Figure 11.1: Design FMEA for Automotive Engine System

For each of the following bond graphs, assign causality, predict the number

PROBLEMS

1.10.1

REFERENCE

STATE SPACE EQUATIONS AND AUTOMATED SIMULATION

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A ball is suspended at the end of a string in a coordinate grid, as shown.

S-2. Write the equation for the motion of the ball. Assume the string is inextensible.

S-3. Write the equation for the motion of the ball. Assume the string is inextensible.

S-6. Make a bond graph model of the pulley system shown in part a of the problems.

For the electrical circuit shown below, make a bond graph model of the circuit.

S-7. Complete the following:

(a) Problem 5.1 (b) Problem 5.2 (c) Problem 5.3 (d) Problem 5.4 (e) Problem 5.5 (f) Problem 5.6 (g) Problem 5.7 (h) Problem 5.8

For the problems listed below, in each case make a bond graph model of the circuit.

(i) Problem 5.9 (j) Problem 5.10 (k) Problem 5.11 (l) Problem 5.12

S-8. Complete the following:

(a) Problem 5.13 (b) Problem 5.14 (c) Problem 5.15 (d) Problem 5.16 (e) Problem 5.17 (f) Problem 5.18 (g) Problem 5.19 (h) Problem 5.20

For the problems listed below, in each case make a bond graph model of the circuit.

(i) Problem 5.21 (j) Problem 5.22 (k) Problem 5.23 (l) Problem 5.24 (m) Problem 5.25 (n) Problem 5.26 (o) Problem 5.27 (p) Problem 5.28

S-9. Complete the following:

(a) Problem 5.29 (b) Problem 5.30 (c) Problem 5.31 (d) Problem 5.32 (e) Problem 5.33 (f) Problem 5.34 (g) Problem 5.35 (h) Problem 5.36
5.11 On the diagram, physical system variables and parameters are identified. Explain the steps to be taken to solve the given problem in standard form. Where \( q = \) output voltage of linear amplifier; \( q' = \) output voltage of non-linear amplifier; \( q'' = \) output voltage of amplifier. Then position angle: \( \theta = \) output position angle.

5.10 Using the bond graph, show an analogous multi-variable system. The state equations for the bond graph are:

\[
\begin{align*}
\dot{x} &= a x + b u + e(t) \\
\dot{y} &= c x + d u + f(t)
\end{align*}
\]

Write the state equations for the system using the bond graph:

\[
\begin{align*}
\dot{x} &= a x + b u + e(t) \\
\dot{y} &= c x + d u + f(t)
\end{align*}
\]

5.8 Consider the simple model of a vertical spring shown below, where the suspended mass is \( m \). The spring stiffness is \( k \) and the velocity is \( v \). The mass is \( m \). The system is modeled in terms of \( x \) and (mass) \( d \).

\[
\begin{align*}
\dot{x} &= a x + b u + e(t) \\
\dot{y} &= c x + d u + f(t)
\end{align*}
\]

The damping effect of the fluid is proportional to the square of the velocity, \( \dot{x} = \phi \). The damping force is \( -k \dot{x} \).

\[
\begin{align*}
\dot{x} &= a x + b u + e(t) \\
\dot{y} &= c x + d u + f(t)
\end{align*}
\]

The damping effect of the fluid is proportional to the square of the velocity, \( \dot{x} = \phi \). The damping force is \( -k \dot{x} \).
Consider the mechanical system shown below:

5-14

\[ \begin{align*}
\mathbf{A} &= [\begin{pmatrix} A & B \\ C & D \end{pmatrix}]
\end{align*} \]

(a) Recompute the state-space model of the system with coil resistance included.

(b) Recompute the state-space model without coil resistance and inductance neglected.

(c) Write the state-space equations for each circuit in the system shown above.

(d) Write the state-space equations for the system and verify they are equivalent to those above.

(e) The differential equations that govern the dynamics of the system are:

\[ \begin{align*}
L_1 \frac{d}{dt} i_1(t) + R_1 i_1(t) &= V_1(t) \\
L_2 \frac{d}{dt} i_2(t) + R_2 i_2(t) &= V_2(t) \\
L_3 \frac{d}{dt} i_3(t) + R_3 i_3(t) &= V_3(t) \\
C \frac{d}{dt} v(t) &= i_1(t) - i_2(t)
\end{align*} \]

(f) Initial conditions:

\[ \begin{align*}
i_1(0) &= 0 \\
i_2(0) &= 0 \\
v(0) &= 0
\end{align*} \]

(g) The type of control system is:

- Back-EMF control
- Torque control
- Voltage control
- Current control

(h) Motor controller, add a signal source to the load.

(i) Assume the device is connected to a voltage amplifier, so that \( V = 0 \).

(j) Assume the device is connected to a current amplifier, so that \( i = 0 \).

(k) Assume the device is connected to a current amplifier, so that \( i = 0 \).

(l) Assume the device is connected to a voltage amplifier, so that \( V = 0 \).

(m) Construct a bond graph model of the device, linking the electrical port and the system mass.
A one-story building model is shown with a d.c. motor on the roof. The idea is that a reaction force is generated.  

Write coupled equations for $x_1$, $y_1$, and $z_1$. 

\[ H_1 = H_2 = 6 \quad \text{N} \] 

\[ \frac{C}{L_1} = \frac{C}{L_2} = 6 \quad \text{N/m} \] 

\[ R_1 = 10 \quad \text{N} \] 

\[ R_2 = 11 \quad \text{N} \] 

\[ T = 8 \quad \text{N} \] 

\[ S = 3 \quad \text{N} \] 

\[ q \quad \text{N} \] 

5.17 The d.c. motor shown has windings resistance $r_w$, copper inertia $J_w$, and output torque $T_m$. 

The output torque $T_m$ and the torque at the shaft $T_s$ are given. 

Your solution to part (q) above: 

\[ T_s = \frac{J_w}{C} \] 

5.18 The d.c. motor shown has windings resistance $r_w$, copper inertia $J_w$, and output torque $T_m$. 

The output torque $T_m$ and the torque at the shaft $T_s$ are given. 

Your solution to part (q) above: 

\[ T_s = \frac{J_w}{C} \] 

5.19 Make a bond graph model of the circuit and assign causality.
ANALYSIS OF LINEAR SYSTEMS

6.1 INTRODUCTION