1st law of thermodynamics:

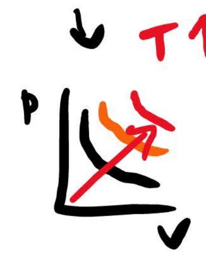
$pV = nRT$

$$Q = U + W$$

- heat supplied → Q (-ve if heat removed)
- Δ internal E → U ($\propto$ Temp) (-ve if cools)
- work done by gas → W (-ve if compressed) $= p\Delta V$

adiabatic constant: γ

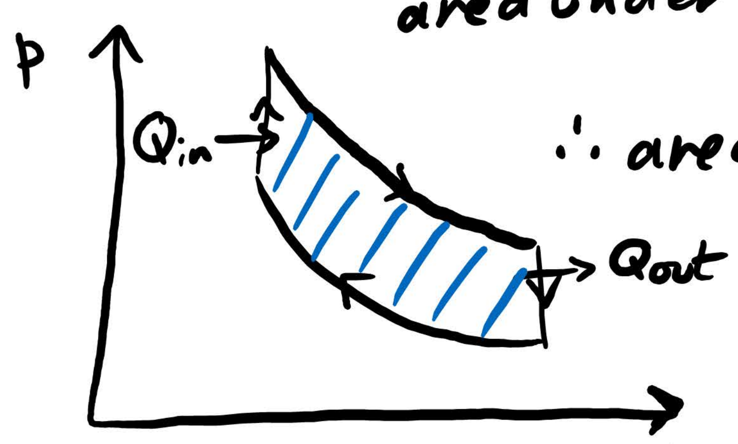
- Adiabatic: $Q = 0 \therefore -U = W \therefore p_1V_1^\gamma = p_2V_2^\gamma$
- Isothermal: $U = 0 \therefore Q = W \therefore p_1V_1 = p_2V_2$
- Constant V: $W = 0 \therefore Q = U \therefore \frac{p_1}{T_1} = \frac{p_2}{T_2}$
- Isobaric: $\Delta P = 0 \therefore \frac{V_1}{T_1} = \frac{V_2}{T_2}$



* INDICATOR DIAGRAM

area under lines = work done by/on gas

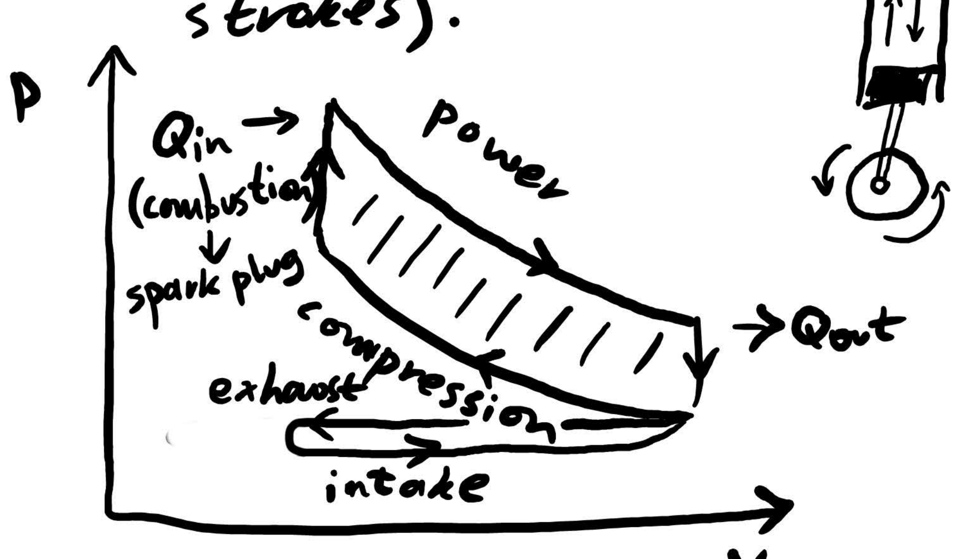
∴ area enclosed in loop = net work out per cycle.

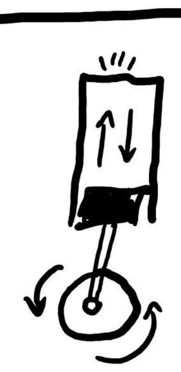


Heat Engine: any device that causes net work to be done by gas by adding Q.

