MAE 3723, Systems Analysis – Fall 2019 Prerequisite Exam

1) (30 points) The following is a dynamics problem given on my ENSC 2123 Final Exam this summer.

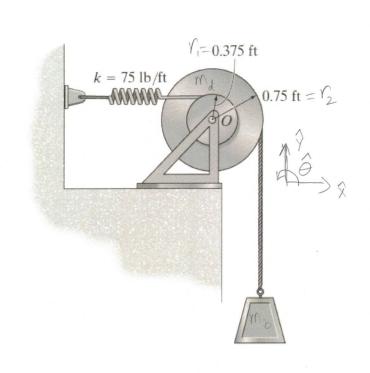
If the 250-lb block is released from rest when the spring is unstretched, determine the velocity of the block after it has descended 5 ft. The drum has a weight of 50 lb and a radius of gyration of $k_0 = 0.5$ ft about its center of mass O.

Do not solve this problem as presented. Instead, use the information in the problem to do the following:

a) Draw complete freebody diagrams for the block and the pulley. Hint: show the forces in the rope and spring.







b) Write an equation relating the force in the spring to the change in angle of the pulley.

$$F_s = -K \Delta x = -K \Gamma_1 \theta$$

$$F_3(\theta) = -kr, \theta$$

 \sqrt{c} Use the freebody diagrams to write the rotational form of Newton's Second Law (ΣM = Iα) for the pulley.

$$\sum M_0 = I \propto \rightarrow F_5 r_1 - F_b r_2 = I \dot{a}$$

$$I\ddot{\theta} - (-Kr_1\theta) = F_T r_2$$

MAE 9723, Systems Analysis – Fall 2019 Prenequiable factor

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do the following:

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d) Use the freebody diagrams to write Newton's Second Law ($\Sigma F = ma$) for the block.

Write an equation relating the acceleration of the block to the angular acceleration of the pulley.
$$F_{+} = M_{b} \mathring{y} + F_{gb} \qquad m_{a} K_{o} \mathring{\theta} + k r_{1} \mathring{\theta} = F_{+} r_{2} \\ + \frac{1}{r_{2}} (m_{1} K_{o} \mathring{\theta} + k r_{1} \mathring{\theta}) = F_{+} r_{2}$$

$$\ddot{Y} = r_2 \ddot{\theta}$$

Solve those equations to determine the acceleration of the block at the instant it is released.

Remember that the moment of inertia of the pulley is $\,{\sf I}=m\,\,{\sf k_o}^2$

$$\frac{1}{r_2} \left(m_d \, k_o^2 \ddot{\theta} + k \, r_1 \, \theta \right) = m_b \ddot{\gamma} + F_{ab}$$

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$$\frac{1}{r_2} \left(m_d \, k_o^2 \ddot{\theta} \right) = m_b \ddot{\gamma} + m_b \ddot{\gamma} +$$

$$\dot{y} = -35.34 \, ft/s^2$$

g) Briefly explain the process you would use to solve the problem as originally presented Given that time is not stated in the problem, I would use the Work energy principle to solve the problem.

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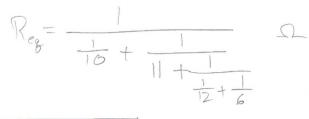
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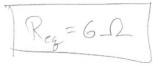
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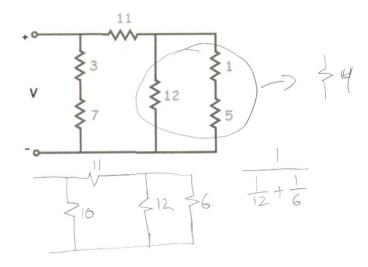
Remember that the moment of linertia of the million is 1 = 10 Kg

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- (20 points) From your knowledge of Physics and Electrical Circuits, for the parallel and series resistor circuit shown:
 - a) Compute the equivalent resistance







 $^{\prime}$ b) The input voltage is 14V. Compute the current $\,i$ produced by that 14-volt power supply

c) Compute the power delivered by the 14 V source.

$$P = IV = (14V)(2.33A) = 32.67W$$

P=32.67W

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Compute the prover universed by the 1.4 V source

√3) (25 points) From your knowledge of Physics and Electrical Circuits: for the following RLC circuit, derive an ordinary differential equation relating the current i (and it's derivatives) to the supply voltage $v_s(t)$ (and it's derivatives).

