Problem 1

A constant excited DC motor moves a load via a long flexible shaft, e.g. a flywheel. The flexibility of the shaft and the friction in the bearing can be adequately described by an equivalent spring constant $c$ and a damping constant $r$.

a) Determine the dynamic equations describing the electric subsystem, i.e. the constant excited DC motor.

b) Determine the dynamic equations of the mechanical subsystem consisting of a rotor which is fixed to a shaft and a flywheel.

c) Sketch a signal flow diagram of the entire system by connecting the signal flow diagrams of each subsystem.

Remark: This will be easier by sketching the physical system such that all existing variables of the dynamic equations appear explicitly.
Physical equations of the DC motor:

\[ e_M = c_M \psi_F \omega_1 \]
\[ M_A = c_M \psi_F i_A \]

motor

u_A = rotor voltage
i_A = rotor current
e_M = electromotive force
R_A = rotor resistance
L_A = rotor inductance
J_M = moment of inertia of the rotor without the shaft
M_A = driving torque
\omega_1 = angular velocity of the rotor
\psi_F = magnetic flux of the exciting winding
C_M = specific torque coefficient

shafts with flywheel

\varphi = angular of torsion
J_W = moment of inertia of the shaft
J_R = moment of inertia of the flywheel
M_C = moment of torsion
M_r = damping moment
\omega_2 = angular velocity of the flywheel

Problem 2

Simplify the signal flow diagram of the DC motor connected to a load (solution of problem 1c) such, that the negative feedback of the moment of torsion \( M_C \) remains as the only feedback.