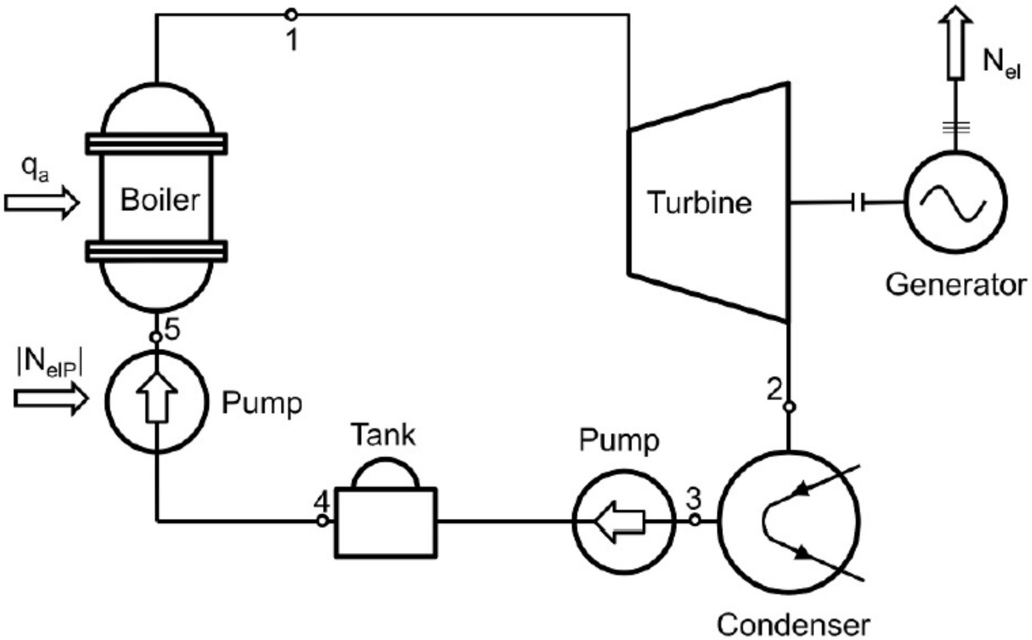
SH2706
Sustainable Energy Transformation Technologies

Home Assignment 4

HA4_P07



A Coal-fired boiler generates superheated steam with pressure 3.5 (MPa) and temperature 775 (K).

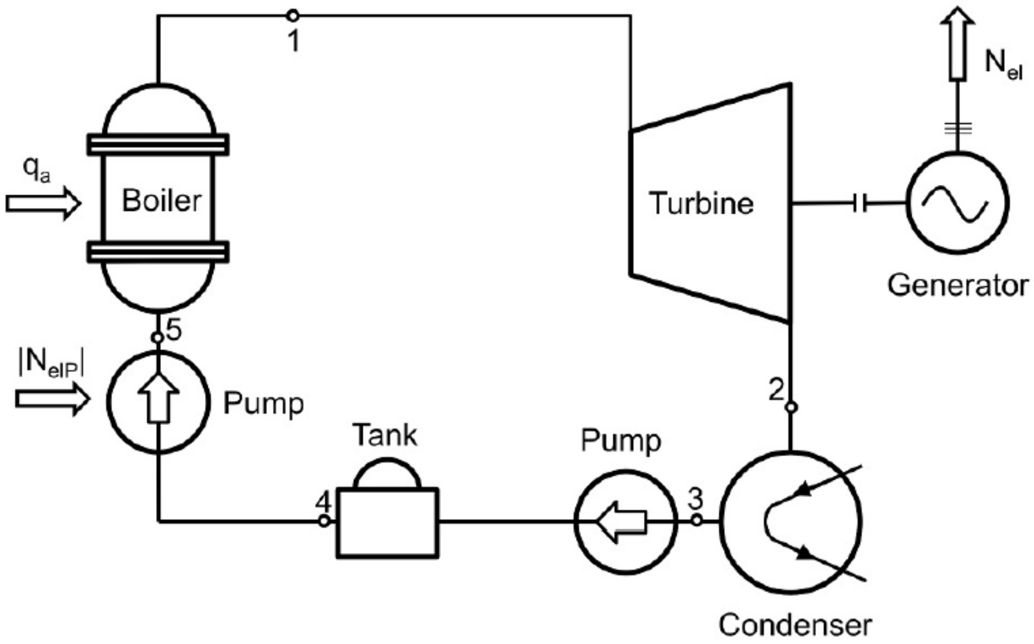
The Condenser pressure is p2 = p3 = 6 (kPa) and the steam mass flow rate is 13 (kg/s). The Electric power of the generator is 11 (MW). Condensate leaving the condenser has a temperature 308 (K) and next is pumped into a vessel with pressure 0.1 (MPa). The pump feeding the boiler pumps condensate from the tank and the discharge pressure is 3.5 (MPa).

