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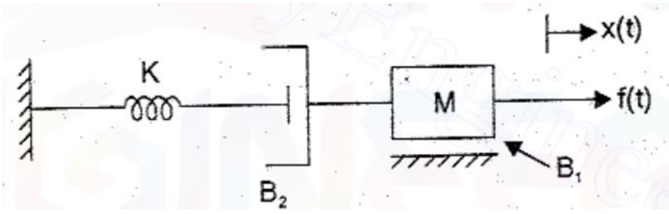
Internal Assessment Test I - Solutions

Sub:	**Control Systems**							Code:	18EE61
Date:	10.05.2022	Duration:	90 mins	Max Marks:	50	Sem:	VI	Branch:	EEE

Answer Any FIVE FULL Questions

1 Determine the transfer function of the given mechanical system.



Solution:

$$\therefore M\frac{d^2x}{dt^2} + B_1\frac{dx}{dt} + B_2\frac{d}{dt}(x - x_1) = f(t)$$

On taking Laplace transform of the above equation we get,

$$Ms^2 X(s) + B_1 s X(s) + B_2 s [X(s) - X_1(s)] = F(s)$$

$$f_{b2} = B_2\frac{d}{dt}(x_1 - x) \; ; \quad f_k = K x_1$$

By Newton's second law, $f_{b2} + f_k = 0$

$$\therefore B_2\frac{d}{dt}(x_1 - x) + K x_1 = 0$$

On taking Laplace transform of the above equation we get,

$$B_2 s [X_1(s) - X(s)] + K X_1(s) = 0$$

$$(B_2 s + K) X_1(s) - B_2 s X(s) = 0$$

$$\therefore X_1(s) = \frac{B_2 s}{B_2 s + K} X(s)$$

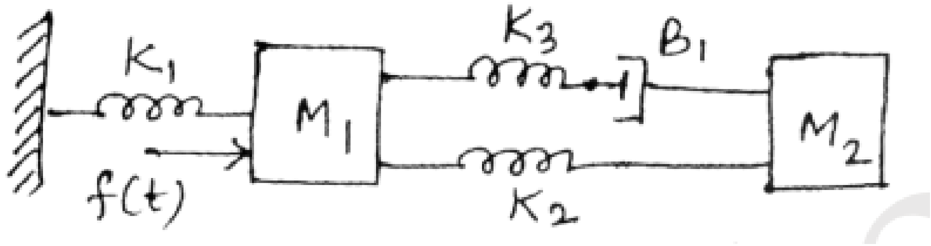
Substituting for $X_1(s)$ from equation (2) in equation (1) we get,

$$\left[M s^2 + (B_1 + B_2) s\right] X(s) - B_2 s\left[\frac{B_2 s}{B_2 s + K}\right] X(s) = F(s)$$

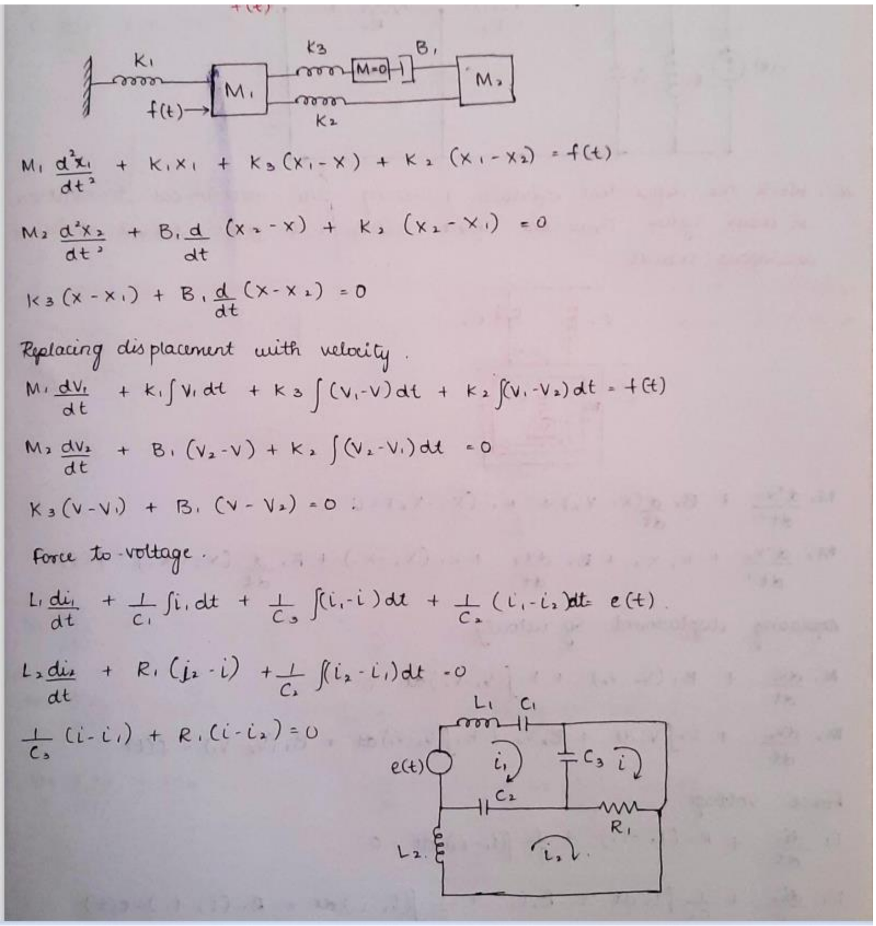
$$X(s)\frac{\left[[M s^2 + (B_1 + B_2) s] (B_2 s + K) - (B_2 s)^2\right]}{B_2 s + K} = F(s)$$

