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Setup

```
clear;
close all;
```

Question 3

```
V_m = 18;              % [V]
omega_noload = 11800; % [rpm]
R = 0.68;              % [ohms]
L = 0.078;             % [mH]
J = 9.82;              % [g*cm^2]
b = 3.14*10^-4;        % [mN*m*sec]
R_wh = 4.57;           % [K/W]
R_ha = 13.6;           % [K/W]
tou_w = 22;            % [sec]
tou_h = 646;           % [sec]
T_max = 125;           % [deg C]
T_amb = 25;            % [deg C]
```

Part a)

```
K_m = omega_noload/V_m % [rpm/V]
```

```
K_m =
655.5556
```

Part b)

```
K_m = K_m * 2*pi()/60 % [rpm/V] -> [rad/V*sec]
```

K_m =
68.6496

```
b = b * 10^-3 % [mN*m*sec] -> [N*m*sec]
```

b =
3.1400e-07

```
syms K_t K_v

eqn1 = K_m == K_t/(b*R + K_t*K_v)
```

eqn1 =

$$\frac{590\,\pi}{27} = \frac{K_t}{K_t\,K_v + \frac{8066557531378615}{37778931862957161709568}}$$

```
eqn2 = K_t == K_v
```

eqn2 = $K_t = K_v$

```
[K_t, K_v] = solve([eqn1 eqn2], [K_t K_v])
```

K_t =

$$\left(-\frac{590\,\sqrt{\frac{729}{348100} - \frac{8066557531378615\,\pi^2}{9444732965739290427392}} - 27}{1180\,\pi}\right)$$

$$\left(\frac{590\,\sqrt{\frac{729}{348100} - \frac{8066557531378615\,\pi^2}{9444732965739290427392}} + 27}{1180\,\pi}\right)$$

K_v =

$$\left(-\frac{590\,\sqrt{\frac{729}{348100} - \frac{8066557531378615\,\pi^2}{9444732965739290427392}} - 27}{1180\,\pi}\right)$$

$$\left(\frac{590\,\sqrt{\frac{729}{348100} - \frac{8066557531378615\,\pi^2}{9444732965739290427392}} + 27}{1180\,\pi}\right)$$

```
double(min(K_t)) % [N*m/A] = [V*sec/rad] too small so ignore
```

ans =
1.4673e-05

```
K_t = double(max(K_t)) % [N*m/A] = [V*sec/rad]
```

K_t =
0.0146

```
K_v = double(max(K_v)) % [V*sec/rad] = [N*m/A]
```

```
K_v =
0.0146
```

Part c)

```
i_stall = V_m/R % [A]
```

```
i_stall =
26.4706
```

Part d)

```
T_stall = K_t*i_stall % [N*m]
```

```
T_stall =
0.3852
```

```
T_stall = T_stall * 10^3 % [N*m] -> [mN*m]
```

```
T_stall =
385.2013
```

Part e)

```
b % [N*m*sec]
```

```
b =
3.1400e-07
```

```
speed_torque_gradient = R/(b*R+K_t*K_v) % [rad/N*m*sec]
```

```
speed_torque_gradient =
3.2079e+03
```

Part f)

```
b % [N*m*sec]
```

```
b =
3.1400e-07
```

```
omega_noload = omega_noload * 2*pi()/60 % [rpm] -> [rad/sec]
```

```
omega_noload =
1.2357e+03
```

```
i_noload = (b/K_t)*omega_noload % [A]
```

```
i_noload =
0.0267
```

Part g)

```
T_stall = T_stall * 10^-3  % [mN*m] -> [N*m]
```

```
T_stall =
0.3852
```

```
T_max_power = 0.5*T_stall % [N*m]
```

```
T_max_power =
0.1926
```

```
omega_max_power = 0.5*omega_noload % [rad/sec]
```

```
omega_max_power =
617.8466
```

```
P_max = T_max_power*omega_max_power % [W]
```

```
P_max =
118.9977
```

Part h)

```
i_nom = sqrt((T_max-T_amb)/(R*(R_wh+R_ha))) % [A]
```

```
i_nom =
2.8449
```

```
K_m % [rad/V*sec]
```

```
K_m =
68.6496
```

```
b % [N*m*sec]
```

```
b =
3.1400e-07
```

```
T_nom = (1/(K_m))*i_nom - (b/K_t)*V_m % [N*m]
```

```
T_nom =
0.0411
```

```
T_nom = T_nom * 10^3 % [N*m] -> [mN*m]
```

```
T_nom =
41.0526
```

Part i)

```
T_nom = T_nom * 10^-3  % [mN*m] -> [N*m]
```

```
T_nom =
0.0411
```

```
T_stall % [N*m]
```

```
T_stall =
0.3852
```

```
speed_torque_gradient % [rad/N*m*sec]
```

```
speed_torque_gradient =
3.2079e+03
```

```
omega_nom = speed_torque_gradient*(T_stall - T_nom) % [rad/sec]
```

```
omega_nom =
1.1040e+03
```

```
P_nom = T_nom*omega_nom % [W]
```

```
P_nom =
45.3220
```

Part j)

```
C_w = tou_w/R_wh % [J/K]
```

```
C_w =
4.8140
```

```
C_h = tou_h/R_ha % [J/K]
```

```
C_h =
47.5000
```

