Question One: Answer the following.

3 3/4

(8 Marks)
(6*1/2 Marks)

Two stroke engines are Lighter than four stroke engines for the same power output and speed.
Heavier Slower Lighter None of the mentioned

1 1/2

Two stroke engines are liable to cause a ______ consumption of lubricating oil.
Lighter Heavier [✓ Unpredictable] None of the mentioned

What does scavenging air mean?
Burnt air containing combustion products Air sent under compression
Forced air for cooling the engine cylinder
[✓ Air used for forcing the burnt gases out of cylinder during the exhaust period]

The intake and exhaust mechanisms of a two-cycle engine are timed by the
Piston [✓ Camshaft] Valves Crankshaft

In internal combustion engines flywheel is used to :
[✓ To store inertia force] Balancing of camshaft.
Help in combustion process All of the above.

Oil rings in the piston :
Provides sealing between crankcase and combustion chamber.
[✓ Resists lube oil to stay in crankcase.]
Both of the above answers
ONLY first answer (i.e. sealing)

This engine design is now almost obsolete. State its name and 2 reasons for not producing it anymore.

2/4

T-head configuration valve

① high surface area ⟶ Heat loss ↑, fuel condensate on it (Pollution ↑)

② Long way for intake and exhaust to take which make a pressure ~~difference~~ drop in it

(1 Mark)

What is the name of the part pointed at with the arrow? State two of its main functions.

slsirts

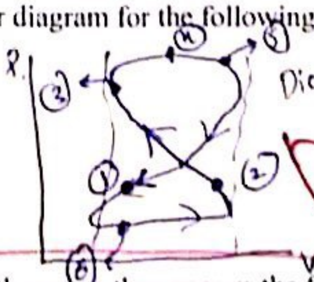
① to prevent tilting of the piston

② ~~make~~ ~~higher~~ helps with heat transfer

(1 Marks)

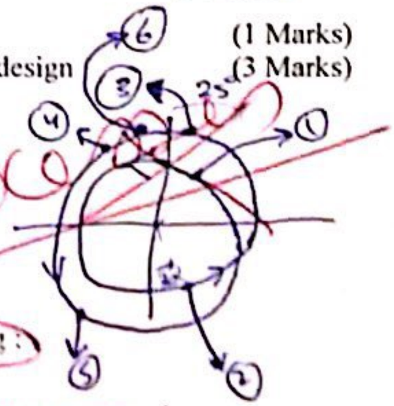
Draw the proper valve timing and indicator diagram for the following engine design (3 Marks)

① IV opens at 25° before TDC
② IV closes at 30° after BDC
③ Fuel injection starts at 5° before TDC
④ Fuel injection closes at 25° after TDC
⑤ EV opens at 45° before BDC
⑥ EV closes at 15° after TDC



Diesel

process



Show all the processes on the diagrams with arrows then answer the following :
How much is the valve overlap? ……25+15=40°
The factor that controls the opening of both valves is called : ……… engine speed

2

~~$\rho v A$~~ $PV = mRT$ $v = \frac{m}{\rho}$

$\frac{P}{\rho} = RT$ $\rho = \frac{P}{RT}$

6

Q2) Answer the following : **(6x2 Marks)**

2-A) Indicator diagram test, Energy balance, brake power test.

The following data were observed from a dynamometer and indicator diagram tests conducted on single cylinder, four-stroke oil engine. The cylinder diameter = 150mm, stroke length = 250mm, area of indicator diagram = 600 mm², length of indicator diagram = 50mm, spring constant = 1.5mm/bar, engine speed= 420 rpm, net brake load = 60 kg, dynamometer arm radius = 40cm, fuel consumed = 3 kg/h, air-fuel ratio 14.5:1, fuel calorific value = 44 MJ/kg, engine combustion efficiency = 98%, cooling water flow rate = 0.08 kg/s, cooling water temperature rise = 45 K, exhaust gas temperature is 375 °C, water specific heat = 4.1868 kJ/kg-K, average exhaust specific heat = 1.1 kJ/kg-K. Take 1 bar = 100 kPa. Atmospheric conditions are 25 °C and 100 kPa, R_{air} = 0.287 kJ/kg-K.

Give TWO reasons why engine testing is conducted. (6 Marks)

① to. • compare the desired values with the actual one

② check pollution rates

Calculate :

a) Mechanical and volumetric efficiencies.
b) Indicated power.
c) Brake and indicated work.
d) Brake specific fuel and brake specific air consumptions.
e) Engine specific power and specific volume.
f) Make an energy balance for this test both as values and % of energy input.

$$\eta_{vol} = \frac{0.0121}{1.17 \frac{\pi}{4} 0.15^2 \; 0.25 \; \frac{420}{120}} = 0.669$$

4

$$\bar{P}_{mc} = \frac{A}{L} * C = \frac{600 \text{ mm}^2}{50 \text{ mm}} \cdot \frac{1 \text{ bar}}{1.5 \text{ mm}}$$

$$= 800 \text{ kPa}$$

$$\tau_B = g \times P_{net} * R = 9.81 * 60 * 0.4 = 235.44 \text{ Nm}$$

$$\bar{P}_{nB} = \frac{\tau_B}{V_{s1}\left(\frac{n_c}{2\pi n_r}\right)} \quad \frac{235.44}{\frac{\pi}{4}(0.15)^2(0.25)\left(\frac{1}{(2\pi)}\right)}$$

$$= 670 \text{ kPa}$$

mechanical eff.

$$\eta_m = \frac{\bar{P}_B}{\bar{P}_{mI}} = 0.837$$

4

$$\dot{m}_a = 14.5 \; \dot{m}_f = (14.5)(3)/3600$$

$$= 0.0121 \text{ kg/s}$$

volumetric eff.