$$\therefore \frac{X(s)}{F(s)} = \frac{B_2 s + K}{[M s^2 + (B_1 + B_2) s] (B_2 s + K) - (B_2 s)^2}$$

2	Write the differential equation governing the mechanical translational systems. Draw the force voltage and force current electrical analogous circuits.



Solution:



$$M_1 \frac{d^2x_1}{dt^2} + K_1 x_1 + K_3 (x_1 - x) + K_2 (x_1 - x_2) = f(t)$$

$$M_2 \frac{d^2x_2}{dt^2} + B_1 \frac{d}{dt} (x_2 - x) + K_2 (x_2 - x_1) = 0$$

$$K_3 (x - x_1) + B_1 \frac{d}{dt} (x - x_2) = 0$$

Replacing displacement with velocity.

$$M_1 \frac{dv_1}{dt} + K_1 \int v_1 dt + K_3 \int (v_1 - v) dt + K_2 \int (v_1 - v_2) dt = f(t)$$

$$M_2 \frac{dv_2}{dt} + B_1 (v_2 - v) + K_2 \int (v_2 - v_1) dt = 0$$

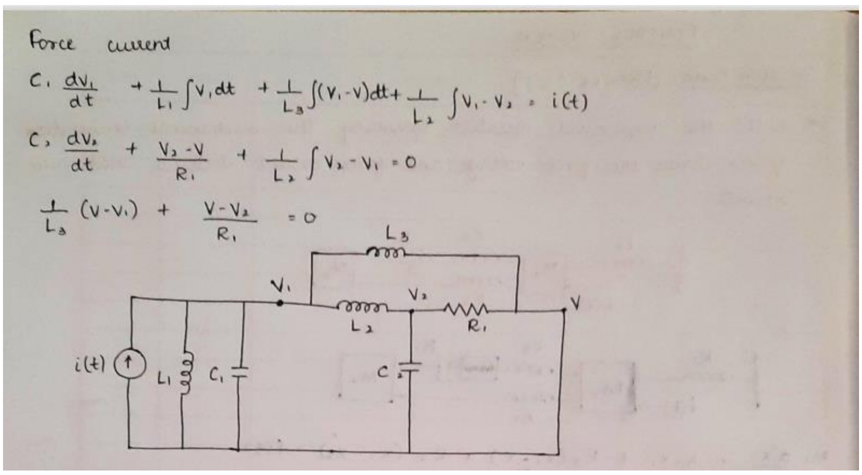
$$K_3 (v - v_1) + B_1 (v - v_2) = 0$$

Force to voltage.

$$L_1 \frac{di_1}{dt} + \frac{1}{C_1} \int i_1 dt + \frac{1}{C_3} \int (i_1 - i) dt + \frac{1}{C_2} (i_1 - i_2) dt = e(t)$$

$$L_2 \frac{di_2}{dt} + R_1 (i_2 - i) + \frac{1}{C_2} \int (i_2 - i_1) dt = 0$$

$$\frac{1}{C_3} (i - i_1) + R_1 (i - i_2) = 0$$



Force current

$$C_1 \frac{dv_1}{dt} + \frac{1}{L_1} \int v_1 dt + \frac{1}{L_3} \int (v_1 - v) dt + \frac{1}{L_2} \int v_1 - v_2 = i(t)$$

$$C_2 \frac{dv_2}{dt} + \frac{v_2 - v}{R_1} + \frac{1}{L_2} \int v_2 - v_1 = 0$$

$$\frac{1}{L_3} (v - v_1) + \frac{v - v_2}{R_1} = 0$$

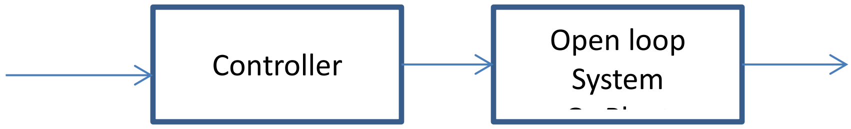
3 Define open-loop control systems and list the advantages and disadvantages with examples.

