# Fluid Power (Ch 12 p254)

Tuesday, 30 August 2011
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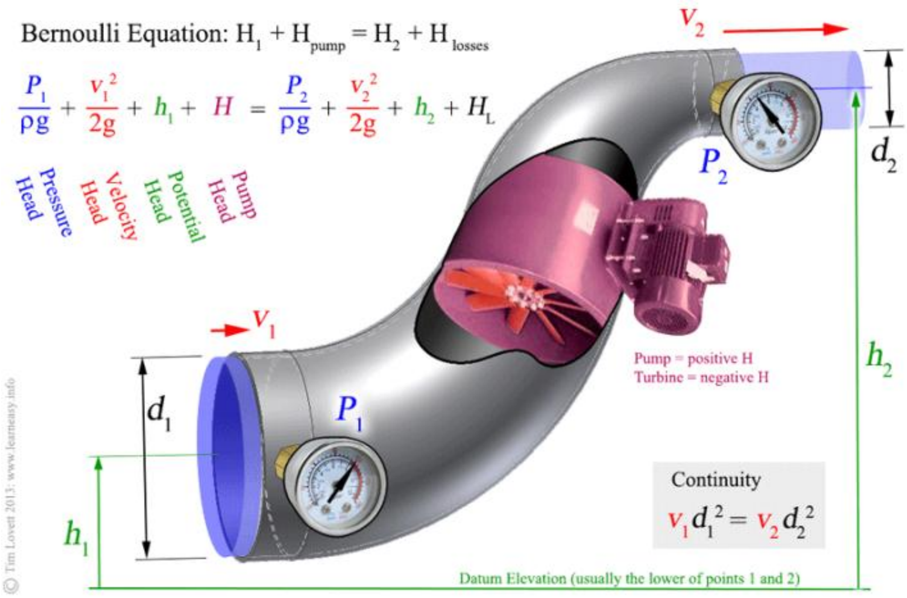
**Continuity:**

$$\dot{V} = vA$$




**Power:**

$$P = \dot{m}gH$$

(Pressure dominant system. e.g. Hydraulics)

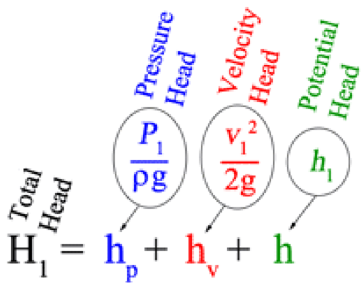
$$P = p\dot{V}$$

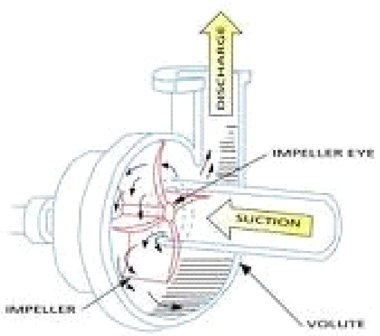
**Full Bernoulli:**

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + h_1 \pm H = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_2 + H_L$$

$$P = \dot{m}gH$$

P = power (W)
$\dot{m}$ = mass flow rate (kg/s)
H = total Head change ($H = H_2 - H_1$)




**Simplifications;**
Inlet diam = outlet diam
*(Velocity head unchanged)*
Inlet height = outlet height
*(Potential head unchanged)*
Pressure usually changes!

Hydraulics. Pressure is very high, flowrates not very significant, potential heights negligible.
Watch this...
Hydraulics 20Mpa
$h_p = p/\rho g$

$= 20e6/(820*9.81)$
$= 2,486$ m
About 2.5 km high!!

So, this equation

$$P = \dot{m}gH$$

becomes $P = \dot{m}gh_p = \dot{m}gp/\rho g = \dot{m}p/\rho = p\dot{V}$

$$P = p\dot{V}$$

So, to use POWER in Bernoulli equation, you need to convert to HEAD...

$$H = \frac{P}{\dot{m}g}$$

# Efficiency

Tuesday, 13 September 2011
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## Efficiency

p257

$$\eta = \frac{P_f}{P}$$

$P_f$ ← FLUID POWER

$P$ ← SHAFT (Mech) POWER

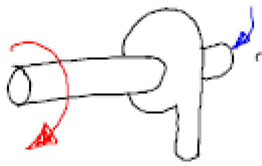
$$\eta = \frac{OUT}{IN}$$

$T\omega = \rho\dot{V}$

$P_f$

$P_f = \dot{m}gH$

$P_f = \rho\dot{V}$



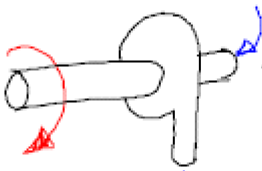
PUMP

MECH POWER

$P = T\omega$

$$\eta = \frac{P_f}{P}$$

FLUID POWER $= \rho\dot{V}$



TURBINE

MECH POWER

$P = T\omega$

$$\eta = \frac{P}{P_f}$$

FLUID POWER $= \rho\dot{V}$

$\eta < 1$ Check common sense!