$$\eta_{vol} = \frac{\dot{m}_a}{\rho_a \frac{\pi}{4} d^2 s \frac{N}{60 n_r}}$$

$$\rho_a = \frac{P}{RT} = 1.17 \text{ kg/m}^3$$

$$\dot{W}_I = P_{mI} \frac{\pi}{4} d^2 s \frac{N}{60 \times n_r} = 12.37 \text{ kW}$$

$$\boxed{\text{indicated power} = 12.37 \text{ kW}}$$

$$\dot{W}_B = 12.37 * 0.837 = 10.35 \text{ kW}$$

indicated work

$$\boxed{W_I = \frac{\dot{W}_I}{\frac{N}{60} \frac{1}{n_r}} = 3.53 \text{ kJ}}$$

brake work

$$\boxed{W_B = \frac{\dot{W}_B}{\frac{N}{60} \frac{1}{n_r}} = 2.96 \text{ kJ}}$$

Brake specific fuel consumption

$$BSFC = \frac{3 \text{ (kg)}}{(10.35)(h) \text{ kW}} = 0.290 \text{ kg/kWh}$$

brake specific air cons.

$$BSAC = \frac{3 \times 14.5}{10.35} = 4.203 \text{ kg/kWh}$$

specific power

$$SP = \frac{10.35}{\frac{\pi}{4}(0.15)^2} = 585.7 \text{ kW/m}^2$$

4

B) Engine Testing and design

A 4-cylinder, 4-stroke petrol engine has bore = 57mm and stroke 90mm and connecting rod length 180mm. It is tested using brake dynamometer, which has arm radius 0.356m at 2800 rpm. The net brake load with all engines firing was 155N and fuel consumption 6.74 L/hr. The fuel used has calorific value 44200 kJ/kg and specific gravity 0.735. The brake loads when cylinders were cut-off in this order 1,2,3,4 keeping the engine speed constant were 111 N, 106.5N, 104.2N and 111N respectively.

3

(6 Marks)

What is the name of this test? Why it is conducted? What are the main conditions for conducting this type of tests?

~~dynamometer then~~ morse test

to calculate the indicated parameters of each cylinder and then the whole engine (power, torqe, P_{mi})

1

2

Calculate : Brake Torque, Brake and friction mean effective pressure, brake thermal effciency.

$$T_B = P\,R_r = (0.356)(155) = 55.18 \text{ N.m}$$

Brake torque

ke
EP

$$P_{mB} = \frac{\tau_B}{V_{s_1}\left(\frac{n_c}{2\pi n_r}\right)} = \frac{55.18}{\frac{(4)\frac{\pi}{4}(0.057)^2(0.09)}{(2\pi)(2)}}$$

$$= 754.8 \text{ kPa}$$

If the combustion ends at 22° aTDC, what is the value of distance moved by piston as well as its velocity at this angle.

$$S(\theta) = a\cos(\theta)\sqrt{r^2 - a^2\sin^2\theta}$$

$$a = \frac{S}{2} = 0.045 \text{ m}$$

assume $r = 4a$ for small engines

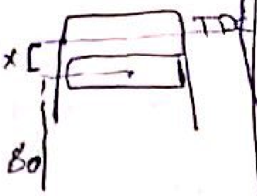
$$\Rightarrow r = 0.18 \text{ m.}$$

$S\theta =$ ~~[illegible] ×10^-3~~ 0.221

$X =$ ~~[illegible]~~ $a + r - S\theta$

$=$ 0.~~04~~ ~~7.477×10^-3~~

$=$ ~~[illegible]~~



$$\frac{V(\theta)}{\bar{V}_p} = \frac{\pi}{2}.\sin\theta\left[1 + \frac{\cos\theta}{\sqrt{R^2 - \sin^2(\theta)}}\right]$$

$$= \frac{\pi}{2}\sin 22\left[1 + \frac{\cos(22)}{\sqrt{4^2 - \sin^2 22}}\right]$$

$$= 0.725$$

$$\bar{V}_p = 2S\frac{N}{60} = 504$$

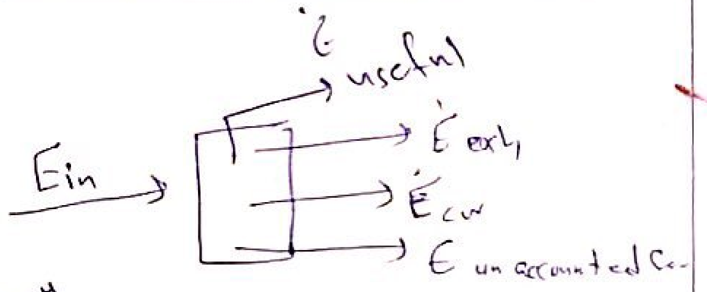
exact velocity $V(\theta) = (0.725)(504)$

$= 365.4$ m/s

Q 2 contined

Specific volume $= \frac{V_{s\,tot}}{\dot{W}_b}$

$= 4.27 \times 10^{-4}\ \frac{m3}{kW}$



energy of fuel

$\dot{E}_{in} = \left(\frac{1}{20}\right)(44000)(0.98) =$

$= 2156$ kJ/min

cooling water

$\dot{E}_{cw} = (0.08 \times 60)(4.1868)(45)$

$= 904.176$ kJ/min

exhaust

$\dot{E}_{exh} = \left(\frac{(3 + (14.5)(3))}{60}\right)(1.1)(350)$

$= 298.375$ kJ/min

un accounted for

$\dot{E}_{un\ acc} = 2156 - 904.176 - 298 - (60)(\dot{W}_B)$

$= 962.449 - 621 =$

$= 341.449$ kJ/min

$\frac{\dot{E}_{cw}}{\dot{E}_{in}} = 0.419$

$\dot{E}_{useful} = (10.35)(60) = 621$ kJ/

$\frac{\dot{E}_{useful}}{\dot{E}_{in}} = 0.288$

$\frac{\dot{E}_{un\ accounted}}{\dot{E}_{in}} = 0.158$

E	τ_B	55.18 τ_i
1	111 ~~× 0.8~~ 0.356 = 39.516	17 ~~.664~~ .664
2	37.914	17.266
3	37.1	18.08
4	39.516	17.664

$$\tau_{i_{tot}} = 70.674$$

$$\tau_{friction} = \tau_{i_{tot}} - \tau_{B_{tot}} =$$

$$70.674 - 55.18$$

friction torque = 15.494 N.m

$$\dot{W}_B = 2\pi \frac{N}{60} \tau_B$$

$$= 16.18 \text{ kW}$$

brake thermal eff.

