

Question 1

Describe what is meant by the following processes:

- a. Adiabatic
- b. Isothermal
- c. Polytropic

Give suitable, real world examples in each case.

(6 Marks)

- d. From first principles, show that:

$$C_p - C_v = R$$

(14 Marks)

Question 2

- a. Draw and label a P-V diagram for a standard 'ideal' Otto cycle.

(5 Marks)

- b. Draw and label a P-V diagram for a standard 'ideal' Diesel cycle

(5 Marks)

- c. Draw a P-V diagram for a real engine, labelling the 4 different parts of a typical four-stroke cycle and the important parameters of the cycle.

(5 marks)

- d. Label on the above P-V diagram where you would expect to see:

- i. Start of Combustion
- ii. End of Combustion
- iii. Inlet Valve Closing
- iv. Exhaust Valve Opening
- v. Any area where the pressure would be below ambient.

(5 marks)

Question 3

You are required to carry out calculations on a naturally aspirated I.C. engine with a cylinder displacement of 255cc and a compression ratio of 13:1.

Assume that the cycle is an constant volume otto cycle with instantaneous burning and heat input at Top Dead Centre (TDC). Assume that the intake stroke is complete at Bottom Dead Centre (BDC) and that the exhaust valve opens at BDC. The engine is not quite adiabatic but has a polytropic index of 1.31 during compression and 1.24 during the expansion stroke. Assuming that the air intake temperature is 18°C @ 1Bar, Calculate:

- The rise in temperature of the air/fuel mixture during combustion. (6 marks)
- The temperature of the air/fuel gas just before the start of combustion. (3 marks)
- The temperature of the exhaust gas. (3 marks)
- The peak pressure in the cylinder. (2 marks)
- The work done during expansion. (4 marks)
- The potential energy recoverable from the exhaust gas per cycle. (2 marks)

You may use the following information:

Density of air at 20°C = 1.2 kg m⁻³

Volumetric efficiency is 92%

Combustion efficiency is 90%

Calorific value of fuel = 44x10⁶ J kg⁻¹

Stoichiometric Air/Fuel ratio = 14.7:1

Specific heat of air/fuel or exhaust gas at constant volume = 1007 J kg⁻¹ K⁻¹

Question 4

- Describe what you understand by the term 'Entropy'? (3 marks)
- Explain what you understand by the '2nd law of Thermodynamics'? (3 marks)
- Explain what is meant by 'Specific Heat Capacity'? (2 marks)
- Draw a P-V diagram for a two-stroke engine, labelling the different parts of the cycle and the important parameters of the cycle. (4 marks)
- If during combustion, the fuel releases an average of 15J per degree for 20 degrees during combustion, calculate the increase in pressure in the cylinder over 20 degrees of crank rotation if the volume changes from 44.1 cc to 37.2 cc and the initial pressure at the start of the 20 degree change is 25.4 Bar? You may assume that the polytropic index is 1.35 and that γ is 1.35 (8 marks)

Diwedd/End



EXAMINATION SOLUTIONS

(to accompany the examination paper sent to the external examiner
but NOT to be seen by students)

Programme:	BEng Engineering	Level:	5
Module:	Mock Questions		
Author:	Owen	Page:	

Q	Question	Marks
1a	Adiabatic refers to a process with no heat transfer to the surroundings. It can also be thought of as a 'fast' process. $PV^\gamma = C$ ($\gamma = 1.4$)	6
b	An isothermal process is a process that occurs at a constant temperature. There is time for heat transfer to occur fully so it can be thought of as a 'slow' process. $PV = C$	
c	A polytropic process represents a case in between the two cases described above. There is time for a certain amount of heat transfer to occur. Most real systems are of this type. $PV^n = C$	
d	from the first law $\Delta Q = \Delta U + \Delta W$ (constant pressure) $nC_p \Delta T = \Delta U + \Delta W$ (constant volume) $nC_v \Delta T = \Delta U + \Delta W$ but at constant vol $\Delta W = 0$ So $nC_v \Delta T = \Delta U$	



At constant pressure

$$n C_p \Delta T = \Delta U + \Delta W$$

but also $\Delta W = P \Delta V$ (work = pressure $\times$ vol)