advantages

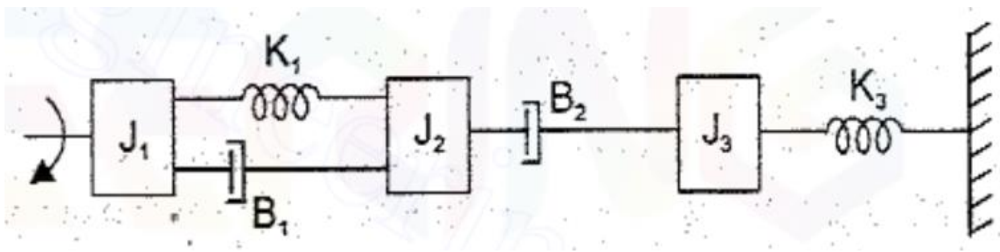
- Simple in construction and design.
- Economical.
- Easy to maintain.
- Generally stable

disadvantages

- They are inaccurate.
- They are unreliable.
- Any change in output cannot be corrected automatically.



4 Write the differential equation governing the mechanical rotational systems. Draw the Torque-voltage and Torque-current electrical analogous circuit.



$$\left(\text{i.e., } \frac{d^2\theta}{dt^2} = \frac{d\omega}{dt}\ ;\quad \frac{d\theta}{dt} = \omega \text{ and } \theta = \int \omega\, dt\right)$$

$$J_1 \frac{d\omega_1}{dt} + B_1(\omega_1 - \omega_2) + K_1 \int (\omega_1 - \omega_2)\, dt = T$$

$$J_2 \frac{d\omega_2}{dt} + B_1(\omega_2 - \omega_1) + B_2(\omega_2 - \omega_3) + K_1 \int (\omega_2 - \omega_1)\, dt = 0$$

$$J_3 \frac{d\omega_3}{dt} + B_2(\omega_3 - \omega_2) + K_3 \int \omega_3 dt = 0$$

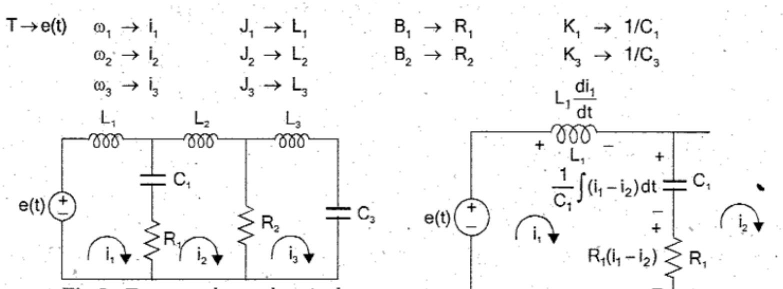


Fig 5 : Torque-voltage electrical

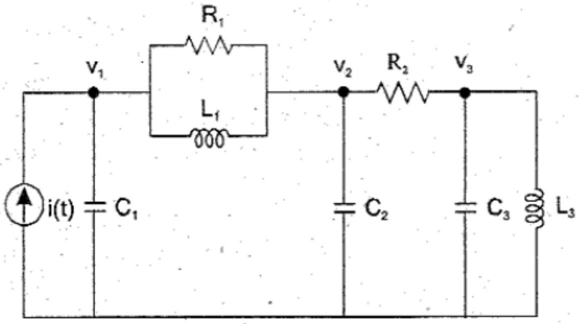
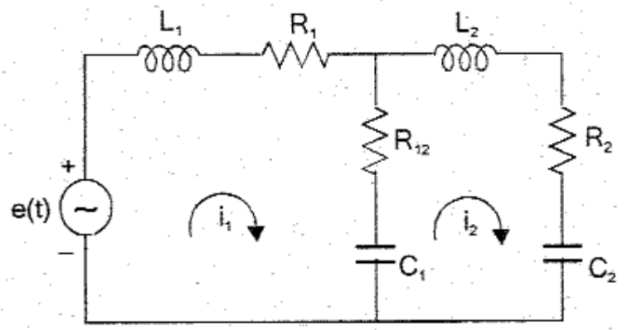


***Fig 9 :** Torque-current electrical analogous circuit.*

5 Draw the equivalent mechanical Translational analogous system.



The free body diagram of M_1 is shown in fig 2. The opposing forces are marked as f_{m1}, f_{b1}, f_{b12} and f_{k1}.