$$\eta_{th_B} = \frac{16.18}{\left(\frac{6.74\,L}{hr} \cdot \frac{hr}{3600\,sec} \cdot \frac{m^3}{1000\,L} \cdot \frac{735\,kg}{m^3}\right)(44200)(1)}$$

$$= 0.266$$

مدة هذه الورقة 20 دقيقة فقط

يجب ان تجاوب هذه الورقة أولا وتجمع بعد 20 دقيقة من بدء الامتحان ولن يقبل غير ذلك.

Student Name : omarsami khader University No. : 0130466

Serial No. : 12 Section : ....

5

*************************** Concept ******************************

Q1) Answer the following.

✓ State one function for each one of the following component:

Cam shaft : ~~cam~~ rotating cam that connect valves which open or closed

Piston rings : prevent Leakage of compressed air

Flywheel : start the engine

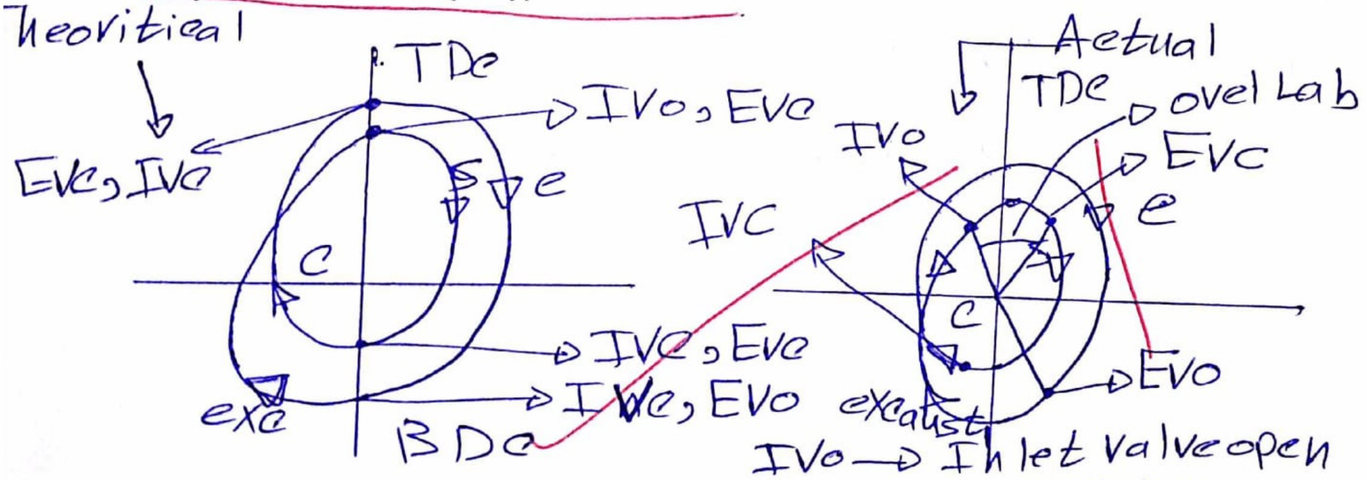
Piston crown : prevent inlet mixture to exit from exaust port

✓ Complete the following tables :

Parameter	Spark Ignition SI	Compression Ignition CI
Fuel Used (In terms of volatility and SIT)	High volatility and High SIT	Low violatility and Low SIT
Fuel Introduction	by inlet valve	by injector
Charge induced	Air + fuel	Air only
Mixture Ignition	spark ignition	compress air then add fuel

Parameter	2 Stroke	4 Stroke
Cooling load	High	Low
Thermal efficiency	Low	High
Power produced	High	Low
Lubrication method	oil mixed with fresh mixture	by rings

✓ Describe with clean diagrams the difference between theoretical and actual valve timings. State why there is difference (if any) between the two.

