might I observe?

an electric field and a magnetic field

3. (4 pts)

Two events occur in an inertial system K at the same time but 4 km apart. What is the time difference measured in a system K' moving between these two events when the distance of separation of the events is measured to be 5 km? Remember what's always constant.

↑ the interval

using the book's form (different by overall minus sign from "my way"):

$$\Delta s^2 = \Delta s'^2$$

$$-c^2\Delta t^2 + \Delta x^2 = -c^2\Delta t'^2 + \Delta x'^2$$

$\Delta x = 4$ km

$\Delta t = 0$

$\Delta x' = 5$km

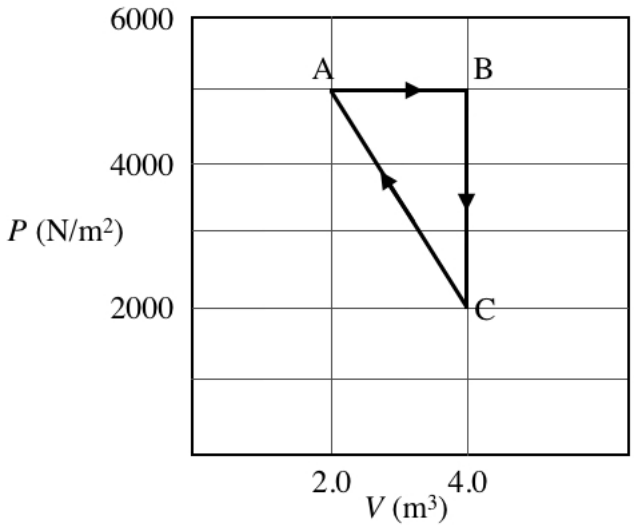
$$\Delta t'^2 = \frac{\Delta x'^2 - \Delta x^2}{c^2}$$

$$= \frac{(5\times10^3)^2 - (4\times10^3)^2}{(3\times10^8)^2}$$

$$\Delta t'^2 = \frac{9\times10^6}{9\times10^{16}}$$

$$= 10^{-10}\ s^2$$

$$\Delta t = 10^{-5}\ s$$



4. Work either this one or #5. (total for problem: 10 pts, 5 points if extra credit)

Make an X: This is my primary _____ or my extra credit _____ problem.

One mole of an ideal gas is taken through the cyclic process ABCA as shown in the figure.

a. (1 pts) What is the temperature at point a?

$PV = nRT$ for ideal gas

$$T_A = \frac{P_A V_A}{nR} = \frac{(5000)(2)}{(1)(8.31)} = 1203\ K$$

b. (3pts, if extra credit, 1pt) What is the internal energy change in the cycle?

$\emptyset$ temperature "comes back"

c. (3 pts, if extra credit, 2pts) What is the work done by the gas in the cycle?

$W_{AB} = P_A \Delta V_{AB} = (5000)(2) = 10{,}000 \text{ J}$

$W_{BC} = 0$

$W_{CA} = P_C \Delta V_{CA} + \Delta P_{AC} \Delta V_{CA} = (2000)(-2) + \frac{1}{2}(3000)(-2) = -7000 \text{ J}$

$W_{net} = 3000 \text{ J}$

same as area of ABC triangle directly.

d. (3 pts, if extra credit, 1pt) What is the net amount of heat added to the gas during a cycle?

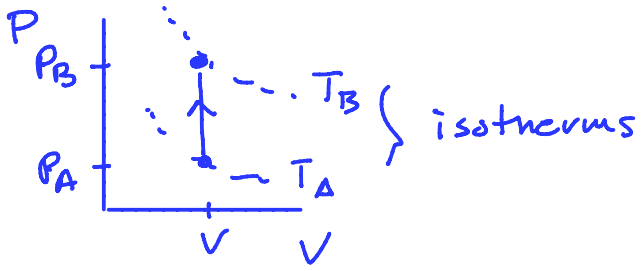
$\Delta Q = W + \Delta U = 3000 \text{ J}$

5. Work either this one or #4. (total for problem: 10 pts, 5 points if extra credit)

Make an X: This is my primary _____ or my extra credit _____ problem.

A monotonic, ideal gas undergoes an isochoric (at constant volume) transition from lower pressure P_A to higher pressure, P_B.

a. (2 pts, if extra credit, 1pt) Draw the P-V diagram for the process.



b. (2 pts, if extra credit, 1pt) If the initial temperature is T_A and the final temperature is T_B, which is the higher temperature?

T_B

c. (3 pts, if extra credit, 2pts)

In terms of R and the temperatures, what is the expression for the change of entropy? I'll start you:

The first law says: $dQ = dU + dW$. We showed that $dU = nC_V dT$ and $dW = PdV$...but the volume doesn't change so

$$dQ = nC_V dT$$

Now find the change in entropy

$\Delta S = \frac{\Delta Q}{T}$ → infinitesimals

$TdS = dQ$ from 1st law

$dQ = dU + dW$

Φ

$\frac{dQ}{T} = nC_v \frac{dT}{T} + nR \frac{dV}{V}$

So:

$\int dS = \int \frac{dQ}{T} = \int C_v \frac{dT}{T}$

$\Delta S = C_V \int_{T_A}^{T_B} \frac{dT}{T} = C_V \ln T_B/T_A = \frac{3}{2} R \ln T_B/T_A$

d. (3 pts, if extra credit, 1pt) Does the entropy increase or decrease?

increases