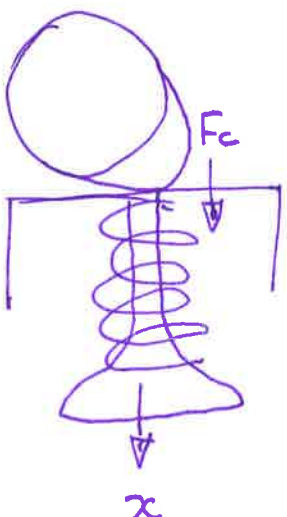




EXAMINATION SOLUTIONS

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

Programme:	BEng Motorcycle Engineering	Level:	5
Module:	Powertrain and Control		
Author:	Owen Williams	Page:	

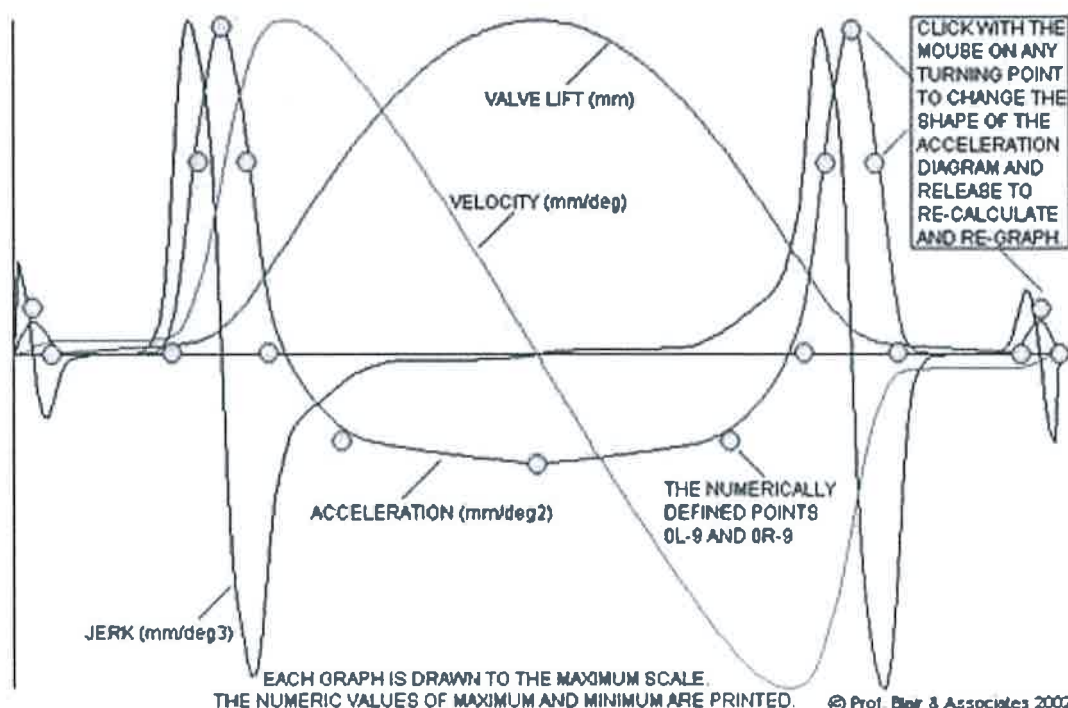
Q	Question	Marks
1a	 Let x_0 = initial compression $F_c - K(x + x_0) = Ma$ $F_c = K(x + x_0) + Ma$ at full lift $0 = 22(8 + 4) + 0.08a$ $-264 = 0.08a$ $a = -3300 \text{ m/s}^2 \text{ for float}$	



16

Angle	Lift	Velocity	Acceleration
106	7.988		
107	7.994	0.006	
108	7.998	0.004	-0.002
109	8.000	0.002	-0.002
110	8.000	0	-0.002
111	7.998	-0.002	-0.002
112	7.994	-0.004	-0.002
113	7.998	-0.006	-0.002

C



- d from the table, max acceleration = -0.002 mm/°
- valve acceleration (m/s²) = $\frac{-0.002 \times (6 \times \text{RPM}_{\text{cam}})^2}{1000}$
- = $\frac{-0.002 \times (6 \times 6000)^2}{1000}$
- = 2592 m/s²
- This is 78.5% of max acc² before float.