# Example Pump

Example: Hydraulic Pump
Hydraulics: (Pressure dominant)

$$P = p\dot{V}$$

Convert from Absolute pressure...
p = 6500 - 101.3 = 6398.7 kPa

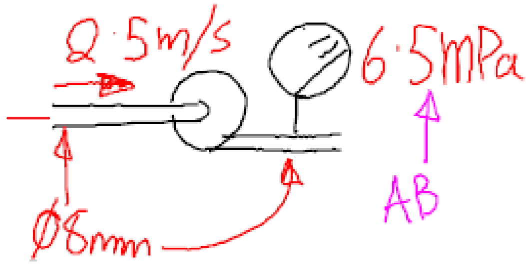
$$\dot{V} = vA$$

= 2.5 * Pi * 0.008^2/4
= 0.00012566 m3/s

$$P = p\dot{V}$$

= 6398.7*1000 * 0.00012566
= 804.060642 W

> Watch this...
> Hydraulics 20Mpa
> $h_p = p/\rho g$
> = 20e6/(820*9.81)
> = 2,486 m
> About 2.5 km high!!




$$P = \dot{m}gH$$

Oil density = 820 kg/m3
m = Vρ = 0.00012566 * 820 =
= 0.1030412 kg/s
H = hp + ~~hv~~ + ~~h~~
= p / ρg
= 6398700 / (820*9.81)
= 795.4427 m

$$P = \dot{m}gH$$

= 0.1030412*9.81*795.4427
= 804 W

# Examples continued

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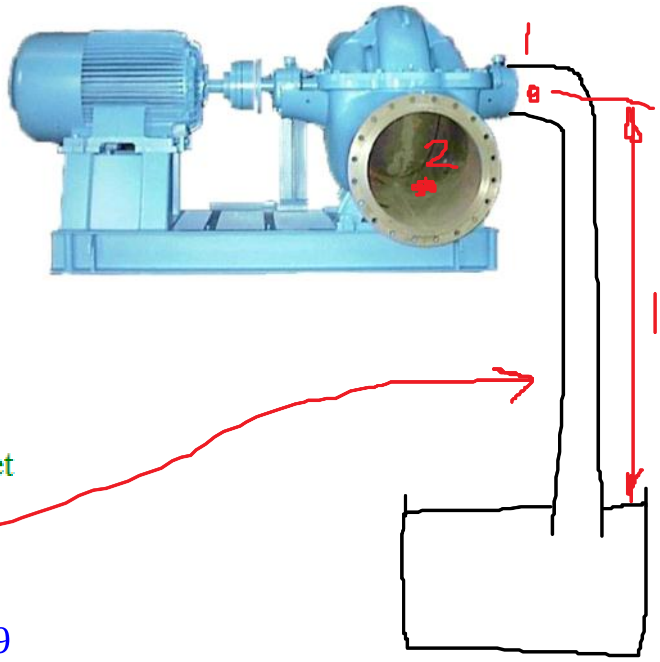


Q1: This 9.3 kW pump handles 46 L/s. (a) Find the increase in head.

$$P = \dot{m}gH$$

$$H = P/\dot{m}g = 9300/(46*9.81) = 20.609 \text{ m}$$

Q2: (cont) This 9.3 kW pump handles 46 L/s. The inlet pressure is -11 kPa. (b) What is outlet pressure?

All in pressure head...

$$H2 = H1+hp = -11000/(1000*9.81) + 20.609$$
$$= -1.1213 + 20.609 = 19.4877 \text{ m}$$

Outlet pressure: $hp = p/\rho g$ so $p = hp*\rho g = 19.4877*1000*9.81 = 191174.337$
$= 191.174 \text{ kPa}$

Q3: (cont) This 9.3 kW pump handles 46 L/s. The inlet pressure is -11 kPa. Motor power is 17 kW. (c) What is the efficiency (percentage)?

$$\eta = 9.3/17 = 0.5471$$

Example of efficiency and power equations for conversion from electrical to shaft to fluid power.

Shaft power

Fluid Power

# Example 12.5 (p260)

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Find the power of the turbine when head loss= 0.6m and exit velocity = 3.5m/s.