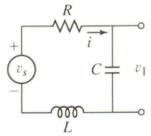
$$-V_{S} + V_{R} + V_{C} + V_{L} = 0$$

$$V_{R} + V_{C} + V_{L} = V_{S}$$

$$cR + \frac{1}{c} \int cdt + iL = V_{S}$$

$$\frac{d}{dt} \left(cR + \frac{1}{c} \int cdt + iL \right) = \frac{d}{dt} \left(V_{S} \right)$$

$$\frac{d}{dt} \left(cR + \frac{1}{c} \int cdt + iL \right) = \frac{d}{dt} \left(V_{S} \right)$$



Electrical Elements - Basic

Resistance:

v = iR

Capacitance:

Inductance:

 $v = L \frac{di}{dt}$

 $i = C \frac{dv}{dt} \qquad \forall z = \frac{1}{C} \int C \, dt$

(2.5 points) from your trouviedge of Physics and Flantical Greattic for the following BLC drowing on crive an arrive an arrive and invited to the supply colored at a feet without two colored and arrive at the supply and are a fift and it affected two.

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- 4) (25 points) From your knowledge Differential Equations and Engineering Analysis:
 - (a) Write the Laplace transform of the following differential equation:

$$2\dot{x} + 6x = 4t \text{ with initial condition } x(0) = 8$$

$$2\left(s \times - \times (o)\right) + 6 \times = \frac{4}{5^2}$$

$$2s \times - 16 + 6 \times = \frac{4}{5^2}$$

b) Solve your transformed equation for X(s), not x(t).

$$2 \le X - 16 + 6X = \frac{4}{s^{2}}$$

$$X(2s+6) = \frac{4}{s^{2}} - 16$$

$$X(s) = \left(\frac{1}{2s+6}\right) \left(\frac{4}{s^{2}} - 16\right)$$

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() (£5 polety) Fram yourknowledge differential caustions and Entreping Analysis:

Write the Laplace marshim of the following differential, whitevir,

X-100x representation with with a section of

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c) Determine the inverse Laplace transform for X(s) to determine x(t).

$$\chi(s) = \left(\frac{1}{2s+6}\right)\left(\frac{y}{s^2} - 16\right)$$

$$= \frac{4}{s^2(2s+6)} - \frac{16}{2s+6}$$

$$= \frac{2}{s^2(s+3)} - \frac{8}{s+3}$$

$$\chi(t) = -8e^{-3t} - \frac{2}{9}u(t) + \frac{2}{3}t + \frac{2}{9}e^{-3t}$$

$$\frac{-8}{5+3}$$
 ° $\mathcal{L}^{-1}(8(\frac{1}{5+3}))^{\frac{1}{5}} = \frac{-8}{6}e^{-3t}$

$$\frac{2}{s^{2}(s+3)} = \frac{A}{5} + \frac{B}{52} + \frac{C}{5+3}$$

$$2 = A(5)(s+3) + B(s+3) + Cs^{2}$$

$$2 = As^{2} + 3As + Bs + 3B + Cs^{2}$$

$$As^{2} + Cs^{2} = 0$$

 $3As + Bs = 0$
 $3B = 2$

$$\begin{bmatrix} 1 & 0 & 1 \\ 3 & 1 & 0 \\ 0 & 3 & 0 \end{bmatrix} \begin{bmatrix} A \\ B \\ C \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 2 \end{bmatrix} \xrightarrow{7} \begin{bmatrix} A \\ B \\ C \end{bmatrix} = \begin{bmatrix} -\frac{2}{4} \\ \frac{7}{4} \end{bmatrix}$$

$$= \frac{-2}{95} + \frac{2}{352} + \frac{2}{9(5+3)}$$
$$-\frac{2}{9}ult) + \frac{2}{3}t + \frac{2}{9}e^{-3t}$$

X(s)	$x(t), t \geq 0$
1. 1	$\delta(t)$, unit impulse
2. $\frac{1}{s}$	$u_s(t)$, unit step
3. $\frac{c}{s}$	constant, c
$4. \frac{e^{-sD}}{s}$	$u_s(t-D)$, shifted unit step
$5. \frac{n!}{s^{n+1}}$	f"
6. $\frac{1}{s+a}$	e^{-at}

2.
$$\frac{dx}{dt}$$

$$sX(s) - x(0)$$

$$3. \quad \frac{d^2x}{dt^2}$$

$$s^2X(s)-sx(0)-\dot{x}(0)$$

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