d float occurs at an acceleration of -3300 m/s^2

So working back to get RPM --

$$1000 \times (-3300) = -0.002 \times (6 \times \text{Cam RPM})^2$$

$$(6 \times \text{RPM}_{\text{cam}})^2 = \frac{-3300 \times 1000}{-0.002}$$

$$(6 \times \text{RPM}_{\text{cam}})^2 = 1650 \times 10^6$$

$$6 \times \text{RPM}_{\text{cam}} = \sqrt{1650 \times 10^6}$$

$$\text{RPM}_{\text{cam}} = \frac{40620.2}{6}$$

$$\text{RPM}_{\text{cam}} = 6770$$

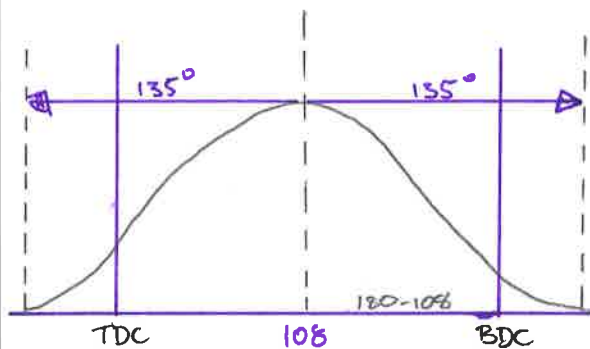
$\therefore$ The crank RPM that float would occur at is 13,540 RPM

Comment on safe limit required.

(5)



2a



Duration : 270°

The angle between max opening (MOP) and midway between BDC and closing.

$$\frac{72 + 135}{2} = 103.5^\circ$$

The intake port length is 80 mm

The time for 1 pulse is $\frac{2N(L + 0.08)}{330}$

The time for the crank to turn 103.5° at Peak torque RPM (4600)

$$T = \frac{103.5}{360} \times \frac{60}{4600}$$

So we get $\frac{103.5}{360} \times \frac{60}{4600} = \frac{2N(L + 0.08)}{330}$

$$L + 0.08 = \frac{330}{2N} \times \frac{103.5}{360} \times \frac{60}{4600}$$

$$L + 0.08 = 0.619$$

$$L = \underline{0.539 \text{ m}}$$

(for $N=2$, we get 0.229 m)



6 Using the values determined in part a, we can jump to:

Time for crank at 7,000 RPM

$$T = \frac{103.5}{360} \times \frac{60}{7000}$$

So we get

$$L + 0.08 = \frac{330}{2N} \times \frac{103.5}{360} \times \frac{60}{7000}$$

$$L + 0.08 = 0.4066$$

$$L = 0.3266$$

(for $N=2$, we get $L = 0.1233$)

Packaging may be difficult for an $N=1$ at 0.54 m (Peak torque), but $N=2$ for peak torque and $N=1$ for peak power (0.229 and 0.3266 m may be packaged well as a variable system since the total change is 91.6 mm

(+)



c Rearranging the formula to give

$$\text{RPM} = \frac{103.5}{360} \times \frac{60 \times 330}{2N(L+0.08)}$$

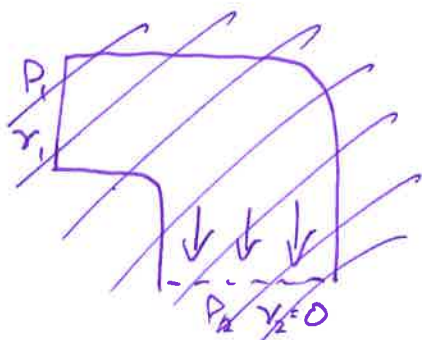
we get

	0.229 m	0.366 m
1	~~9211~~	7000
2	4605	3500
3	3070	2333
4	2302	1750
5	1842	1400
6	1535	1166
7	1315	1000

For a fixed intake, there is not a vast difference and the main benefits would be in terms of a smoother torque delivery for the road application. As such 0.229 would give the best spread.

(5)

d



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

$$P = \rho RT$$

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

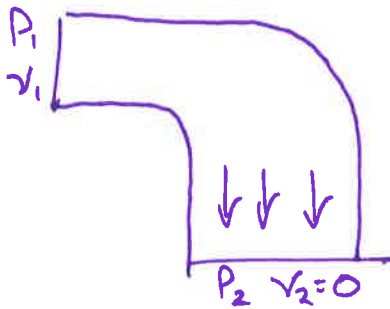
Changing the temperature from 50°C to 20°C
changes absolute temp from 323K to 293K

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

$\therefore$ This 10% density increase will result in a 10% performance increase.