Bernoulli & Power $H_1 = H_2$

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + h_1 \pm H = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + h_2 + H_L$$

$h_p$ $h_v$

+H = PUMP
-H = TURBINE

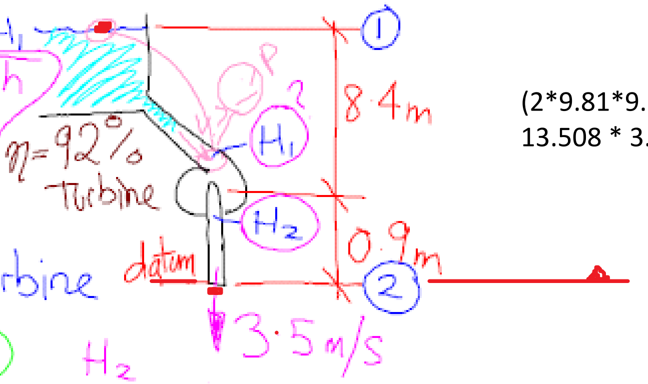
HEAD LOSS

Prob 12.5 p260

$H_1 = H_2$

Total Head stays the same unless friction or pump/turbine

Check $H_1$: $V_2 = \sqrt{2gh} = 13.5$ m/s




$H_1$ FIND $H_2$

(2*9.81*9.3)^0.5 = 13.508 m/s
13.508 * 3.6 = 48.6288 m/s

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + h_1 \pm H = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_2 + H_L$$

$H_L$ = 0.6

$$P = \dot{m}gH$$

Find the Power produced for every $1m^3$ of water per second.

$h_1$= 8.4+0.9 = 9.3 m

$H_t$ = turbine head ?

$h_{v2}$ = 3.5^2 / (2*9.81) = 0.6244 m

$H_t$ = 0.6244 - 9.3 + 0.6 = -8.0756 m

Find the power per $m^3$ of water...

Take 1 $m^3$ per second...

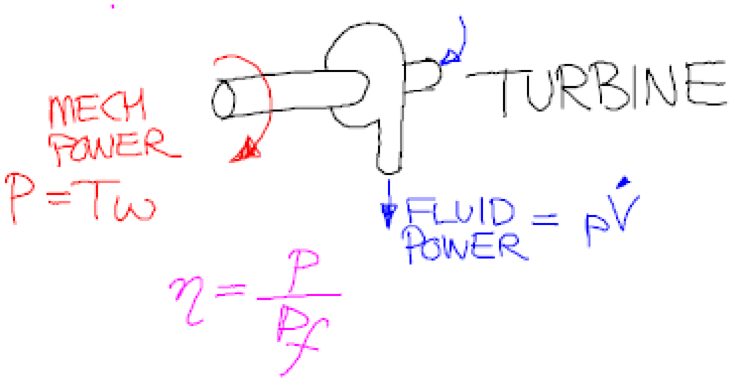
$$P = \dot{m}gH$$

= 1000*9.81*-8.0756

= -79221.636 W

= -79.2216 kW (fluid power taken by the turbine)

Output power (efficiency = 92%)




P out = 79.2216 * 0.92 = 72.8839  kW (shaft power)

... *Keep going...*

This is shaft power, which is...

P = Tω

Generator at 95%,

Electric power = 72.8839 *0.95 = 69.2397  kW (electrical power)

P = VI

# Examples continued

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**Continuity:**

$$\dot{V} = vA$$

$$\dot{m} = \rho gh$$

**Power:**

$$P = \dot{m}gH$$

(Pressure dominant system. e.g. Hydraulics)

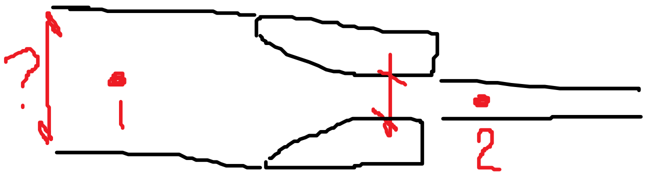
$$P = p\dot{V}$$

**Full Bernoulli:**

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + h_1 \pm H = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_2 + H_L$$

Q7: A water-jet cutter produces a jet of 0.4 mm diameter at a speed of 930 m/s. (orifice diam is much smaller than water inlet tube) (a) What pressure is needed?

