**ENGINEERING PHYSICS**

**2-4 Efficiency and thermodynamics**

1. $T_H$ = 80°C = 353 K, $T_C$ = 20°C = 293 K, P = 4 W to motor (rate of doing work, W) i.e. 4 $Js^{-1}$
$Q_{OUT}$ per second = 36 J i.e. 36 $Js^{-1}$

(a) (i) $Q_{IN} = W + Q_{OUT}$ = 4 + 36 = 40 $Js^{-1}$

(ii) efficiency = $\frac{\text{useful output}}{\text{input}} = \frac{4}{40}$ = 0.10 to 2 sf (or 10%)

(b) theoretical efficiency = $\frac{T_H - T_C}{T_H} = \frac{353 - 293}{353}$ = 0.16997…. = 0.17 to 2 sf (or 17%)

2. $T_H$ = 79°C = 352 K, $T_C$ = 9°C = 282 K, output power = 3.2 MW = 3.2 x $10^6$ $Js^{-1}$

(a) theoretical efficiency = $\frac{T_H - T_C}{T_H} = \frac{352 - 282}{352}$ = 0.19886…. = 0.20 to 2 sf (or 20%)

(b) assuming the theoretical efficiency is reached then,

Rate of extraction from hot water = input = $\frac{\text{output power}}{\text{efficiency}} = \frac{3.2 \times 10^6}{0.20}$

= 16 x $10^6$ $Js^{-1}$

= 16 MW

3. $T_H$ = 1200 K, $T_C$ = 350 K, gas calorific value = 32 $MJkg^{-1}$ = 32 x $10^6$ $Jkg^{-1}$,
rate of gas supply = 8.4 $kgh^{-1}$ = 2.33 x $10^{-3}$ $kgs^{-1}$, output power = 3.2 MW = 3.2 x $10^6$ $Js^{-1}$
output power = 40 kW = 40 x $10^3$ $Js^{-1}$

(a) theoretical efficiency = $\frac{T_H - T_C}{T_H} = \frac{1200 - 350}{1200}$ = 0.7083…. = 0.71 to 2 sf (or 71%)

(b) (i) power input = gas calorific value x rate of supply

= 32 x $10^6$ $Jkg^{-1}$ x 2.33 x $10^{-3}$ $kgs^{-1}$

= 74.66… x $10^3$ $Js^{-1}$

= 75 kW to 2 sf

(ii) heat transfer to cold sink assuming theoretical efficiency reached:

$Q_{IN} = W + Q_{OUT}$ so $Q_{OUT} = Q_{IN} - W$ = 75 kW – 40 kW = 35 kW

4. (a) (i) Max thermal efficiency is not achieved because: (any two)

- the indicator loop does not have sharp corners like the theoretical one, so less work is done. This is because real valves do not open and close instantaneously.

- perfect combustion does not occur so the maximum temperature is not reached.

- the expansion and compression strokes do not occur perfectly adiabatically as is assumed.

(ii) Maximum mechanical efficiency is not achieved because:

- friction between moving parts cannot be eliminated

- lubricating oils are viscous and hence exert some resistance to the motion of the moving parts.

(b) In summer the cold sink would not be as cold so the difference $T_H - T_C$ would not be as great. Since the theoretical efficiency is $\frac{T_H - T_C}{T_H}$ then this will decrease.

However, an engine is not a thermodynamic heat engine. The mechanical efficiency may increase as the oil will not be as cold and as viscous to start with, but at the operating temperature this may be a negligible effect.

The theoretical percentage efficiency of a petrol engine is given by $\left(1 - \frac{T_D - T_A}{T_C - T_B}\right)$ x 100%

$T_D - T_A$ = the PV curve gap in temperature for the cooling

$T_C - T_B$ = the PV curve gap in temperature for the ignition

As it is warmer in summer, the temperature gaps ($T_D - T_A$ and $T_C - T_B$ ) will be smaller and the curves will be closer together. Less will therefore be lost in the cooling cycle so the efficiency will increase.