The energy efficiency of the coal-fired boiler is 0.82. Pump's internal efficiency is 0.8, mechanical efficiency 0.96 and electric motor efficiency 0.89.

Calculate the energy efficiency of the electric power plant η_{EEL} .

HA4_P07

```
% (Lecture 14, Slide 24)

rho3=XSteam('rho_pT',p3,T3);

i3=XSteam('h_pT',p3,T3);

NelP1=W*(p4-p3)*fromBar2Pa/rho3/etaiP/etamP/etaEM;

i4=i3+(p4-p3)*fromBar2Pa/rho3/etaiP * fromJ_kg2kJ_kg;

rho4=XSteam('rho_ph',p4,i4);

NelP2=W*(p5-p4)*fromBar2Pa/rho4/etaiP/etamP/etaEM;

i5=i4+(p5-p4)*fromBar2Pa/rho4/etaiP * fromJ_kg2kJ_kg;

i1=XSteam('h_pT',p1,T1);

qF_kW=W*(i1-i5)/etaB;

etaEEL=(Nel_kW - NelP1_kW - NelP2_kW)/qF_kW;
```



HA4_P08

Turbine rotor rotates with speed of 160 rpm (revolutions per minute).

Express this in Hz (hertz)

c

HA4_P08

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Express this in Hz (hertz)

$f = n/60;$

HA4_P09

The reactivity in a steady-state thermal reactor with no external neutron sources, in which the neutron generation time is 1E-4 (s), is suddenly made positive and equal to 0.008 such that the reactor is prompt critical.

Assuming one group of delayed neutrons (Lambda = 0.08 1/s, Beta = 6.5E-3) determine the reactor power increase in percent of the initial power after time 0.2 (s).

C

HA4_P09

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```
% (Lecture 16)
% Find roots of the characteristic equation
aux1 = Beta/LAMBDA-Rho/LAMBDA+Lambda;
s1 = (-aux1+sqrt(aux1^2+4*Lambda*Rho/LAMBDA))/2;
s2 = (-aux1-sqrt(aux1^2+4*Lambda*Rho/LAMBDA))/2;
% Calculate the relative power increase
aux2 = (s1+Lambda)/s1/(s1-s2);
aux3 = (s2+Lambda)/s2/(s2-s1);
x = Rho*(Lambda/s1/s2+aux2*exp(s1*t)+aux3*exp(s2*t))/LAMBDA;
```

One group approximation

$$\frac{dn}{dt} = \frac{\rho - \beta}{\Lambda} n + \lambda C + S$$

$$\frac{dC}{dt} = \frac{\beta}{\Lambda} n - \lambda C$$

One group approximation has an exact analytical solution for a step change of reactivity!

$$x(t) \equiv \frac{n(t) - n_0}{n_0} = \frac{\rho_0}{\Lambda}\left[\frac{\lambda}{s_1 s_2} + \frac{s_1 + \lambda}{s_1(s_1 - s_2)} e^{s_1 t} + \frac{s_2 + \lambda}{s_2(s_2 - s_1)} e^{s_2 t}\right]$$

where $$s_{1,2} = \frac{-\left(\frac{\beta}{\Lambda} - \frac{\rho_0}{\Lambda} + \lambda\right) \pm \sqrt{\left(\frac{\beta}{\Lambda} - \frac{\rho_0}{\Lambda} + \lambda\right)^2 + 4\frac{\lambda \rho_0}{\Lambda}}}{2}$$

HA4_P10

Calculate the maximum power (kW) that can be generated by the Savonius rotor with radius 1 (m) and height 2 (m) if wind speed is 25 (m/s) and air density is 1.3 (kg/m^3)

C

HA4_P10

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```
% (Lecture 17)
max_power = (16/27)*RHO*R*H*U^3;
```