So

$$n C_p \Delta T = \Delta U + P \Delta V$$

and at constant vol

$$n C_v \Delta T = \Delta U \quad \text{so}$$

$$C_v = \frac{\Delta U}{n \Delta T} \quad \text{and}$$

$$C_p = \frac{\Delta U}{n \Delta T} + \frac{P \Delta V}{n \Delta T}$$

$$C_p = C_v + \frac{P \Delta V}{n \Delta T}$$

Now remember $PV = nRT$

$$R = \frac{PV}{nT} = \frac{P \Delta V}{n \Delta T}$$

$$\text{So } C_p = C_v + R$$

or

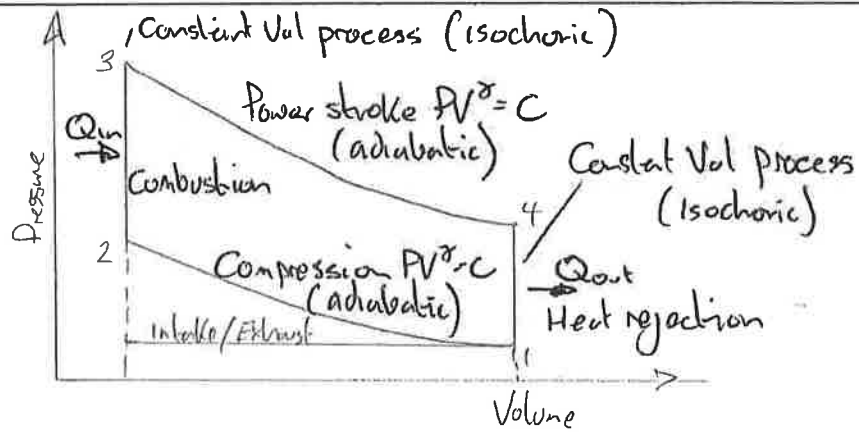
$$\underline{C_p - C_v = R}$$

(14)

Total 20

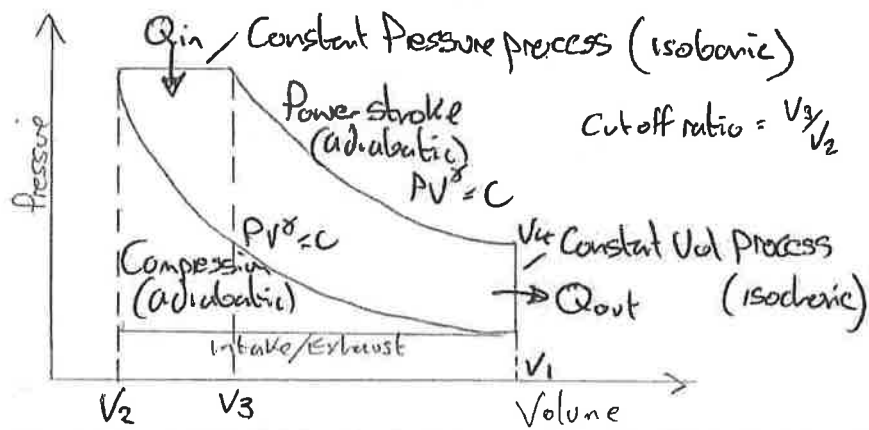


2a



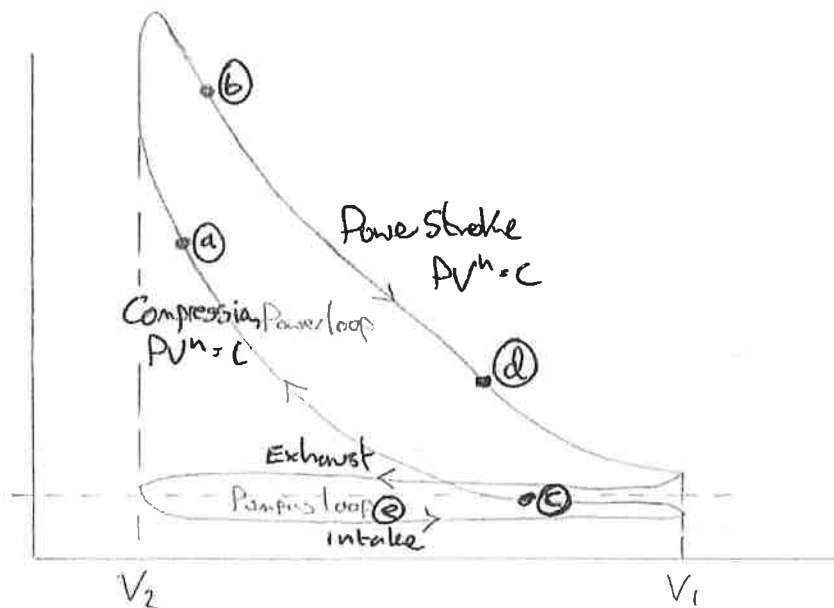
5

6



5

c



5

d

(a) (b) (c) (d) (e)

5

Total 20



3a Air ~~Volume~~ mass trapped = $0.42 \times 255 \times 10^{-6} \times 1.2$
 $= 2.815 \times 10^{-4} \text{ Kg.}$

* Fuel mass trapped = $2.815 \times 10^{-4} \times (14.7)^{-1}$
 $= 1.915 \times 10^{-5} \text{ Kg.}$

* Heat output = $0.9 \times 1.915 \times 10^{-5} \times 44 \times 10^6$
 $= 758.38 \text{ J}$

* Temperature Rise = $\frac{Q}{mc} = \frac{758.38}{(2.815 \times 10^{-4} + 1.915 \times 10^{-5}) \times 1007}$

$\Delta T = 2504.9 \text{ K}$

(6)

6 Using $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$ so $T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{\gamma-1}$

