Department of Physics
PHYS102 - Physics II
Midterm Examination
Fall 2015-16
(Nov. 25, 2015)

Solution

Name & Surname:	*Number:*	*Group:*	*Signature:*

1. The exam includes 4 questions.
2. You are not allowed to use any source of information.
3. All electronic devices are forbidden to be used during the exam.
4. Your mobile phone must be turned off before the exam starts.
5. You may use an ordinary calculator.
6. Duration of the exam is 90-minutes.

Good Luck

P1: (10 pts)	P2: (10 pts)	P3: (10 pts)	P4: (10 pts)	Total: (40 pts)

$\mu = 10^{-6}$, $1atm = 1.01 \times 10^5 pa.$ $\quad 1m^3 = 10^3 L$, $1atm.L = 101J$

$W = \int PdV$	$\Delta S = \int \frac{dQ}{T}$	$\Delta E_{int} = Q - W$
$\Delta U = \Delta E_{int} = nC_v \Delta T$	$\vec{E} = \sum k \frac{q_i}{r_i^2} \hat{r}_i,$	$Q_f = mL_f$
$Q_v = mL_v$	$Q = mc\Delta T$	$\vec{F} = q\vec{E}$
$\vec{F} = k_e \frac{q_1 q_2}{r^2} \hat{r}$	$PV = nRT$	*Adiabatic*: $P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$
$R = 8.314 \frac{J}{mol.K}$	$c_{water} = 4186 \frac{J}{kg.°C}$	$L_f = 333000 \frac{J}{kg}$
diatomic: $C_v = \frac{5}{2} R,$ $C_p = \frac{7}{2} R, \quad \gamma = 1.4$	$c_{ice} = 2220 \frac{J}{kg.°C}$	$e = \frac{W}{Q_H}$

P1: Thermodynamics: (3+5+2 pts)

2 kg of ice at −30 °C is dropped into 10 kg of water at 70 °C.

a) Find the final temperature T_f of the mixture.
b) Find the total change of entropy for this process.
c) Based on your result in part (b), is the Second Law of Thermodynamics satisfied in this process? Why?

a) $m_{ice} C_{ice}(0+30) + m_{ice} L_f + m_{ice} C_w (T_f - 0) + m_w C_w (T_f - 70) = 0$

$\Rightarrow T_f = 42.4\,°C$

b) $\Delta S_{ice} = \int_{-30+273}^{273} \frac{dQ}{T} + \frac{m_{ice} L_f}{273} + \int_{273}^{42.4+273} \frac{dQ}{T} = 4165.087 \frac{J}{K}$

$\Downarrow$ $m_{ice} C_{ice} \ln\left(\frac{273}{243}\right)$ $\qquad$ $\Downarrow$ $m_{ice} C_w \ln\left(\frac{315.4}{273}\right)$

$\Delta S_w = \int_{343}^{315.4} \frac{dQ}{T} = m_w C_w \ln\left(\frac{315.4}{343}\right) = -3511.584 \frac{J}{K}$

$\Delta S_t = \Delta S_{ice} + \Delta S_w = 653.4 \frac{J}{K} > 0$

c) Yes, $\Delta S_t > 0$

P2: Thermodynamics: (3+3+4 pts)
An ideal diatomic gas expands adiabatically from an initial volume of 1.0 L, pressure 1.4 $atm.$ and temperature 127°C, to the final volume of 4.0 L. Find:

a) The final pressure.
b) The final temperature.
c) The work done by the gas in this process.

a) $P_1 V_1^{\gamma} = P_2 V_2^{\gamma} \Rightarrow P_2 = P_1 \left(\frac{V_1}{V_2}\right)^{\gamma}$

$P_2 = 1.4 \left(\frac{1}{4}\right)^{7/5} atm. = 0.20\ atm$

b) $T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1} \Rightarrow T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{\gamma-1}$