Question 4

Part a)

```
T_stall % [Nm]
```

```
T_stall =
0.3852
```

```
% number of torques
num_T_load = 1000;
T_load = linspace(0, T_stall, num_T_load) % [Nm]
```

```
T_load = 1×1000
         0    0.0004    0.0008    0.0012    0.0015    0.0019    0.0023    0.0027 ···
```

```
T_load = transpose(T_load) % [Nm]
```

```
T_load = 1000×1
         0
    0.0004
    0.0008
    0.0012
    0.0015
    0.0019
    0.0023
    0.0027
    0.0031
    0.0035
```

⋮

Part b)

```
T_stall % [N*m]
```

```
T_stall =
0.3852
```

```
speed_torque_gradient % [rad/N*m*sec]
```

```
speed_torque_gradient =
3.2079e+03
```

```
omega_ss = speed_torque_gradient*(T_stall - T_load) % [rad/sec]
```

```
omega_ss = 1000×1
10^3 ×
    1.2357
    1.2345
    1.2332
    1.2320
    1.2307
    1.2295
    1.2283
    1.2270
    1.2258
    1.2246
     ⋮
```

Part c)

```
P_mech = T_load.*omega_ss % [W]
```

```
P_mech = 1000×1
         0
    0.4760
    0.9510
    1.4251
    1.8982
    2.3704
    2.8416
    3.3119
    3.7812
    4.2496
     ⋮
```

Part d)

```
b % [N*m*sec]
```

```
b =
3.1400e-07
```

```
K_t % [V*sec/rad]
```

```
K_t =
0.0146
```

```
P_elec = V_m*((T_load + b*omega_ss)/K_t) % [W]
```

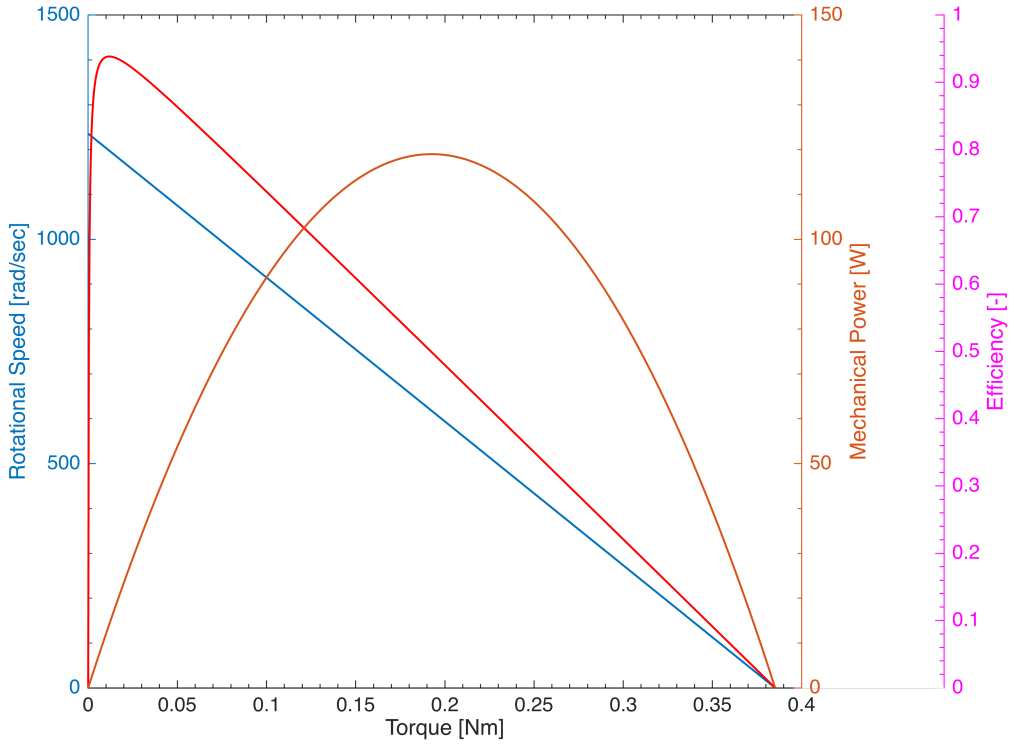
```
P_elec = 1000×1
    0.4799
    0.9564
    1.4329
    1.9093
    2.3858
    2.8623
    3.3387
    3.8152
    4.2917
    4.7681
     ⋮
```

```
efficiency = P_mech./P_elec % [-]
```

```
efficiency = 1000×1
         0
    0.4977
    0.6637
    0.7464
    0.7956
    0.8282
    0.8511
    0.8681
    0.8811
    0.8912
     ⋮
```

Question 5

```
figure('Position', [0 0 1000 600]);
[ax, hlines] = plotyyy(T_load, omega_ss, T_load, P_mech, T_load,
efficiency, ["Rotational Speed [rad/sec]", "Mechanical Power [W]",
"Efficiency [-]"]);
set(hlines,LineWidth=1)
set(get(ax(1),'xlabel'),'String',"Torque [Nm]");
```


1500
1000
500
0
Rotational Speed [rad/sec]
150
100
50
0
Mechanical Power [W]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Efficiency [-]
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
Torque [Nm]