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + h_1 \pm H = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_2 + H_L$$




$h_{v2}$ = 930^2/(2*9.81) = 44,083 m
p1 = 44083*(1000*9.81) = 432454230 Pa = 432.454230 MPa

Q8: (cont) A water-jet cutter produces a jet of 0.4 mm diameter at a speed of 930 m/s. (orifice diam is much smaller than water inlet tube) (b) What is the volume flowrate?

$$\dot{V} = vA$$

V = 930* Pi*(0.4/1000)^2/4 = 0.0001168673 $m^3/s$
= 0.1168673 L/s

Q9: (cont) A water-jet cutter produces a jet of 0.4 mm diameter at a speed of 930 m/s. (orifice diam is much smaller than water inlet tube) (c) What power is required?

$$P = p\dot{V}$$

P = 432454230*0.0001168673 = 50540 W

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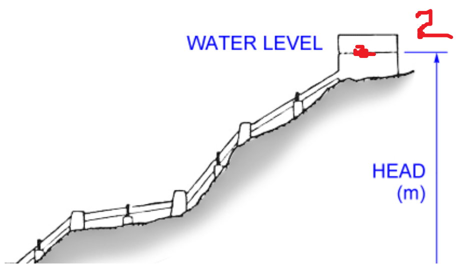
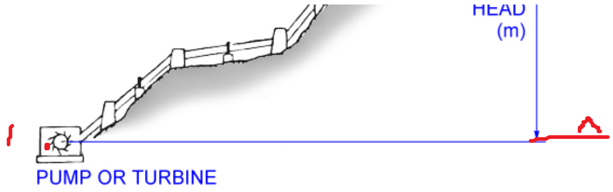
Q11: A pump transfers water at 41 L/s from 120 m to 132 m elevation. Head loss is 2.3 m. Pump effiiciency is 66%. (a) What fluid power is required?

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + h_1 \pm H = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_2 + H_L$$



$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + h_1 \pm H = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_2 + H_L$$




There is no pipe diameter given.
This means we cannot calculate the velocity.
So we must assume a large pipe diameter - hence a negligable velocity head.
h2 = 132-120 = 12 m
The pump is doing ALL the work, so the fluid must be starting from ZERO pressure...
H = 12 + 2.3 = 14.3 m

$P = \dot{m}gH$

= 41*9.81* 14.3 = 5751.603 W (fluid power)
Pump efficiency is 66%, so the shaft power required:
5751.603 / 0.66 = 8714.55 W (shaft power)

So total efficiency is: 0.66*0.66 = 0.4356 %

# Wind Turbine

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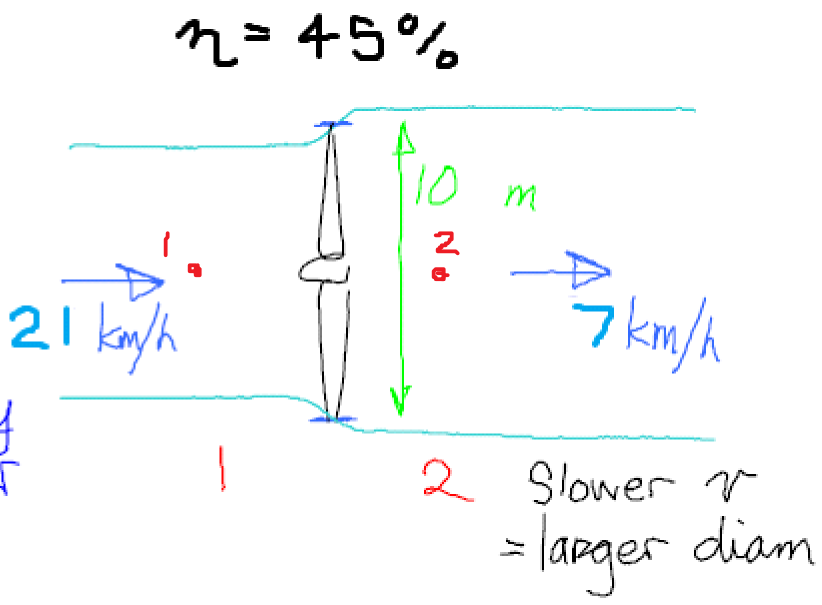
Wind Turbine

See q12.5 p261

PROPELLOR TRICK

Take the average velocity @ the propellor




(a) Find the mass flow rate
Find V (at propellor): V = vA
Velocity at propellor = (21+7)/2 = 14 km/h
v = 14/3.6 = 3.8889 m/s
A = pi*5^2 = 78.5398 $m^2$
V = vA = 3.8889 * 78.5398 = 305.4334 $m^3/s$
Convert to kg/s: ρ = 1/0.85 = 1.1765 kg/m3
m = ρV = 305.4334*1.1765 = 359.34 kg/s
(b) Find the change in head across the turbine

