5/1

turbine ≡ rotational device that extracts energy from a moving fluid

Hydro Turbines

↓

mostly dams - why?

where is energy in moving fluid?

kinetic energy $= \frac{1}{2} m v^2$

kinetic energy density $= \frac{\text{energy}}{\text{mass}} = \frac{1}{2} v^2$

gravitational potential energy = mgh

potential energy density = gh

pressure? from units:

$P = \frac{\text{Force}}{\text{Area}}$, $E = \text{Force} \cdot \text{distance}$ } $E = \frac{\text{Force} \cdot \text{distance}}{\text{Area}} \cdot \text{Area} = \text{Pressure} \cdot \text{Volume}$

*for incompressible fluid (assume temp & volume constant)

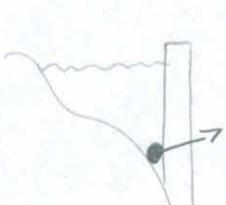
in terms of mass: $E = \text{Pressure} \cdot \text{mass} \cdot \frac{\text{Volume}}{\text{mass}}$

$= \text{Pressure} \cdot \text{mass} / \text{density}$

pressure energy density: $E = \text{Pressure}/\text{density} = P/\rho$

$\therefore \sum \text{energy density} = \frac{1}{2} v^2 + gh + P/\rho$ → Bernoulli's Equation

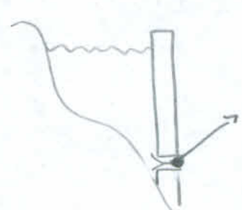
conservation of energy



$v = 0$

$h = 0$

$e = P/\rho$



$h = 0$

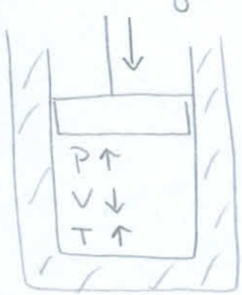
$P = 0$

$e = \frac{1}{2} v^2$

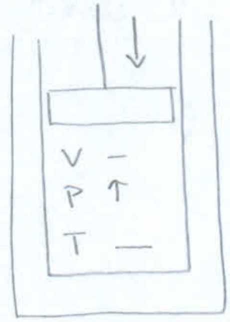
$e = P/\rho = \frac{1}{2} v^2$

what is an incompressible fluid?

NOT gas:



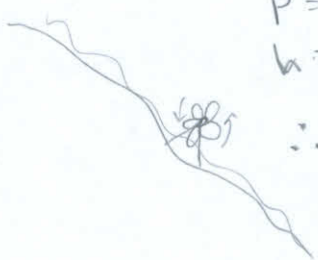
water:



→ volume constant!

→ temp constant ⟹ we can ignore thermal energy

free stream hydro:



$P = 0$

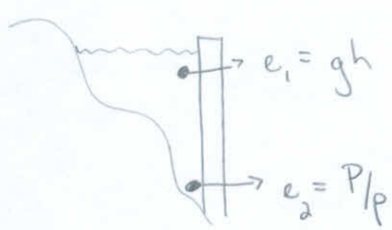
$h > 0$ but can't harness it

$\therefore\ e = \frac{1}{2}v^2 \rightsquigarrow v_{river} \sim 1\ m/s$

$e = 0.5\ J/kg$

×2,000!!!

dam:



$h \sim 100\ m \rightarrow e_1 \sim 1000\ J/kg$

P from weight of water

F from weight of water $= mg = \rho V g = \rho \cdot A \cdot h \cdot g$

$P = \frac{F}{A} = \rho h g$

$e = \frac{P}{\rho} = hg \Longrightarrow$ no energy gradient in dam

How did we get 2,000 times as much energy from the same water?

Dam doesn't create energy; it prevents energy loss. Normal rivers lose energy due to friction (equivalent to resistance in electrical circuits) → convert to heat on stuff it bumps into.

(see slides for dam definitions & tradeoffs)

$q = \frac{m}{t}$

$$\text{Power} = \frac{\text{Energy}}{\text{time}} = \frac{\text{Energy}}{\text{mass}} \cdot \frac{\text{mass}}{\text{time}} = \text{head} \cdot \text{flow} = \varepsilon q$$

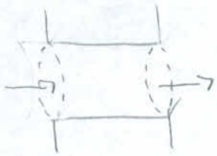
$\varepsilon = gh$

q

compare $P = IV$: $I \sim q$

$V \sim \varepsilon$

OR



$$q = \frac{\text{mass}}{\text{time}} = \rho A v$$

$$P = \varepsilon q$$