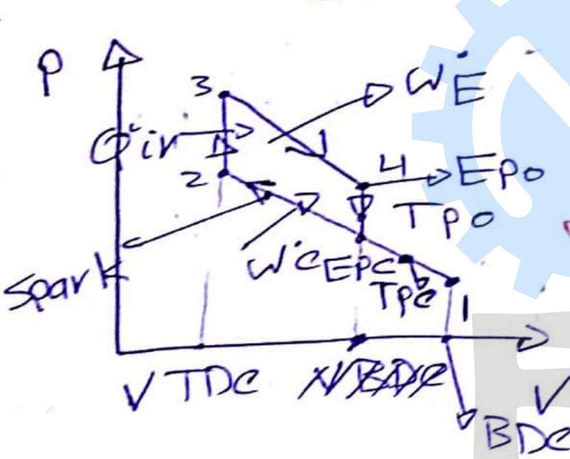


S → suction
exc → ex chaust
e → ex pansion

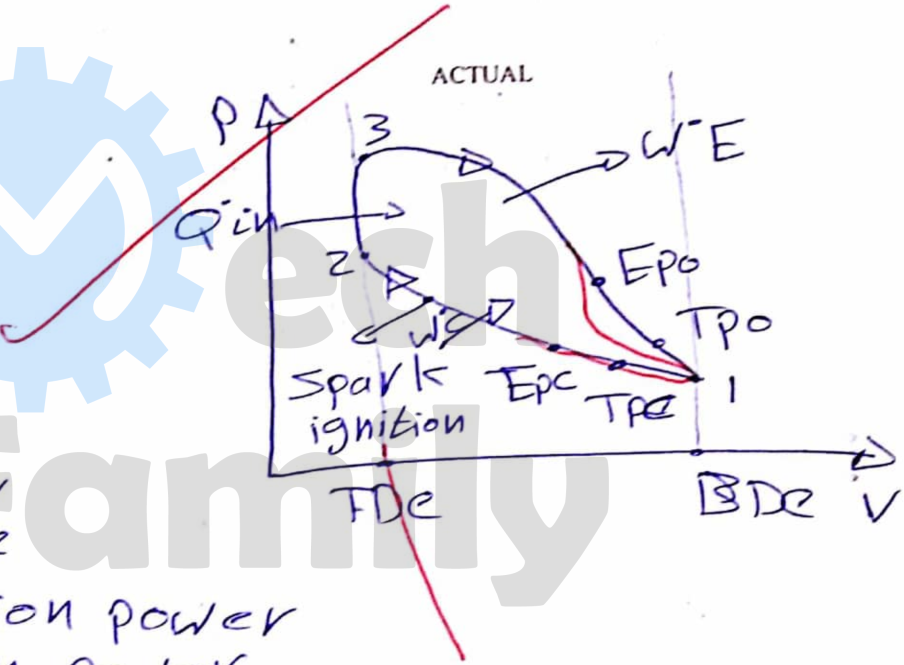
IVo → Inlet valve open
C → comprision
EVo → Exaust valve open
EVc → " " closed
IVc → Inlet valve closed

- ✓ Draw the Actual and theoretical indicator diagram for 2-stroke SI engine. Show processes on them and key events.

THEORETICAL



ACTUAL



$\dot{W}_C$ → compression power

$\dot{W}_E$ → expansion power

$\dot{Q}_{in}$ → inlet power ~~(Fuel~~

Tpo → Transfer port open

Tpc → " " closed

Epo → Exaust port open

Epc → Exaust port closed

######################## **Engine Testing** ######################

Q2) An eight-cylinder four-stroke SI engine of 80 mm bore and 100 mm stroke is tested at 4500 rpm on a dynamometer which has 55 cm arm. The dynamometer scale reading was 40 kg. The time for 100 cc of fuel consumption is recorded as 9.5 seconds. The calorific value of fuel is 44,000 kJ/kg. Air at 1 bar and 27°C was supplied to the carburettor at the rate of 6 kg/minute. Assume specific gravity of fuel to be 0.7. Clearance volume of each cylinder is 65 cc.

Determine the

a) Brake power and mean effective pressure
b) Brake sfc and sac,
c) brake thermal efficiency, the volumetric efficiency, and the relative efficiency.
d) Engine specific power, output per displacement

>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>> Cylinder Design >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

Q3) A three liter spark-ignition V-6 engine operates on a four-stroke cycle at 2500 rpm. The compression ratio is 8.5, the length of the connecting rod is 17.2 cm, and the engine is square. At this speed, combustion ends at 20° aTDC.

Determine:

(a) The cylinder bore and the stroke length
(b) The average piston speed
(c) The clearance volume of one-cylinder
(d) The piston speed at the end of combustion
(e) The distance the piston travels from IDC at the end of combustion
(f) The volume in the combustion chamber at the end of combustion

Q2) $V_{engine} = 3L$ $n_c = 6$ $n_r = 2$
$N = 2500\,rpm$ $CR = 8.5$ $r = 17.2cm$
$S = D$

5

combusition
$\Downarrow$
20° aTDC

$V_{s1} = 3/6 = 0.5L = 0.5 \times 10^{-3} m^3$

$~~CR~~ = \frac{V_s + V_c}{V_c}$ $(CR - 1) V_c = V_s$

$V_c = \frac{V_s}{7.5} = 0.067L$

(a) ~~①~~ $V_s = \frac{\pi}{4} B^2 S$ $B = S$

$V_s = \frac{\pi}{4} B^3$ ~~D = S = 12.523cm~~

$0.5 \times 10^{-3} = \frac{\pi}{4} B^3$ $B = S = 8.6cm$

cylinder bore ~~(D)~~ (B) = stroke Length (S)
= 8.6cm

(b) $\bar{u}_p$ (averagepiston Speed) $= \frac{2SN}{60}$

$= \frac{2 \times 8.6 \times 10^{-2} \times 2500}{60}$

$= 7.167 m/s$

(c) ~~③~~ Vc (clearance volume) = 0.067L
$= 0.067 \times 10^{-3} m^3$

ⓓ $u_p(\theta)$ (instatinious piston speed at end of combusition)

$$= \bar{u}_p \left(\frac{\pi}{2}\right) \sin\theta \left[1 + \frac{\cos\theta}{\sqrt{R^2 - \sin^2\theta}} \right]$$

$\theta = 20°$

$R = \frac{r}{a}$ r → connecting rod Length, a → crank

$S = 2a$

$a = \frac{S}{2} = 4.3cm$ $R = \frac{17.2}{4.3} = 4$

$$u_p(\overset{20°}{\cancel{\theta}}) = 7.167 \times \frac{\pi}{2} \times \sin 20° \times \left(1 + \frac{\cos 20°}{\sqrt{16 - \sin^2(20°)}} \right)$$

$$= 4.7583 \, m/s$$

ⓔ $x = r + a - S(\theta) = 17.2 + 4.3 - S(20°)$

$= 17.2 + 4.3 - 21.1776$

distance from Top dead center $= 0.3223cm$

$$S(20°) = 4.3 \cos(20°) + \sqrt{17.2^2 - (4.3)^2 \sin^2(20°)}$$

$$= 21.1777 \, cm$$

ⓕ $V(\overset{\circ}{\cancel{20}})$ (Volume in the compusition champer after the end of the combusition)

$$= V_c \left(1 + \frac{1}{2}(7.5) \left[4 + 1 - \cos 20° - \sqrt{16 - \sin^2(20°)} \right) \right.$$