$T_2 = 400 \left(\frac{1}{4}\right)^{\frac{7}{5}-1} = 229.7\,K = -43.26\,°C$

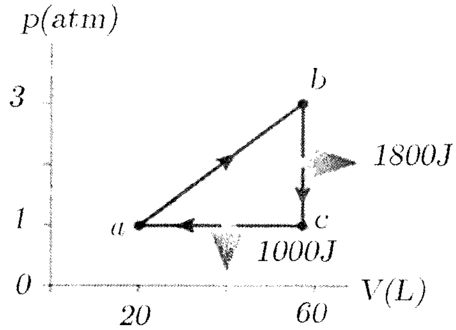
c) $W = -\Delta E_{int} = -n C_v (T_2 - T_1)$

$W = -n \frac{5}{2} R (T_2 - T_1) = -\frac{5}{2}(P_2 V_2 - P_1 V_1)$

$W = -\frac{5}{2}(0.2 \times 4 - 1.4 \times 1) \times 101\,J = 151.5\,J$

P3: Thermodynamics: (2+2+4+2 pts)

A heat engine uses a gas that operates under the *PV* – cycle given in the figure. Heats leaving the cycle along *bc* and *ca* are shown.



a) Calculate the net work done by the gas in one cycle.

b) Calculate the change in the internal energy for one complete cycle.

c) Calculate the heat added to the system along the *ab* path.

d) Calculate the thermal efficiency of the heat engine.

a) $W = \frac{1}{2}(60-20)(3-1)\ \text{atm}.L = 40\ \text{atm}.L = 4040\ J$

b) $\Delta E_{cycle} = 0$

c) $W = Q \Rightarrow 4040 = -1800 - 1000 + Q_{ab}$

$Q_{ab} = 6840\ J$

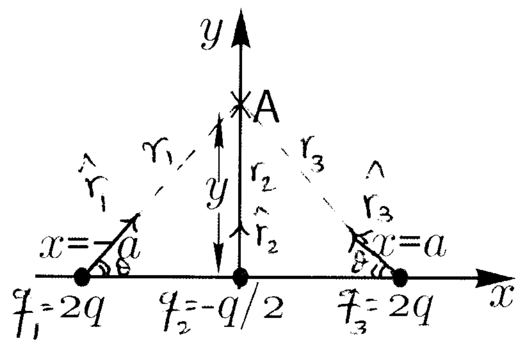
d) $e = \frac{W}{Q_H} = \frac{4040}{6840} = 0.59 = \%59$

P4: Electricity: (5+5 pts)

Consider the following charge configuration on xy-plane. The charges are fixed at their locations.

a) Find the total electric field vector $\vec{E}$ (in terms of q, a and y) due to the charges at a point A on y -axis.

b) Find the location of a fourth charge along the y-axis (in terms of a) such that the total electric force on it will be zero.



a) $\vec{E}_A = k_e \sum_{i=1}^{3} \frac{q_i}{r_i^2}\hat{r}_i = k_e q\left(\frac{2}{a^2+y^2}(\hat{i}\cos\theta+\hat{j}\sin\theta)\right.$

$\left.-\frac{1}{2y^2}\hat{j}+\frac{2}{a^2+y^2}(-\hat{i}\cos\theta+\hat{j}\sin\theta)\right)$

$= k_e q\left(\frac{4y}{(a^2+y^2)^{3/2}}-\frac{1}{2y^2}\right)\hat{j}$

$\sin\theta = \frac{y}{\sqrt{y^2+a^2}}$

$\cos\theta = \frac{a}{\sqrt{y^2+a^2}}$

b) $\vec{E}_A = 0 \Rightarrow \frac{4y}{(a^2+y^2)^{3/2}} - \frac{1}{2y^2} = 0$

$\Rightarrow \frac{8y^3}{(a^2+y^2)^{3/2}} = 1 \Rightarrow \frac{2y}{\sqrt{a^2+y^2}} = 1$

$\Rightarrow \frac{4y^2}{a^2+y^2} = 1 \Rightarrow y^2 = \frac{a^2}{3} \Rightarrow y = \frac{\pm a}{\sqrt{3}}$