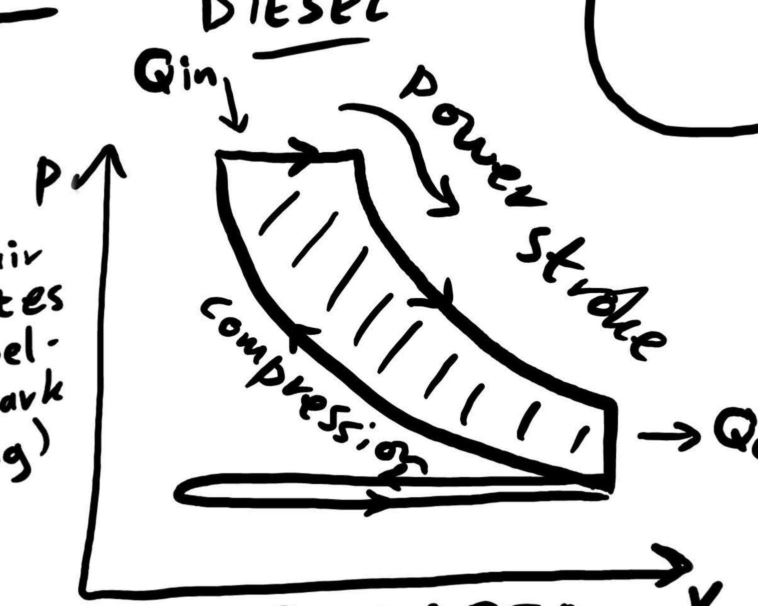
* OTTO CYCLE: PETROL ENGINES

(can omit exhaust strokes).



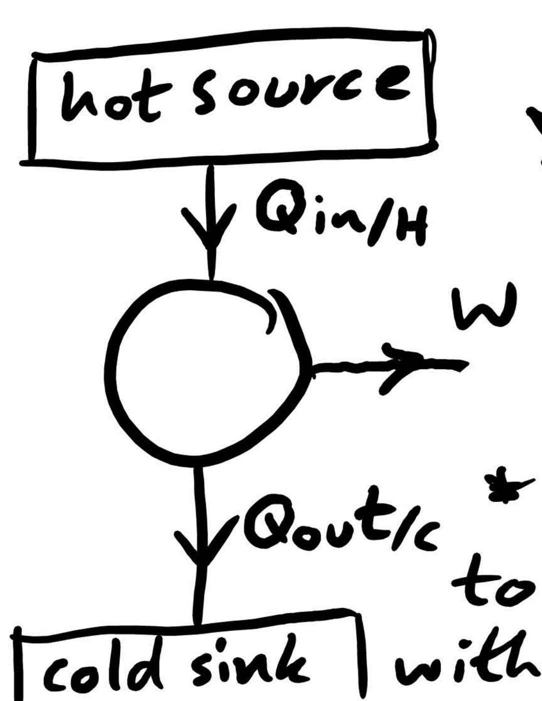


DIESEL



BIGGER AREA = MORE WORK!

- ENERGY FLOW DIAGRAM



THERMODYNAMICS

- Impossible for Qin = W (perfect engine!)

* 2nd law: 'It is not possible to convert heat continuously into work without at the same time transferring some heat from a warmer body to a colder body'.

∴ no engine can be 100% efficient.

* Max theoretical efficiency:

$$\varepsilon = \frac{W}{Q_H} = \frac{Q_H - Q_c}{Q_H} = \frac{T_H - T_c}{T_H}$$

(in K!)

ROTATIONAL DYNAMICS

mass: 'how hard it is to get an object moving'

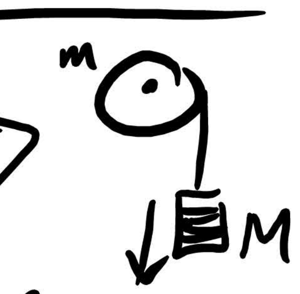
moment of inertia: " " " " " " " " spinning'

Dimension	Linear eqv	Symbol	Unit	Equation
moment of inertia	mass	I	kgm^2	Ring/mass $I = mr^2$; Disc $I = \frac{1}{2}mr^2$
torque	Force	T	Nm	$T = I\alpha$; $T = Fr$ *
angular disp	disp.	θ	rad	/////
ang. vel.	velocity	ω	$rad\,s^{-1}$	$\omega = \frac{\Delta\theta}{t}$
ang. acc^n	acc^n	α	$rad\,s^{-2}$	$\alpha = \frac{\Delta\omega}{t}$
ang. momentum	momentum	L	kgm^2s^{-1}	$L = I\omega$
work done	←	W or E	J	$E = T\theta$
power	←	P	W	$P = T\omega$

suvat:

$v = u + at$	$\omega_2 = \omega_1 + \alpha t$
$v^2 = u^2 + 2as$	$\omega_2^2 = \omega_1^2 + 2\alpha\theta$
$s = ut + \frac{1}{2}at^2$	$\theta = \omega_1 t + \frac{1}{2}\alpha t^2$
$s = \left(\frac{u+v}{2}\right)t$	$\theta = \frac{\omega_1 + \omega_2}{2}t$

* $E_K = \frac{1}{2}I\omega^2$ ⇒



GPE lost = E_K mass + E_K wheel (+ work done wheel)

$$Mgh = \frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2 (+ T\theta)$$

($T\theta$ due to friction)

* Angular momentum coupling

Two spinning objects coupling, reach common ω.

Total ang. mom^n conserved, even if energy lost.

$$L_1 + L_2 = L_{12}$$

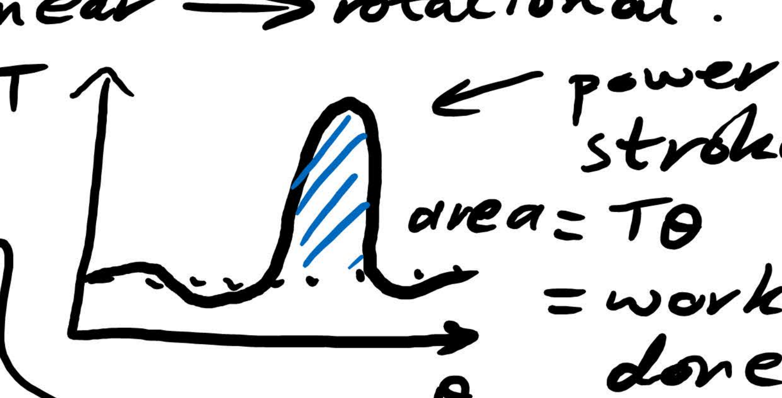
$$I_1\omega_1 + I_2\omega_2 = (I_1 + I_2)\omega_3$$

ENGINEERING PHYSICS

* Input P: from burning fuel
* Indicated P: work done (pV loop) × cycles per s × # cylinders
* Brake P: output P.
* Mechanical $\varepsilon = \frac{\text{brake P}}{\text{ind P}}$
* overall $\varepsilon = \frac{\text{brake P}}{\text{input P}}$
* Thermal $\varepsilon = \frac{\text{ind P}}{\text{input P}}$

FLYWHEELS: needed to smooth torque resulting from linear → rotational.

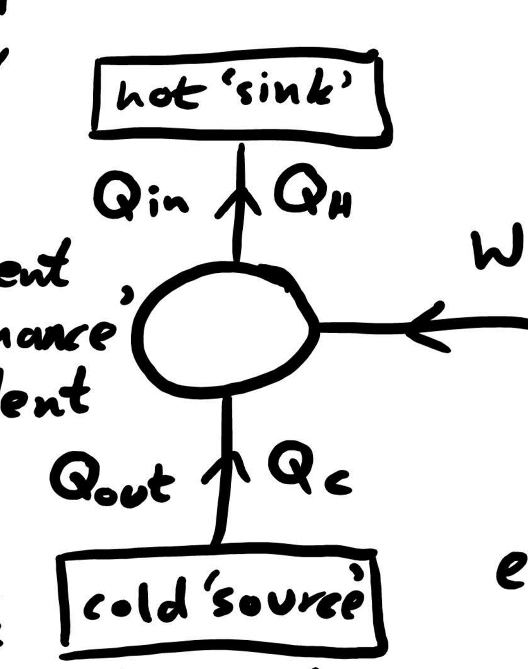
- Stores E_K!



HEAT PUMP & REFRIGERATOR

'Do the opposite to an engine: work is done on gas to get Qout'.

* COP: > 1. Higher = 'better'.



'Coefficient of Performance' 'efficiency' equivalent

$$COP_{fridge} = \frac{Q_c}{W} = \frac{Q_c}{Q_H - Q_c} = \frac{T_H}{T_H - T_c}$$

$$COP_{heat\ pump} = \frac{Q_H}{W} = \frac{Q_H}{Q_H - Q_c} = \frac{T_H}{T_H - T_c}$$

→ better than electrical radiators

* COMBINED HEAT & POWER

Can use some work from engine to drive generator + heat pump: more efficient than just using electricity to heat.