(More molecules going in ...)

(3)



Using Bernoulli's equation, we get:

$$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$$

$$P_2 = P_1 + \frac{1}{2}\rho v_1^2$$

at 250 km/h (69.44 ms⁻¹)

$$P_2 = 10^5 + \frac{1}{2} \times 1.2 \times (69.44)^2$$

$$P_2 = \underline{1.029 \text{ Bar}}$$

This equates to a 2.3% increase

(5)

Total

20

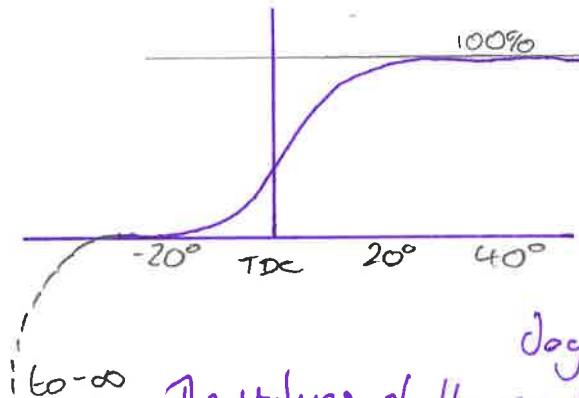


3a Webe function:

$$MFB = 1 - e^{-a\left(\frac{\theta - \theta_0}{\Delta\theta}\right)^{n+1}}$$

(2)

b



The function is used to determine the mass fraction of air/fuel mix burned every degree between 0% and 100%.

The values of the constants a and n control the shape of the function hence the burn profile.

(3)

c

The total heat released is 863 J.

The total pressure will be:

$$\begin{aligned} P_2 &= P_1 \left(\frac{V_1}{V_2} \right)^{\gamma} + \frac{\Delta Q_r (\gamma - 1)}{V_2} \\ &= 25.4 \left(\frac{48.2}{35.2} \right)^{1.35} + \left(\frac{863(1.25 - 1)}{35.2 \times 10^{-6}} \right) \times \frac{1}{10^5} \\ &= 37.45 + 61.3 \\ &= \underline{98.74 \text{ Bar.}} \end{aligned}$$

(5)



3d First law $\Delta Q = \Delta U + P\Delta V$ but since adiabatic

$$\Delta Q = 0 \quad \text{so} \quad 0 = MC_v \Delta T + P\Delta V$$

Now start with

$$PV = nRT$$

$$\Delta PV = nR \Delta T \quad \text{but}$$

$$\Delta PV = (P + \Delta P)(V + \Delta V) - P \cdot V \quad \text{Small}$$

$$\Delta PV = \cancel{PV} + P\Delta V + V\Delta P + \cancel{\Delta P \Delta V} - \cancel{P \cdot V}$$

$$\Delta PV = P\Delta V + V\Delta P \quad \text{so using}$$

$$0 = MC_v \Delta T + P\Delta V \quad \text{and} \quad \Delta T = \frac{\Delta PV}{nR}$$

we get

$$0 = \frac{MC_v(P\Delta V + V\Delta P)}{nR} + P\Delta V$$

$$\text{Now } C_p = C_v + R \quad \text{so} \quad \frac{C_p}{C_v} = \frac{C_v}{C_v} + \frac{R}{C_v}$$

$$\gamma = 1 + \frac{R}{C_v} \rightarrow (\gamma - 1) = \frac{R}{C_v}$$

$$\text{So} \quad 0 = \frac{P\Delta V + V\Delta P}{(\gamma - 1)} + P\Delta V \quad \times \text{ by } (\gamma - 1)$$

$$0(\gamma - 1) = P\Delta V + V\Delta P + (\gamma - 1)P\Delta V$$

$$0 = \cancel{P\Delta V} + V\Delta P + \gamma P\Delta V - \cancel{P\Delta V}$$

$$0 = V\Delta P + \gamma P\Delta V \quad \div PV$$

$$\frac{0}{PV} = \frac{\cancel{V\Delta P}}{\cancel{PV}} + \frac{\gamma \cancel{P\Delta V}}{\cancel{PV}}$$

$$0 = \frac{\Delta P}{P} + \gamma \frac{\Delta V}{V}$$



We now need to integrate.

