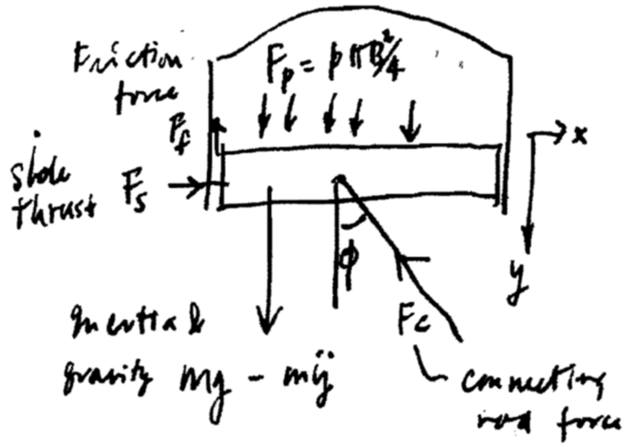
1.2



Note:
1.The inertia force term changes direction during the piston descend.
2. The side thrust F_s is the normal reaction to balance out the x-component of the connecting rod force.

Newton's law $\quad m\ddot{y} = mg - F_c\cos\phi + p\frac{\pi B^2}{4} - F_f$

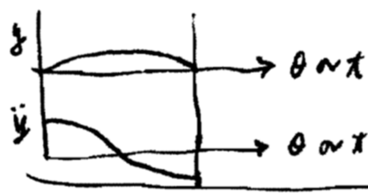
Side thrust $\quad F_s = F_c \sin\phi$

friction $\quad F_f = f F_s \quad$ f is friction coefficient

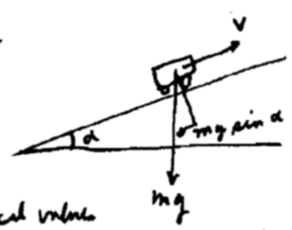
θ and ϕ related by $\phi = \sin^{-1}(a\sin\theta/l)$

For a 85 mm bore piston at p=100 bar, the pressure force is

$$F_P = \frac{\pi B^2 P}{4} = \frac{\pi 0.085^2 x10^7}{4}$$
$$= 5.67x10^4 N$$
$$= 12740 \text{ lb}$$



2-5



$P_{required} = P_{gravity} + P_{drag} + P_{friction}$

$= [mg\sin\alpha + \frac{1}{2}\rho_a C_D A_v V^2 + C_R mg\cos\alpha]\, V$

$= [1500\times9.81\times\sin 15^\circ + \frac{1}{2}\, 1.2\times0.4\times2\times22.4^2 + .013\times1500\times9.81\times\cos15]\times22.4$

$= [3808.5 \quad + \quad 240.8 \quad + \quad 184.8 \quad]\times22.4$

$= \underline{95\,kW}$

typical values
$C_D = 0.4$
$C_R = 0.013$
$m = 1500$ kg

A_v (frontal area) $= 2\,m^2$
$V = 50$ mph $= 22.4$ m/s
$\alpha = 15^\circ$

Note: The drag and friction components are roughly equal. The power to propel against gravity is much higher.

Av. acceleration for 40 to 60 mph in 5 sec. (1 mph = 0.447 m/s)

$a = \frac{\Delta V}{t} = \frac{20\times0.447}{5} = 1.79\, m/s^2$

$ma = 1500\times1.79 = \underline{2685\,N} \quad$ (603 lb force)

2.8

$\eta_{f(brake)} = 0.3$

$bsfc = \frac{\dot{m}_f}{\dot{m}_f Q_{HV} \eta_f} = \frac{1}{Q_{HV}\eta_f}$; Put in conversion factors $bsfc\left[\frac{kg}{kWhr}\right] = \frac{1}{Q_{HV}(J/kg)\,\eta_f} \times 3.6\times10^6$

Fuel	Isooctane	Gasoline	Methanol	H_2
Q_{HV} (lower) (J/kg)	44.3×10^6	44.0×10^6	20.0×10^6	120×10^6
Bsfc (kg/kWhr)	0.271	0.273	0.600	0.100

2.13 1.6 litre displacement engine, 4 cylinder, WOT @ 2500rpm.

Say $B/L = 1 \Rightarrow \frac{\pi}{4}L^3 = 400cc$ or $L = 8\,cm$

mean piston speed $\bar{S}_p = 2NL = 2\times\frac{2500}{60}\times0.08 = \underline{6.67\ m/s}$

Max piston speed (see fig. 2.2 of Text) $\simeq 1.6\,\bar{S}_p = \underline{10.7\ m/s}$

Max charge velocity at intake = Max piston speed × Area ratio $= 10.7\times5 = \underline{54\ m/s}$

(The following are estimates of the time taken for the various processes. Refer to figure 1-8 in Text for more precise numbers.)

- Time per cycle @ 2 revolution per cycle $= \left(\frac{60}{2500}\times2\right) = \underline{48\ ms}$
- Intake, compression, expansion and exhaust each takes up ~ 1/4 of the cycle time ~ $\underline{12\ ms}$
- Combustion: Starts ~ 20° BTC, ends ~ 40° ATC. Duration = 60°

  time $= \frac{60}{720}\times48\ ms = \underline{4\ ms}$
- Flame velocity: Say flame starts at the center (spark plug centrally located). It has to traverse the radius in 4ms

  Flame velocity $= \frac{.04\ m}{4\times10^{-3}s} = \underline{10\ m/s}$
- WOT intake "run length" $= \frac{V_D}{A_{port}} = \frac{V_D}{A_{piston}\times1/5} = \frac{\text{Stroke}}{1/5} = \underline{40\ cm}$
- Exhaust "run length" $= \frac{V_D}{A_{port}} \times$ Temperature ratio $= 40\,cm \times \frac{425+273}{300}$

  $= \underline{93.07\ cm}$

2.61 Internal Combustion Engines
Spring 2017