HA4_P11

Calculate azimuth of the Sun on June 3 at 12:00 as seen from the AlbaNova building (coordinates: 59.3536 N, 18.0578 E)

Assume that the year has 365 days.

The answer should be in angle degree.

c

HA4_P11

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Assume that the year has 365 days.

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```
% (Lecture 18)
June_day = 3;
LT = 12; % local time
LAMBDA = 18.0578; % local longitude
FI = 59.3536;     % local latitude
Nd = 3*31+28+30+June_day;
arg1_deg = 360*Nd/365+9.5;
arg2_deg = 2*360*Nd/365+5.4;
arg3_deg = 3*360*Nd/365+105.2;
arg1_rad = arg1_deg*pi/180; % in radians
arg2_rad = arg2_deg*pi/180; % in radians
arg3_rad = arg3_deg*pi/180; % in radians
d=0.3948-23.2559*cos(arg1_rad)-0.3915*cos(arg2_rad)
d=d-0.1764*cos(arg3_rad); %Declination
arg1_deg = 360*Nd/365+85.9;
arg2_deg = 2*360*Nd/365+108.9;
arg3_deg = 3*360*Nd/365+105.2;
```

```
ET=0.0066+7.3525*cos(arg1_rad)+9.9359*cos(arg2_rad);
ET=ET+0.3387*cos(arg3_rad); % in minutes      % Equation of time
ST = LT - (4*(15-LAMBDA) - ET)/60; % note units! in h  % Solar time
w = (12 - ST)*15; % in degrees  % Hour angle
FI_rad = FI*pi/180;
w_rad = w*pi/180; % in radians
d_rad = d*pi/180; % in radians
arg_psi = cos(w_rad)*cos(FI_rad)*cos(d_rad)+sin(FI_rad)*sin(d_rad);
psi_rad = asin(arg_psi);
psi_deg = psi_rad*180/pi;   % Altitude of the Sun
arg_rad = sin(psi_rad)*sin(FI_rad)-sin(d_rad);
arg_rad = arg_rad/cos(psi_rad)/cos(FI_rad);
if ST > 12.00
  az = 180 + acos(arg_rad)*180/pi;  % Azimuth
else
```

HA4_P12

The elements needed for fusion are available all around us. About 10% (by mass) of the human body is hydrogen and 0.015 % (by mass) of that is deuterium. The body also have some trace amounts of lithium, but a bigger source is the battery in your mobile of which 7.6% is ^{6}Li.

How many deuterium atoms are there in a human body that weighs 75kg?

How many lithium-6 atoms are there in your mobile phone if it contains 0.5g Li.

How much energy (in Joules) can be generated from these elements, if you only consider the two main reactions: D + T in the plasma and n+^{6}Li in the blanket?

c

HA4 P12

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```
% Lecture 19, slide 6

nAvogadros = 6.02214076e23;  %Avogadros number

MD = 2.01410178;   % Molar mass of deuterium

M6Li= 6.015122795; %Molar mass of Lithium-6

wD=75*1000*0.1*0.00015; %%  Deuterium in body[g]

aD=wD/MD*nAvogadros %  Deuterium atoms in body

A6Li=0.5*0.076/M6Li*nAvogadros  % Lithium-6 atoms in 0.5g Li

% From lecture notes released energy in D+T reaction (17.6 MeV) and n+6Li (4.8 MeV)

Eone=17.6+4.8;  %% Release of energy from each reaction [MeV]

% in this case, the amount of 6Li is limiting the amount of reactions that is possible

Etot=a6Li*Eone;% Total energy [MeV]

EJ=Etot*1.602176634e-19*1e6 %conversion to [J]
```