$= 1.028 \, V_c$ ~~[illegible]~~

$= 0.086 L$ ~~[illegible]~~

Q3) $n_c = 8$ $n_r = 2$ $B = 80mm$ $= 0.08m$ $S = 100mm$ $= 0.1m$

$N = 4500rpm$ $r = 0.55m$

$m = 40kg$ $V_f = 100 \times 10^{-6} m^3$ $t = 9.5sec$

$Q_{ev} = 44000 \frac{kJ}{kg}$ $p = 1 bar$ $T = 27°C$

$\dot{m}_a = 6 kg/minute$ $SG = 0.7$

$V_c = 65 \times 10^{-6} m^3$ $\rho = 700 kg/m^3$

$T_B = mgr = 40 \times 9.81 \times 0.55 = 215.82 N.m$

ⓐ

Brakepowe $(\dot{W}_B) = \frac{2\pi N}{60} T = 101.71 kW$

P_{mb} (brake mean effictive pressure)

$$= \frac{T_B}{V_{s1}\left(\frac{n_c}{2\pi n_r}\right)}$$

$$V_{s1} = \frac{\pi}{4} B^2 S$$
$$= 5.02655 \times 10^{-4} m^3$$

$$= \frac{T_B}{V_{s1}\left(\frac{2}{\pi}\right)}$$

$= 674.44 kpa$

$V_f = 100\times10^{-6}\,m^3$ $\quad t = 9.5\,sec$

$$\dot{V}_f = \frac{100\times10^{-6}}{9.5} = 1.053\times10^{-5}\,\frac{m^3}{s}$$

$$\rho = \frac{\dot{m}_f}{\dot{V}_f} \qquad \dot{m}_f = \dot{V}_f \times 700$$

$$= 7.37\times10^{-3}\ kg/s$$

$$= 26.53\ \frac{kg}{h}$$

ⓑ BSFC (Break Specific fuel consumption) $= \frac{\dot{m}_f}{\dot{W}_B}$

$$= \frac{26.53}{101.7} = 0.2608\ kg/kwh$$

BSAC (Break Specific Air consumption)

$$= \frac{\dot{m}_a}{\dot{W}_B} = \frac{360}{101.7} = 3.54\ \frac{kg}{Kwh}$$

$$\dot{m}_a = 6\,\frac{kg}{m} \times 60 = 360\,\frac{kg}{min}$$

ⓒ Break Thermal efficiency (η_{thB})

$$= \frac{\dot{W}_B}{\dot{m}_f \times Q_{cv}}$$

$$= \frac{101.7}{7.37\times10^{-3} \times 44000}$$

$$= 0.31362$$

Volumetric efficiency (η_{vol}) $= \frac{\dot{m}_a}{\rho_{air} V_{s1}\, n_c \times \frac{N}{60} \times \frac{1}{n_r}}$

$$\rho_{air} = \frac{P}{RT} = \frac{100}{0.287\times(300)} = 1.16144\ kg/m^3$$

-o-

$$\eta_{vol} = \frac{\dot{m}_a}{\rho_{air} V_{s1} \times 4 \frac{N}{60}} = \frac{0.1 \text{ kg/s}}{1.16144 \times Vs \times 4 \times \frac{4500}{60}}$$

$$= 57.1\%$$

$$\eta_{Ideal} = 1 - \frac{1}{CR^{k-1}} = 57.97\%$$

$$CR = \frac{Vs + Vc}{Vc} = \frac{502.665 + 65}{65} = 8.733$$

$$\text{Relative efficiency } (\eta_r) = \frac{\eta_{thB}}{\eta_{Ideal}} = \frac{0.31362}{0.5797}$$

$$= 54.1\%$$

ⓓ engine specif power (SP) $= \dfrac{\dot{W}_b / 8}{A_p}$

$$A_p = \frac{\pi}{4} D^2 = 5.02655 \times 10^{-3} \text{ m}^2 \qquad = \frac{101.7/8}{A_p}$$

$$= 2529.07 \frac{\text{kW}}{\text{m}^2}$$

output per displaement (OPD)

$$= \frac{\dot{W}_B}{V_{s\,total}} = \frac{101.7}{A_p \times 0.1 \times 8}$$

$$= \frac{25.3 \text{ kW}}{\text{L}}$$

UNIVERSITY OF JORDAN
FACULTY OF ENGINEERING & TECHNOLOGY
MECHANICAL ENGINEERING DEPARTMENT

Winter 2013/2014 **Internal Combustion** **First Exam**

Name: صلاح الدين مصطفى حوراني *Number:* 0100431

Attempt all questions (6 questions).
Time allowed: 50 minutes only.
Answer on the same sheet.

Total Mark: 18 / 20

Q1/ Explain why C.I. engines are preferable to S.I. engines in the following areas: (*3 marks*)

- Fuel Economy

CI engines ~~higher~~ ~~comp~~ have higher compression ratios → higher thermal efficiencies → less fuel consumption

2.5

- Reliability

0.5

CI engines are heavier than SI engines, it is more reliable since it can work on heavy duty due to the high weight

- Safety

CI engines have lower risk since diesel is not Flammable at ~~non~~ normal temperatures

Q2/ The main disadvantage of the two-stroke engine is its low efficiency. Explain why this is the case, and suggest two solutions to overcome this problem. (*3 marks*)

* Some Fresh air during exhaust process is escape with exhaust gases, so some air-fuel mixture is wasted which decrease thermal efficiency

3

* ① accurate timing of closing and opening ~~exhaust and~~ valve ~~would solve this~~

② introduce a supercharger to increase the intake air Pressure

Q3/ Explain the function of the following parts of an internal combustion engine:

- Timing Belt: *(1 mark)*

to open or close valves at the proper time during the cycle, it transmit its power from crankshaft to control valves moveme

