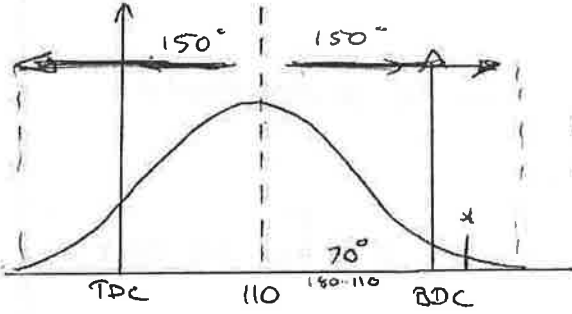




EXAMINATION SOLUTIONS

(to accompany the examination paper sent to the external examiner
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Programme:	BEng Engineering	Level:	5
Module:	Powertrain and Control		
Author:	Owen Williams	Page:	

Q	Question	Marks
1a	 Angle between max opening point (MOP) and midway between BDC and closing is: $\frac{70 + 150}{2} = 110^\circ$ Intake port length i.e. head is 70 mm So time taken for 1 pulse is: $\frac{2n(L + 0.07)}{330}$ Time for crank to turn is: $\frac{110}{360} \times \frac{60}{14,200}$ So we get: $\frac{110}{360} \times \frac{60}{14,200} = \frac{2n(L + 0.07)}{330}$ $L + 0.07 = \frac{330}{2n} \times \frac{110}{360} \times \frac{60}{14,200}$ $L = 0.21 - 0.07 = 0.14 \text{ m}$ $L = 140 \text{ mm}$	

(7)



16 To calculate intake length at 10,000 RPM.

$$\frac{110}{360} \times \frac{60}{10,000} \times \frac{330}{2n} = L + 0.07$$

$$\frac{0.3}{n} = L + 0.07$$

$$\text{for } n=1 \quad L = 0.233 \text{ m}$$

$$n=2 \quad L = 0.08 \text{ m}$$

Packaging for $n=1$ on a motorcycle
does not seem viable

So look again at $n=2$ for 14,000

$$\Rightarrow 0.0365 \text{ for } n=2 @ 14,200$$

So variable intake range needs to be
36.5 mm to 80 mm.

This seems nice.

(3)



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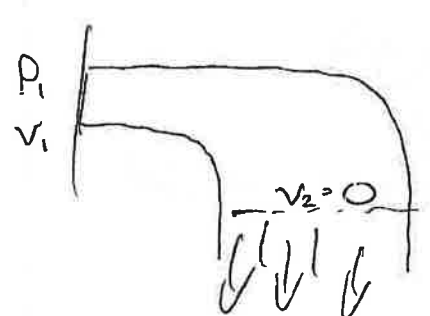
Q	Question	Marks															
1c	Rearranging the original formula to give $RPM = \frac{110}{360} \times \frac{60 \times 330}{2n(L+0.07)} \quad \text{we get}$ <table border="1"> <thead> <tr> <th>n</th><th>36.5mm</th><th>80mm</th></tr> </thead> <tbody> <tr> <td>2</td><td>14202</td><td>10083</td></tr> <tr> <td>3</td><td>9468</td><td>6722</td></tr> <tr> <td>4</td><td>7101</td><td>5041</td></tr> <tr> <td>5</td><td>5681</td><td>4033</td></tr> </tbody> </table> The length of 36.5mm has the most useful spread for this application. A Variable intake based around 36.5 as the shortest length would work well, without the need to go as far as 80mm. An analysis of 36.5 → 50mm would return good results for system optimisation	n	36.5mm	80mm	2	14202	10083	3	9468	6722	4	7101	5041	5	5681	4033	5
n	36.5mm	80mm															
2	14202	10083															
3	9468	6722															
4	7101	5041															
5	5681	4033															



