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:

\[
\begin{align*}
P &= \frac{\text{Force}}{\text{Area}} \\
E &= \frac{\text{Force} \cdot \text{distance}}{\text{Area}}
\end{align*}
\]

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:

\[
E = \text{Pressure} / \text{density} = \frac{P}{\rho}
\]

\[
E = \frac{1}{2} v^2 + gh + \frac{P}{\rho} \rightarrow \text{Bernoulli's Equation}
\]

conservation of energy

\[
e = \frac{P}{\rho} = \frac{1}{2} v^2
\]
What is an incompressible fluid?

**NOT gas:**

**Water:**

- V volume constant!
- T temp constant \( \Rightarrow \) we can ignore thermal energy

Free stream hydro:

\[
p = 0
\]

\[
h > 0 \text{ but can't harness it}
\]

\[
\therefore \quad e = \frac{1}{2} \cdot v^2 \Rightarrow v_{river} \sim 1 \text{ m/s}
\]

\[
e = 0.5 \text{ J/kg}
\]

\[
\times 2,000 \ldots
\]

**Dam:**

\[
e_i = gh
\]

\[
e_2 = \frac{P}{\rho}
\]

- P from weight of water
- F from weight of water = \( mg = \rho \cdot Vg = \rho \cdot A \cdot h \cdot g \)

\[
P = \frac{E}{A} = \rho h g
\]

\[
e = \frac{P}{\rho} = hg \Rightarrow \text{no energy gradient in dam}
\]

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) \( \Rightarrow \) convert to heat on stuff it bumps into.

(see slides for dam definitions & tradeoffs)
Power = \frac{\text{Energy}}{\text{time}} = \frac{\text{Energy}}{\text{mass}} \cdot \frac{\text{mass}}{\text{time}} = \text{head} \cdot \text{flow} = \varepsilon q

P = \varepsilon q

q = \frac{\text{mass}}{\text{time}} = \rho AV

OR

\varepsilon = gh

compare \ P = IV; \ I = q

V \sim \varepsilon