- Flywheel *(1 mark)*

~~a high~~ a body connected to crankshaft usually in cylindrical shape, with high ~~[illegible]~~ moment of inertia it stores energy and uniforms "smooths" & engine operation

2

Q4: Pick the most appropriate answer of the following: *(3 marks)*

1- With regard to emissions:
- x a) C.I. engines produce less NO_x and particulates than S.I. engines
- b) C.I. engines produce more CO and NO_x than S.I. engines
- [✓ c) C.I. engines produce less CO and CO_2 than S.I. engines]
- x d) C.I. engines produce more CO and less NO_x than S.I. engines

2- The average piston speed in an automotive I.C. engine is around:
- a) 12 cm/s
- b) 50 cm/s
- [✓ c) 12 m/s]
- d) 50 m/s

3- The spark in a four stroke S.I. engine is normally given at:
- a) 20° before BDC
- [✓ b) 20° before TDC]
- c) 20° after TDC
- d) 20° after BDC

4- The in-cylinder pressure during the induction stroke in a naturally aspirated engine is normally around:
- a) 0.09 bar
- [✓ b) 0.9 bar]
- c) 9 bar
- d) 90 bar

3

5- The bsfc:
- a) Increases with increasing the speed
- b) Decreases with increasing the speed
- c) Increases with increasing the compression ratio
- [✓ d) Decreases with increasing the compression ratio]

6- From a thermodynamic point of view, if the compression ratio is fixed then:
- [✓ a) Otto cycle is more efficient than Diesel and Dual cycles]
- b) Diesel cycle is more efficient than Otto and Dual cycles
- c) Dual cycle is more efficient than Otto and Diesel cycles
- d) The efficiencies of Otto, Diesel and Dual cycles are equal

Name: صلاح الدين حوراني Number: 0100431

Q5: A 2 litre naturally aspirated four-stroke diesel engine is designed to run at 4500 rpm with a power output of 45 kW. If the volumetric efficiency is equal to 80% and the bsfc is equal to 0.2556 kg/kWh, calculate the bmep and the A/F ratio.
(Assume that the ambient conditions are 101 kPa and 20°C) (5 marks)

4-stroke / $V_{total} = 2L = 0.002 m^3$ / diesel → CI / $N = 4500$ RPM

$\eta_v = 0.8$ / bsfc $= 0.2556$ Kg/Kw.hr / $\dot{W}_b = 45$ kw /

bmep = ? / A/F = ? / ~~$\rho_a = 1.181$ Kg/m³~~

$$\eta_v = \frac{n\,\dot{m}_{air}}{N\,\rho_a V_d}$$

$$\dot{m}_{air} = \frac{\eta_v N \rho_a V_d}{n} = \frac{0.8(4500)(0.002)(1.201)}{(2)(60)} = 0.0721 \text{ Kg/s}$$

$PV = mRT$

$$\frac{m}{V} = \rho = \frac{P}{RT} = \frac{101}{0.287(293)} = 1.201 \text{ Kg/m}^3$$

$$W_b = \frac{\dot{W}_b N}{n}$$

$$W_b = \frac{\dot{W}_b\, n}{N} = \frac{(45{,}000)(2)(60)}{4500} = 1200 \text{ J}$$

$$\text{bmep} = \frac{W_b}{V_d} = \frac{1200 \text{J}}{0.002 \text{ m}^3} = 600 \text{ KPa}$$

$$\text{bsfc} = \frac{\dot{m}_f}{\dot{W}_b} \rightarrow \dot{m}_f = \text{bsfc}(\dot{W}_b) = \left[0.2556 \frac{\text{Kg}}{\text{Kw.hr}}\right] * \left[45 \text{ Kw}\right]\left[\frac{1 \text{hr}}{60 \text{min}}\right]\left[\frac{1 \text{min}}{60 \text{sec}}\right]$$

$$= 3.195 \times 10^{-3} \text{ Kg/s}$$

$$\text{A/F ratio} = \frac{\dot{m}_{air}}{\dot{m}_{fuel}} = \frac{0.0721}{3.195 \times 10^{-3}} = 22.57 \text{ Kg air / Kg fuel}$$

Q6/ An engine operating on the ideal Otto cycle has a compression ratio of 7:1. At the beginning of the compression stroke, the cylinder contains air at 15.6°C and 100 kPa. If the maximum cycle temperature is 1650°C, calculate the temperatures around the cycle, the net specific work and the cycle efficiency.

Note 1: Assume that $c_p = 1.000$ kJ/kg.K and $c_v = 0.714$ kJ/kg.K at all conditions.

Note 2: For an isentropic process:

- $(P_2/P_1) = (v_1/v_2)^{\gamma}$
- $(T_2/T_1) = (v_1/v_2)^{\gamma-1}$
- $w = R(T_2-T_1)/(1-\gamma)$

(4 marks)

Ideal otto cycle / $r_c = 7:1$ / $\gamma = \frac{c_p}{c_v} = \frac{1}{0.714} = 1.4$ / $R = c_p - c_v = 0.286$

Process ① → ② ⇒ isentropic compression

$T_1 = 15.6°C = 288.6°K$

$T_2 = T_1 (r_c)^{\gamma-1} = 288.6° (7)^{1.4-1}$

$= 410.75° K$

$= 137.75°C$ ✓

$$W_{compression} = R\left[\frac{T_2 - T_1}{1-\gamma}\right]$$

$$= 0.286\left[\frac{410.75 - 288.6}{1 - 1.4}\right]$$

$= -87.34$ KJ/kg

Process ② → ③ ⇒ constant volume heat addition ✓

$T_3 = 1650°C = 1923°K$

$q_{in} = C_{\cancel{p}v}(T_3 - T_2) = \overset{0.714}{\cancel{3}}(1923 - 410.75)$