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Q	Question	Marks
1d	 Using Bernoulli's equation we get $P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$ $P_2 = P_1 + \frac{1}{2}\rho v_1^2$ (a) at 30 ms^{-1} $P_2 = 10^5 + 1.2 \times 30^2$ $= 1.01 \text{ Bar (1\% increase)}$ (b) at 90 ms^{-1} $P_2 = 10^5 + 1.2 \times 90^2$ $= 1.09 \text{ Bar (9\% increase)}$ (5)	
Total		20



for best tuning

$$\frac{260}{360} \times \frac{60}{7500} = \frac{2n(L + 0.08)}{563.5}$$

$$L + 0.08 = \frac{260}{360} \times \frac{60}{7500} \times \frac{563.5}{2n}$$

$$L + 0.08 = \frac{1.628}{n}$$

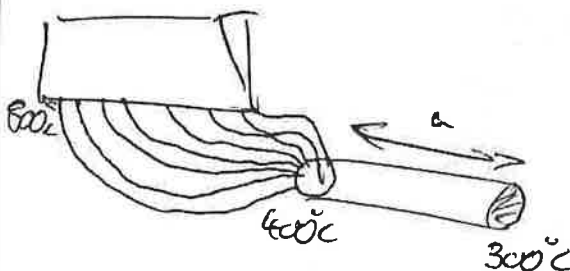
$$L = \frac{1.628}{n} - 0.08$$

when $n=1$, $L = 1.548 \text{ m}$

$n=2$, $L = 0.734 \text{ m}$

go for $n=2$

26



Mean temp to tailpipe
→ 550°C

Mean speed of sound

$$V = 330 \times \sqrt{\frac{273 + 550}{273}}$$

$$V = 552.2 \text{ m s}^{-1}$$

Best tuning is when $\frac{260}{360} \times \frac{60}{5000} = \frac{2n(0.734 + L)}{552.2}$

Assuming $n=1$

$$0.734 + L = \frac{552.2}{2n} \times \frac{260}{360} \times \frac{60}{5000}$$

$$0.734 + L = 2.593 \text{ m}$$

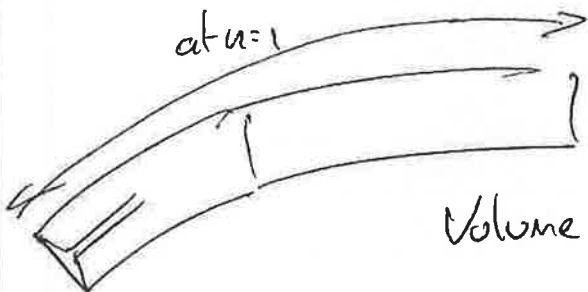
$$L = 1.658 \text{ m} \text{ Reasonable for this application}$$

5



2c Cylinder capacity = $\frac{7500}{8} = 937.5 \text{ cc}$
Air comes in at 20°C
Exhaust mean temp is primary
 600°C

$$\text{Density Ratio} = \frac{600 + 273}{20 + 273} = \underline{2.98}$$



1.628 m
 $= 162.8 \text{ cm}$

Volume in part + primary
 $\sim 162.8 \times \frac{\pi D^2}{4} \text{ cc}$

$$\text{So } 162.8 \times \frac{\pi D^2}{4} = 937.5 \times 2.98$$

$$D^2 = \frac{4 \times 2.98 \times 937.5}{162.8}$$

$$D^2 = 68.64$$

$$D = \underline{8.28 \text{ cm}}$$

(5)



1d for primary,
$$RPM = \frac{563}{2n(1.628)} \times \frac{260}{360} \times \frac{60}{1}$$

for primary plus tailpipe:

$$RPM = \frac{552.2}{2n(2.343)} \times \frac{260 \times 60}{360}$$

n	Primary	Primary + Tailpipe
1	7500	5000
2	3746	2500
3	2500	1666
4	1873	1249
5	1498	1000

The extra harmonics at these lengths correspond to RPMs where we get some proportion of the pulse tuning effect at lower RPMs which will assist in the overall torque spread.

5

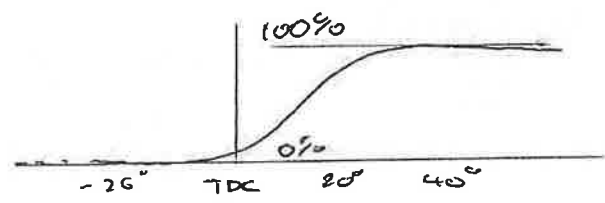
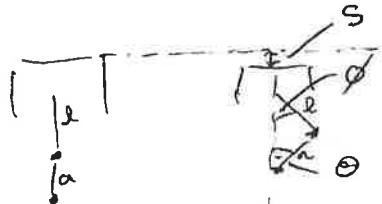
Total 20



