10 Thermal Physics review questions – (HL)

Statement: Thermodynamics is the study of the relation between heat and work.

THERMODYNAMICS - THE LAWS.

1. The zeroth law of thermodynamics is simply that there is a property called temperature and when two object are placed in thermal contact with each other they will eventually reach thermal equilibrium and have the same temperature.

Apply this law to this situation:

A block of metal of mass 0.5kg, temperature 600K, and specific heat capacity 1.7 $kJkg^{-1}K^{-1}$. Is placed into a bath of water of mass 4kg, temperature 300K and specific heat capacity 4.2 $kJkg^{-1}K^{-1}$. Calculate the final temperature of the water and the metal. State any assumptions you are making to arrive at your answer.

$mC\Delta T = mC\Delta T$ (assumes no heat loss)

0.5x1.7x(600-T) = 4x4.2x(T-300)

510 - 0.85T = 16.8T – 5040

5550 = 17.65T ➔ T = 314K

2. The first law of thermodynamics is essentially the conservation of energy law. This can be applied in many ways. Which one of these statements does **not** come from the principle of energy conservation?

A - The amount of heat energy transferred into a system is equal to the rise in internal energy of the system plus the work done by the system.

B - If no heat energy is transferred to a system the internal energy of the system cannot change.

C - In a heat engine that is not changing temperature the heat energy transferred into the engine is equal to the heat energy transferred out of the engine plus the work done by the engine.

D - $Q = \Delta U + W$

3. The second law of thermodynamics states that the entropy (disorderliness) of an isolated system can never decrease. The entropy refers to how disordered the heat energy in a system is. If the heat energy of a system is ordered then all the heat energy is one place. When a system has reached its maximum entropy or disorder all the heat is evenly spread and can no longer be useful.

(a) Explain how this law means that unless one part of a heat engine is at absolute zero you can never use all the heat of a system to do work.

If the cold part is not at absolute zero then there is already disorder so not all the energy can be used

(b) Carnot calculated that the largest percentage of heat that could be turned into work was given by:

$$\text{Efficiency} = 1 - T_{cold}/T_{hot}$$

The cylinder in a car petrol engine has a temperature of 1000K just after the petrol is ignited. What is the theoretical maximum efficiency of the engine

(i) When the exhaust temperature is 450K? **1-450/1000 =65%**

(ii) When the exhaust temperature is 550K? **45%**

4. The third law of thermodynamics states that absolute zero temperature can never be reached. Why?

Heat energy flows from hot to cold so to make something be at absolute zero we need something to be at absolute zero or we would need all of the internal energy of a gas to be

THERMAL PROCESSES:

5. In any thermodynamic process there is heat transfer, work is done or there is a rise in internal energy. Why must at least two of the processes be occurring.

$Q = \Delta U + W$

6. In an adiabatic process no heat is being transferred: A gas expands freely from a high pressure cylinder through a nozzle. If the gas is doing 2500J of work each second what is the change in internal energy of the gas each second?

-2500J (2500J decrease in energy per second)

7. In an isothermal process the temperature of a system is constant. What relationship is there between the pressure and volume of a gas in a isothermal process? **PV=constant**. What relationship between temperature and volume is there in a constant pressure process? **V/T is constant**. What relationship between temperature and pressure is there is a constant volume process? **P/T is constant.**

8. Which of the processes mention in Questions 7 involves no work being done? **Constant volume.**

POWER CYCLES AND HEAT ENGINE QUESTIONS:

[Hint - work done by a gas is the area under the P-V graph, for a fixed amount of gas PV/T is constant]

U - Internal energy.   W- Work done by a system.   Q - Heat transferred to a system.

8. A quantity of gas may be taken along the paths abc and adc in the figure.

(a) Describe what is happening to the gas when it is taken along each of these paths.

ab is isochoric (isovolumetric) the gas is being heated at constant volume, bc is isobaric the gas is expanding at constant pressure and therefore doing work.

ad isobaric the gas is expanding at constant pressure but the pressure is lower than bc so less work is being done. dc is isochoric (isovolumetric) the gas is being heated at constant volume

Along abc W=40kJ and Q= 90kJ., Along adc W= 20kJ.

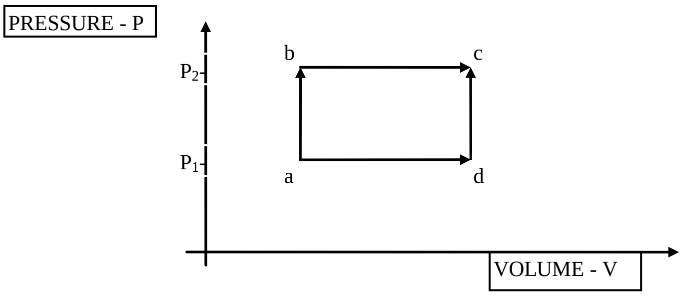
(b) How much greater is pressure P_2 compare to pressure P_1? **Twice as much work so twice as much pressure.**

(c) If Ua=45kJ what is Uc? **Q = ΔU + W ➔ 90kJ = ΔU + 40kJ so ΔU = 50 so Uc is 95kJ**

(d) What is Q along path adc? **Q = ΔU + W = 50 + 20 = 70kJ**

(e) If Ud=70kJ what is Q for the paths (i) ad **Q = ΔU + W = (70-45) + 20 = 55kJ** and (ii) dc? No work is done so **Q = ΔU = 95-70 = 25kJ**

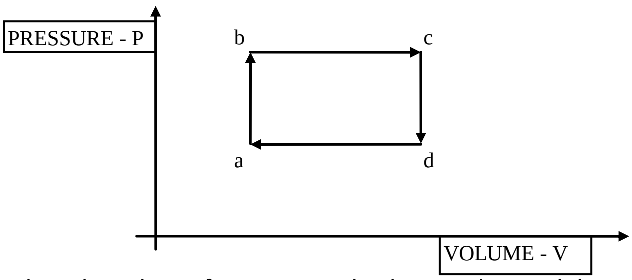
(f) How can you tell from the graph that W for abc is more than W for adc? **W = PΔV and P is higher for bc**



9. The figure shows a thermodynamic cycle adcda which a gas may be taken starting at a.

Temperatures are: At a T=300K; at b and d T=600K and at c T=1200K.

At a the pressure is 100kPa and the volume of the gas is 1.0m^3.



(a) Calculate the values of pressure and volume at b, c and d.

PV/T at a is 100,000x1/300 = 333.3

At b v=1, T=600 so px1/600=333.3 so p = 200,000 = 200kPa

At c P=200,00, T=1200 so 200,000xv/1200 = 333.3 ➔ v=1200x333.3/200,000 = 2m^3

At d P=100kPa (same as a), v=2m^3 (same as c)

(b) On the graph shade in the work done by the gas when expanding and the work done on the gas when being compressed. Explain why the area abcd represent the net work done in this power cycle.

Work done by gas is area under bc, work done on gas is area under ad. The net work done in cycle is the net work done by the gas = work done by gas – work done on gas = area between bc and ad

(c) Using the information below complete this table.

Path	Q	W	ΔU
Ab	150kJ	0	150kJ
Bc	**500kJ**	**PΔV = 200x1 = 200kJ**	300kJ
Cd		0	
Da		**PΔV = 100x-1 = -100kJ**	
Abcda	**0**	**100kJ**	**0**

The values for work done can be calculated from the various areas under the graph. One of the values is negative!.

Remember that no work is done if there is no volume change.

Use the first law to calculate ΔU for ab.

ΔU for bc is twice ΔU for ab. Fill in the remainder of the table.