~~= 1512~~

$= 1079.75$ KJ/kg

Process ③ → ④ ⇒ isentropic expansion

$$\frac{T_4}{T_3} = \left(\frac{1}{r_c}\right)^{\gamma-1}$$

$T_4 = T_3\left(\frac{1}{r_c}\right)^{\gamma-1} = 1923\left(\frac{1}{7}\right)^{1.4-1} = 882.96°K$

$= 609.96°C$ ✓

$$W_{expansion} = \frac{R(T_3 - T_4)}{\gamma - 1}$$

2.5

$$= \frac{0.286\,(1923 - 882.96)}{1.4 - 1}$$

$= 743.63$ KJ/kg

Process ④ → ① ⇒ constant volume heat rejection

$q_{out} = C_v(T_4 - T_1) = 0.714(882.96 - 288.$

$= 424.37$ KJ/kg ✓

$W_{net} = W_{expansion} + W_{compression}$

$= 743.63 - 87.34 = 656.29$ KJ ✓

$\eta_t = 1 - \left(\frac{q_{out}}{q_{in}}\right) = 1 - \left(\frac{424.37}{1079.75}\right) = 60.69\%$ ✓

or

$\eta_t = \frac{W_{net}}{q_{in}} = \frac{656.29}{1079.75} = 60.78\%$

(Basic Concepts of I C Engines)

hose the most correct answer(s).

(5 Marks)

2½

✓ Scavenging air in two stroke CI engines mean:

Compressing fresh air to help ignite fuel.
[✓ Compressing fresh air to remove exhaust.]
All of the above.
Compressing fresh air to cool the engine
Compressing Air and Fuel into cylinder:

✓ For same power output and same compression ratio, as compared to two stroke engines, four-stroke S.I. engines have:

Higher fuel consumptions & Tempeatures

[✓ Higher fuel consumption ~~temperatures~~]
~~higher thermal efficiency~~
lower thermal efficiency
Higher exhaust
None of the above

✓ The energy of expanding gas is transferred by piston to connecting rod through

Crank pin
[✓ Gudgeon pin]
Bearing
Crankcase
Piston
rings

✓ An IC engine has a bore and stroke of 2 units each. The area to calculate heat loss can be

[✓ 2π]
4π
5π
6π
8π

✓ State TWO points on the following : -> 2- in Actual Valve timing EVO bBDC EVC aTDC but in Theo. EVO @ BDC, EVC @ TDC

❖ Difference between actual and theoretical valve timing.

1- in Actual valve timing The Inlet valve open before Top dead center and closed After bottom dead center ~~in suction~~. but in the Theoretical valve timing IVO at TDC and ~~closed~~ IVC at BDC in suction

❖ Difference between 2 and 4 stroke engines

1- for cooling in 2-stoke using fins but in 4-stroke using cooling jackets around cylinders

2- in 2-stroke the mixture and exhaust flows through ports but in four stroke flow through a valves Which is cause over lap.

❖ Function of flywheel.

- Start the engine
- helps in piston movements,

❖ Advantages of VVT system.

- لادخال اكبر كمية من ال fresh air وطرد اكبر كمية من ال exhaust product

❖ Problems with Valve-in-Block system.

-

❖ Disadvantages of ICE compared with ECE.

- ICE fuel consumed more amout of fuel than ECE
- ICE have more cooling load than ECE

Solution : bype.

① specific ↑ fuel .
② Torque lower .
③ vibration Higher

Question TWO (A) Engine Performance parameters (5 Marks)

A six-cylinder, four-stroke CI engine with bore 10cm and stroke 12cm runs at 2000 RPM. The engine has compression ratio 18. The engine is connected to a dynamometer which gives reading 300 N-m. Air enters the cylinder at 90 kPa and 39 C with air-fuel ratio 20. The mechanical efficiency of the engine is 85%, combustion efficiency is 98% and fuel calorific value is 42 MJ/kg. Standard atmospheric air density is 1.181 kg/m^3. Calculate:

Brake and Indicated power.
Brake work per unit mass of air
Brake and Indicated thermal efficiency
Brake and indicated MEP
Specific power and volume
Volumetric efficiency
Brake and Indicated Work
Fuel flow rate
Brake and indicated SFC

- Use suitable assumptions

Question TWO (B) Engine Design (5 Marks)

A 4-cylinder, 2L engine operates on 4-stroke cycle is running at 3000 RPM. The engine has compression ratio 9:1. Stroke-to-bore ratio 1.1:1 and connecting rod length 18cm. Calculate :

Clearance volume for one cylinder
Average Piston speed
Engine dimensions (D and S)
Piston speed at crank angle 60° aTDC
Distance and volume moved by piston at 60° aTDC.

Question TWO (A):

2

$n_c = 6$, $n_r = 2$, $d = 10cm$, $S = 12cm$, $N = 2000\ rpm$, $CR = 18$

$\tau = 300\ N.m$, $P_a = 90\ kPa$, $T_a = 39^\circ C$, $A/F = 20/1$, $\eta_m = 0.85$

$\eta_c = 0.98$, $Q_{cv} = 42000\ kJ/kg$, $\rho_{air} = 1.181$

(Brake power) $\dot{W}_B = 2\pi \frac{N}{60} \tau = 2\pi \times \frac{2000}{60} \times 300 = 62831.85W = 62.83\ kW$

(Indicated power) $\dot{W}_i = \frac{\dot{W}_b}{\eta_m} = \frac{62.83}{0.85} = 73.91\ kW$

(Brake mean Effective pressure) $P_{mB} = \frac{\dot{W}_B}{\forall_{s1} n_c \frac{N}{60} \times \frac{1}{n_r}} = \frac{62.83}{0.25\pi(0.1)^2 \times 0.12 \times 6 \times \frac{2000}{120}}$

$\to P_{mB} = 666.64\ kPa$

(indicated mean effective pressure) $P_{mi} = \frac{P_{mB}}{\eta_m} = \frac{666.64}{0.85} = 784.28\ kPa$

(Brake work) $W_B = P_{mB} \forall_{s1} = 666.64 \times 0.25\pi \times (0.1)^2 \times 0.12 = 0.6282\ kJ$