$T_2 = (18 + 273) \left(\frac{13}{1}\right)^{0.31} = \underline{644.5 \text{ K}}$ (3)

c $\frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{\gamma-1}$ so $T_4 = T_3 \left(\frac{V_3}{V_4}\right)^{\gamma-1}$

$T_4 = (644.5 + 2504.9) \left(\frac{1}{13}\right)^{0.24}$

$T_4 = 1701.7 \text{ K}$

(3)

d Using $\frac{P_1 V_1}{T_1} = C$ $P_2 = P_1 T_2 \times T_1^{-1}$ (Since Constant Vol Combustion)

also $P_2 = P_1 \left(\frac{V_1}{V_2}\right)^{\gamma}$ we can get



3d
Cont

$$P_2 = P_1 \left(\frac{V_1}{V_2} \right)^n = 1 \times \left(\frac{13}{1} \right)^{1.31} = 28.8 \text{ Bar}$$

$$\text{Now } P_3 = P_2 T_3 \times T_2^{-1}$$

$$P_3 = \frac{28.8 \times 3149.4}{644.5} = 140.8 \text{ Bar}$$

(2)

e Work Done during expansion = $\frac{P_3 V_3 - P_4 V_4}{n-1}$

$$W_{exp} = \frac{(140 \times 10^5 \times \left(\frac{255}{13} \right) \times 10^{-6}) - \left(P_3 \left(\frac{V_3}{V_4} \right)^n \times V_4 \right)}{n-1}$$

$$= \frac{274.68 - \left(140 \left(\frac{1}{13} \right)^{1.24} \times 10^5 \times 255 \times 10^{-6} \right)}{0.24}$$

$$= \frac{274.68 - 148.36}{0.24} = 526.3 \text{ J}$$

(4)

f Potential energy recovery

$$Q = mc \Delta T$$

$$Q = (2.815 \times 10^{-4} + 1.915 \times 10^{-5}) \times 1007 \times \Delta T$$

$$Q = 0.303 \times (1701.7 - 291)$$

$$Q = 427.4 \text{ J}$$

(2)

Total 20



C4a

Entropy can be thought of as a systems energy per unit temperature but also as a measure of the molecular disorder or randomness of the system. The concept is key to defining the 'arrow of time' for processes.

$$\Delta S = \frac{\delta Q}{dT}$$

(3)

b

The second law of thermodynamics is a general principle which defines the direction of heat transfer and the efficiencies of heat engines. It can also be thought of as the principle where the entropy of the universe will always increase over time. It is the concept that precludes 'perpetual motion machines'.

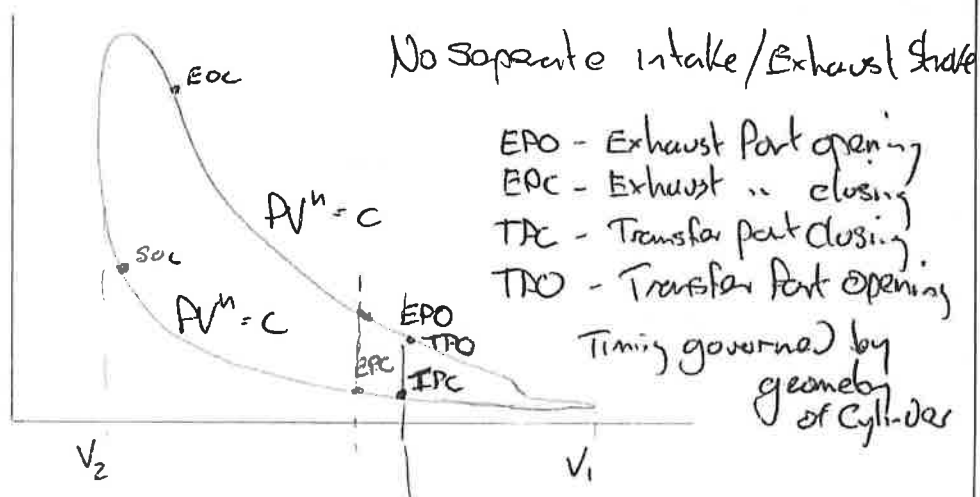
(3)

c

Specific heat capacity is the amount of heat required to raise the temperature of 1kg of substance by 1°C

(2)

d



(4)



4e

The heat release is over 20 degrees at 15.5
Per degree so $Q = 15 \times 20 = 3005$

The pressure without combustion would
be

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

$$P_2 = 25.4 \left(\frac{44.1}{37.2} \right)^{1.35}$$

$$P_2 = 31.96 \text{ Bar}$$

The pressure added due to combustion
will be

$$P_c = \frac{Q(\gamma - 1)}{V_2}$$

$$P_c = \frac{300 \times (0.35)}{37.2 \times 10^{-6}} \times \frac{1}{10^5}$$

$$P_c = 28.23 \text{ Bar}$$

So final Pressure = $P_2 + P_c$

$$= 31.96 + 28.23$$

$$= \underline{60.2 \text{ Bar}}$$

(8)

Total 20