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + h_1 \pm H = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_2 + H_L$$

H = $v_2^2/2g$ - $v_1^2/2g$ = $h_{v2}$ - $h_{v1}$
$h_{v2}$ = (7/3.6)^2/(2*9.81) = 0.1927 m
$h_{v1}$ = (21/3.6)^2/(2*9.81) = 1.7343 m
H = $h_{v2}$ - $h_{v1}$ = 0.1927 - 1.7343 = -1.5416 m

(c) Find power

$$P = \dot{m}gH$$

= 359.34 * 9.81 * -1.5416 = -5434.33 W (5.43 kW)
(c) Find electrical power

5434.33*0.45 = 2445.4485 W (2.445 kW)

# Pumping System Oil

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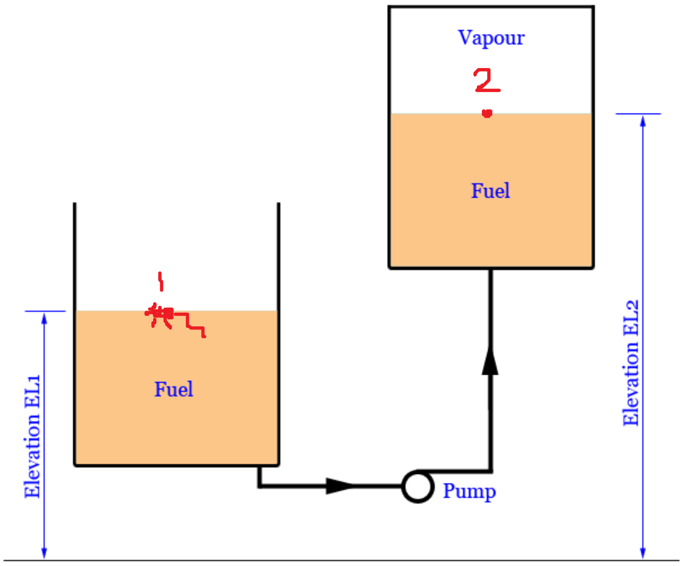
Q22: Fuel (RD=0.77) is pumped at 14 kg/s from an open tank at EL1=2.6m to closed tank at EL2=6.2m with vapour pressure 104 kPa. Calculate power required (ignoring losses)




$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + h_1 + H = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_2 + H_L$$

$h_{p2}$ = 104000/(0.77*1000*9.81) = 13.7681 m

$H = p_2/\rho g + h_2 - h_1$

= 13.7681 + 6.2 - 2.6 = 17.3681 m

$P = \dot{m}gH$

= 14 * 9.81 * 17.3681

= 2385.335 W

# Pumping System 2

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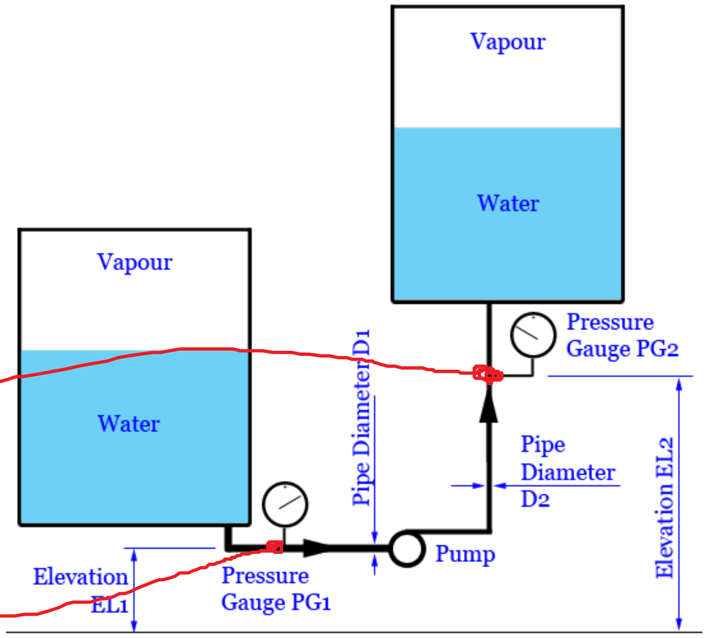
Q26: Flowrate=34L/s, PG1=20kPa, PG2=81kPa, D1=100mm, D2=71mm, EL1=3.6m, EL2=10.4m. (a) Find pump power




$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + h_1 \pm H = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_2 + H_L$$

Use continuity to get velocities at 1 and 2... $\dot{V} = vA$

Then...

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + h_1 \pm H = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_2 + H_L$$

Then ...

$$P = \dot{m}gH$$