(indicated work) $W_i = P_{mi} \forall_{s1} = 784.28 \times 0.25\pi \times (0.1)^2 \times 0.12 = 0.73916\ kJ$

(air desity) $\rho_a = \frac{P_a}{R T_a} = \frac{90}{0.287 \times (37+273)} = 1.0051\ kg/m^3$

(mass for air)

$m_a = \frac{P \forall_{s1}}{RT} = \frac{90 \times 0.25\pi \times (0.1)^2 \times 0.12}{0.287 \times 312} = 9.472 \times 10^{-4}\ kg$

(Brake work per unit mass air) $\frac{W_B}{m_a} = \frac{0.6282}{9.472 \times 10^{-4}} = 663.21\ kJ/kg$ of air complete (A)

(Specific power) $SP = \frac{\dot{W}_b}{n_c A_p} = \frac{62.83}{6 \times 0.25\pi \times (0.1)^2} = 1333.29$ KW/m²

(Specific Volume) $SV - \frac{V_{s\,total}}{\dot{W}_b} = \frac{0.25\pi \times (0.1)^2 \times 0.12 \times 6}{62.83} = 9 \times 10^{-5}$ m³/KW $= 0.09$ L/KW

(fuel flow rate) $\dot{m}_f$ (Assumptions) $- 1$ kg/s

(Brake thermal Efficiency) $\eta_B = \frac{\dot{W}_b}{\dot{m}_f Q_{cv} \times \eta_c} = \frac{62.83}{1 \times 42000 \times 0.98} = 0.15\%$

(indicated thermal Efficiency) $\eta_i = \frac{73.91}{1 \times 42000 \times 0.98} = 0.179\%$

(Air mass flow rate)

$\dot{m}_a = 20\,\dot{m}_f = 20(1) = 20$ kg/s

(volumetric efficiency)

$$\eta_{vol} = \frac{\dot{m}_a}{\rho_{air} V_{s1} n_c \frac{N}{60} \times \frac{1}{n_r}} = \frac{20}{1.0051 \times 0.25\pi \times (0.1)^2 \times 0.12 \times 6 \times \frac{2000}{60} \times \frac{1}{2}}$$

$\eta_{vol} = 211.12$

(brake specific fuel consumption)

$bSFC = \frac{\dot{m}_f}{\dot{W}_b} = \frac{1 \times 3600}{62.83} = 57.29$ kg/kW.hr

$iSFC = \frac{\dot{m}_f}{\dot{W}_i} = \frac{1 \times 3600}{73.91} = 48.7$ kg/kW.hr

$4\frac{1}{2}$

Question Two (B):

$n_c = 4, n_r = 2, V_{s_{total}} = 2L, V_{s_1} = \frac{2}{4} = 0.5L, N = 3000RPm$

$CR = 9:1, \frac{S}{d} = 1.1, r = 18cm$

(Clearance Volume) $CR = \frac{V_{s_1} + V_{c_1}}{V_{c_1}}, 9 = \frac{0.5 + V_{c_1}}{V_{c_1}} \Rightarrow$ ~~[illegible]~~

$\hookrightarrow V_{c_1} = 0.0625L = 6.25 \times 10^{-5} m^3 V_{c_1}$

(Engine Stroke on Bore) $V_{s_1} = 0.25\pi d^2(S) = 0.25\pi d^2 \times 1.1d$

$\frac{0.5}{1000} = 0.25\pi \times 1.1 \times d^3 \Rightarrow d^3 = \frac{0.5}{1000 \times 0.25\pi \times 1.1} =$ ~~[illegible]~~ $5.787 \times 10^{-4} m$

(Bore) $d = \sqrt[3]{\cancel{[illegible]} \; 5.787 \times 10^{-4}} =$ ~~[illegible]~~ $0.0833m = 8.33cm$

(Stroke) $S = 1.1(d) = 1.1 \times 0.0833 = 0.09163m = 9.163cm$

(Average piston speed) $\overline{U_p} = 2S\frac{N}{60} = 2 \times 0.09163 \times \frac{3000}{60} = 9.$ m

$R = \frac{r}{a} = \frac{2r}{S} = \frac{2 \times 18}{9.163} = 3.93$

(piston speed at 60° aTDC) $U_p(60°) = \overline{U_p} \times \frac{\pi}{2} \sin\theta \left[1 + \frac{\cos\theta}{\sqrt{R^2 - \sin}}\right.$

$U_p(60°) = 9.163 \times \frac{\pi}{2} \sin 60 \left[1 + \frac{\cos 60}{\sqrt{(3.93)^2 - \sin^2 20}}\right] = 14.056m$

Complete (B):

$a = \frac{S}{2} = \frac{0.09163}{2} = 0.045815\,m$

(distance from crank shaft to piston) $S(\theta) = a\cos\theta + \sqrt{r^2 - a^2\sin^2\theta}$

$S(60°) = 0.045815\cos 60 + \sqrt{0.18^2 - (0.045815\sin 60)^2} = 0.1984\,m$

(distance from TDC to piston) $x = r + a - S(60°)$

$x = 0.18 + 0.045815 - 0.1984 = 0.027415\,m$

$$\frac{V(60°)}{V_c} = 1 + \frac{1}{2}(CR-1)\left[R + 1 - \cos(\theta) - \sqrt{R^2 - \sin^2\theta}\right]$$

(Volume moved by piston 60° aTDC) $V(60)°$

$$\frac{V(60)°}{V_c} = 1 + \frac{1}{2}(9-1)\left[3.93 + 1 - \cos 60 - \sqrt{3.93^2 - \sin^2 \boxed{20}}\right]$$

60

$$\frac{V(60°)}{V_c} = 3.05\%$$

$V(60°) = 3.0596 \times 0.0625\,L = 0.191225\,L$

$= 1.912 \times 10^{-4}\,m^3$