ENGINEERING PHYSICS

2-3 Heat engines

1. The efficiency of a heat engine is less than 100% because energy is transferred to the surroundings.

$Q_{IN} = W + Q_{OUT}$ where Q_{IN} = heat transfer in
W = work done
Q_{OUT} = heat transfer out to the surroundings

There always needs to be a low temperature sink to draw the energy from the source so $Q_{IN} \neq W$

Efficiency is defined as $\frac{\text{useful work done}}{\text{energy supplied}} \times 100 = \frac{W}{Q_{IN}} \times 100$

And as $W < Q_{IN}$ the efficiency is always less than 100%

2. 4 cylinders, fuel 43 MJ kg^{-1}, rate of fuel = 3.7×10^{-3} kgs^{-1}, 48 cycles per second, work done = 0.23 kW

(a) Input power = 43 MJ $kg^{-1} \times 3.7 \times 10^{-3}$ kgs^{-1} = 159 100 Js^{-1}

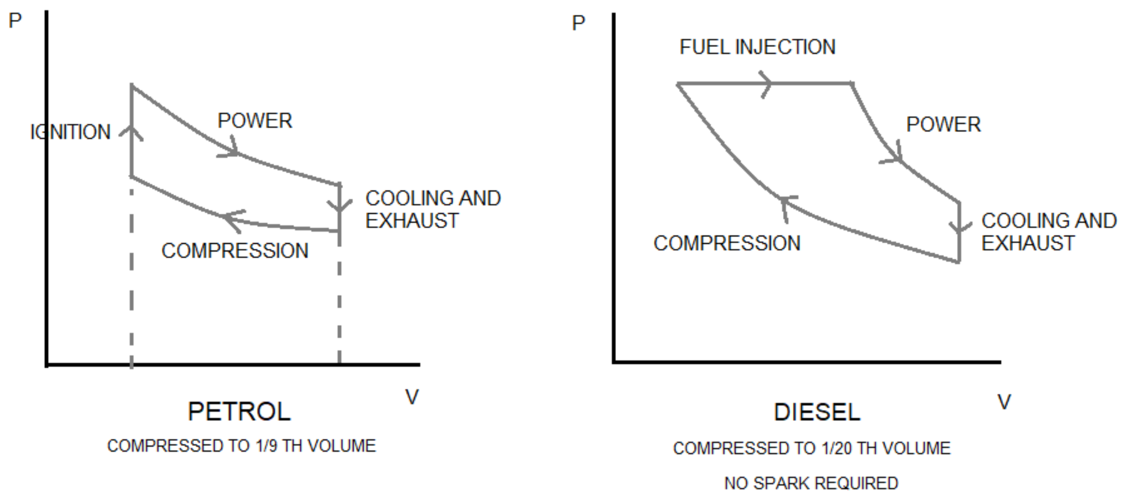
= 160 kW to 2 sf

(b) % thermal efficiency = $\frac{\text{indicated power}}{\text{input power}} \times 100$

Indicated power = 4 cylinders x 48 cycles per second x 0.23 kW = 44.16 kW

% thermal efficiency = $\frac{44.16 \text{ kW}}{160 \text{ kW}} \times 100$ = 28 % to 2 sf

3.



4. 500 $kJkg^{-1}$ of work (for air passing through it) = 500×10^3 Jkg^{-1}, 9.6 kgs^{-1} flow rate,
400 kW (frictional heating so power loss) = 400×10^3 W

(a) (i) work done per second = 500×10^3 $Jkg^{-1} \times 9.6$ kgs^{-1} = 4.8×10^6 Js^{-1}

= 4.8 MW

(ii) output power = $4.8 \times 10^6 - 400 \times 10^3 = 4400 \times 10^3 - 400 \times 10^3$

= 4400×10^3 W

= 4.4 MW

(b) 42 $MJkg^{-1}$ in the fuel, 0.31 kgs^{-1} used

(i) Input power = 42 MJ kg^{-1} x 0.31 kgs^{-1} = 13.02 MJs^{-1}

= 13 MW to 2 sf

(ii) efficiency = $\frac{\text{output power}}{\text{input power}}$ = $\frac{4.4\ \text{MW}}{13\ \text{MW}}$ x 100 = 0.34 to 2 sf (34%)