$$\int 0 = \int \frac{\Delta P}{P} + \gamma \int \frac{\Delta V}{V}$$

$$C = \ln P + \gamma \ln V$$

$$C = \ln P + \ln V^{\gamma}$$

$$C = \ln PV^{\gamma}$$

Therefore we can say

$$\underline{PV^{\gamma} = \text{Constant}}$$



4a Using $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$ so $T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{\gamma-1}$

$$T_2 = (20 + 273) \left(\frac{12}{1}\right)^{0.33} = \underline{665.3 \text{ K}}$$

(3)

b Air mass trapped = $0.9 \times 625 \times 10^{-6} \times 1.2$
 $= 6.75 \times 10^{-4} \text{ kg}$

Fuel mass trapped = $6.75 \times 10^{-4} \times (13.2)^{-1}$
 $= 5.11 \times 10^{-5}$

Heat output = $0.9 \times 5.11 \times 10^{-5} \times 44 \times 10^6$
 $= 2025 \text{ J}$

Temperature rise $\Delta T = \frac{Q}{m c_v} = \frac{2025}{(5.11 \times 10^{-5} + 6.75 \times 10^{-4}) \times 1000}$

$$\Delta T = \underline{2769.5 \text{ K}}$$

(6)

c $T_4 = T_3 \left(\frac{V_3}{V_4}\right)^{\gamma-1} = (665.3 + 2769.5) \left(\frac{1}{12}\right)^{0.33}$
 $T_4 = \underline{1712.7 \text{ K}}$

(2)

d Using $\frac{P_1 V_1}{T_1} = C$ $P_2 = P_1 T_2 \times T_1^{-1}$ and $P_2 \cdot P_1 \left(\frac{V_1}{V_2}\right)^{\gamma}$

$$P_2 = P_1 \left(\frac{12}{1}\right)^{1.33} = 1 (12)^{1.33} = 27.25 \text{ Bar}$$

$$P_3 = P_2 T_3 \times T_2^{-1} = \frac{27.25 \times 3434.8}{665.3}$$

$$P_3 = 140 \text{ Bar}$$

(4)



e The potential energy that could be recovered is :

$$Q = MC_v \Delta T$$

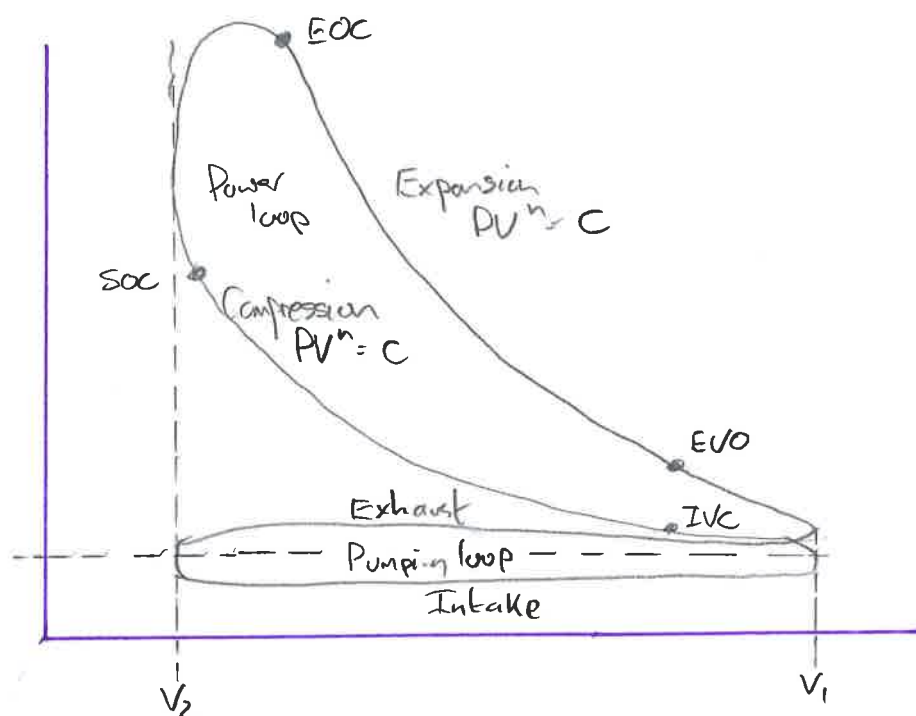
$$Q = (5.11 \times 10^{-5} * 6.75 \times 10^{-4}) \times 1007 \times \Delta T$$

$$Q = 0.7312 \times \Delta T$$

$$Q = 0.7312 \times (1712.7 - 293)$$

$$Q = 1038.1 \text{ Joules}$$

(2)



(3)

Total 20