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Q	Question	Marks
3	Wiebe Function	
a	$MFB = 1 - e^{-a \left(\frac{\theta - \theta_0}{\Delta \theta} \right)^{n+1}}$	(2)
6	 The Function is used to determine the Mass Fraction burned every degree between 0% at 100% burned. The values of 'a' and 'n' control the shape	(3)
c	 $S = a + l - a \cos \theta - l \cos \phi$ where $a \sin \theta = l \sin \phi$ So $\phi = \sin^{-1} \left(\frac{a}{l} \sin \theta \right)$ This gives us $V = V_c + \frac{\pi B^2}{4} (s)$	(3)



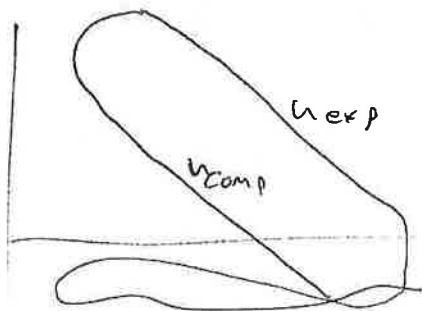
d Given volume every degree and assuming P_1
we get $P_2 = P_1 \left(\frac{V_1}{V_2} \right)^n$ for pressure
without combustion

now implement Wiebe function at correct angle
before TDC. From this, subtract cell 2 - cell 1
to get barit-frachin per degree with
(dQR) Heat = MFB $\times$ calorific value $\times$ fuel mass $\times$ efficiency

From this we can get added pressure
using $P_2 = P_1 \left(\frac{V_1}{V_2} \right)^n + \frac{dQR(\gamma-1)}{V_2}$

where $\frac{dQR(\gamma-1)}{V_2}$ is the added pressure
(N/m²)

when this is all added, we get the
cylinder pressure with combustion.



The gradients of
the straight portions
in compression and
expansion are n

(6)

(3)



3f

ALift

Valve
Velocity

Valve
acceleration

3

Total 20



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Q	Question	Marks
4a	Fuel equivalence Ratio = $\frac{\text{Stoichiometric AFR}}{\text{Actual AFR}}$ at 6000 $FER = \frac{14.7}{10.5} = 1.4$ <u>complete for all</u>	(2)
b	Lambda = FER^{-1} for 6000 $Lambda = \underline{0.714}$ <u>Complete for all</u>	(2)
c	Power = $2\pi \times \text{Torque} \times \frac{\text{RPM}}{60}$ for 6000 RPM $\text{Power} = \frac{2\pi 6000}{60} \times \text{Torque}$ $\text{Power} = \underline{132.2 \text{ kW}}$ <u>Complete for all</u>	(3)



d
$$BSFC = \frac{\text{Fuel mass used}}{\text{Power}}$$

at 6000
$$BSFC = \frac{46.9}{132.2} = 0.355 \text{ kg/kWh}$$

$$BSFC = 355 \text{ g/kWh}$$

Complete for all

e
$$BMEP = \frac{\text{Torque} \times 4\pi}{\text{Displacement}} \quad \text{at 6000}$$

$$BMEP = \frac{210.4 \times 4\pi}{1.6 \times 10^{-3}} = 1.649 \times 10^6 \text{ N/m}^2$$

$$BMEP = 16.52 \text{ Bar}$$

Complete for all

f
$$\text{Overall engine efficiency} = \frac{\text{Mech. energy}}{\text{Fuel energy}}$$

at 6000
$$\frac{\text{Power} \times 3600}{\text{fuel mass/h} \times \text{Calorific Value}} = 0.229$$

$$= 22.9 \%$$



g Reduce friction

(1)

h from $PV = nRT$ and $\rho = \frac{m}{V}$

$$P = \rho RT$$

$$\rho = \frac{P}{RT} \quad \rho \propto \frac{1}{T}$$

Changing temp from 50°C to 20°C
changes absolute temp from 323K to 293K

$\therefore$

$$\frac{\text{Density at } 20^\circ\text{C}}{\text{Density at } 50^\circ\text{C}} = \frac{323}{293} = 1.1$$

Therefore reducing air inlet
temperature from 50°C to 20°C
can increase density by 10%

(3)

Total 20