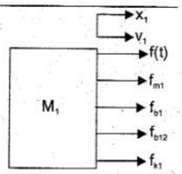


Fig 2.

$$f_{m1} = M_1 \frac{d^2x_1}{dt^2} \quad ; \quad f_{b1} = B_1 \frac{dx_1}{dt}$$

$$f_{b12} = B_{12} \frac{d}{dt}(x_1 - x_2) \quad ; \quad f_{k1} = K_1(x_1 - x_2)$$

By Newton's second law, $f_{m1} + f_{b1} + f_{b12} + f_{k1} = f(t)$

$$\therefore M_1 \frac{d^2x_1}{dt^2} + B_1 \frac{dx_1}{dt} + B_{12} \frac{d}{dt}(x_1 - x_2) + K_1(x_1 - x_2) = f(t) \qquad ......(1)$$

The free body diagram of M_2 is shown in fig 3. The opposing forces are marked as $f_{m2}, f_{b2}, f_{b12}, f_{k1}$ and f_{k2}.

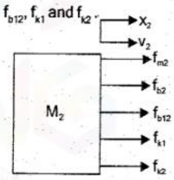


Fig 3.

$$f_{m2} = M_2 \frac{d^2x_2}{dt^2} \quad ; \quad f_{b2} = B_2 \frac{dx_2}{dt} \quad ; \quad f_{b12} = B_{12} \frac{d}{dt}(x_2 - x_1)$$

$$f_{k1} = K_1(x_2 - x_1) \quad ; \quad f_{k2} = K_2 x_2$$

By Newton's second law, $f_{m2} + f_{b2} + f_{k2} + f_{b12} + f_{k1} = 0$

$$M_2 \frac{d^2x_2}{dt^2} + B_2 \frac{dx_2}{dt} + K_2x_2 + B_{12} \frac{d}{dt}(x_2 - x_1) + K_1(x_2 - x_1) = 0 \qquad .....(2)$$

On replacing the displacements by velocity in the differential equations (1) and (2) of the mechanical system we get,

$$\left(\text{i.e., } \frac{d^2x}{dt^2} = \frac{dv}{dt} \quad ; \quad \frac{dx}{dt} = v \text{ and } x = \int v\,dt \right)$$

$$M_1 \frac{dv_1}{dt} + B_1v_1 + B_{12}(v_1 - v_2) + K_1\int(v_1 - v_2)\,dt = f(t) \qquad .....(3)$$

$$M_2 \frac{dv_2}{dt} + B_2v_2 + K_2\int v_2\,dt + B_{12}(v_2 - v_1) + K_1\int(v_2 - v_1)\,dt = 0 \qquad .....(4)$$

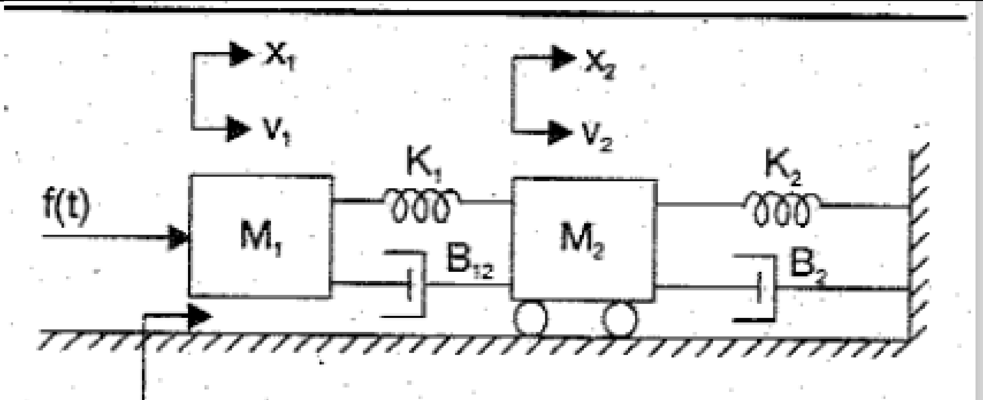
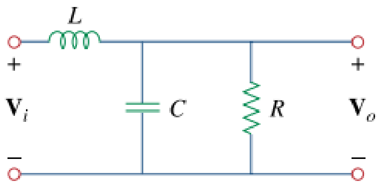
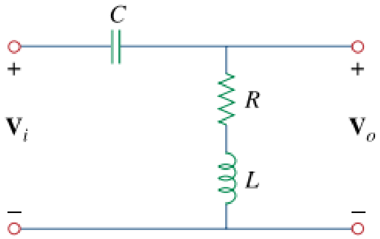


Fig 1.

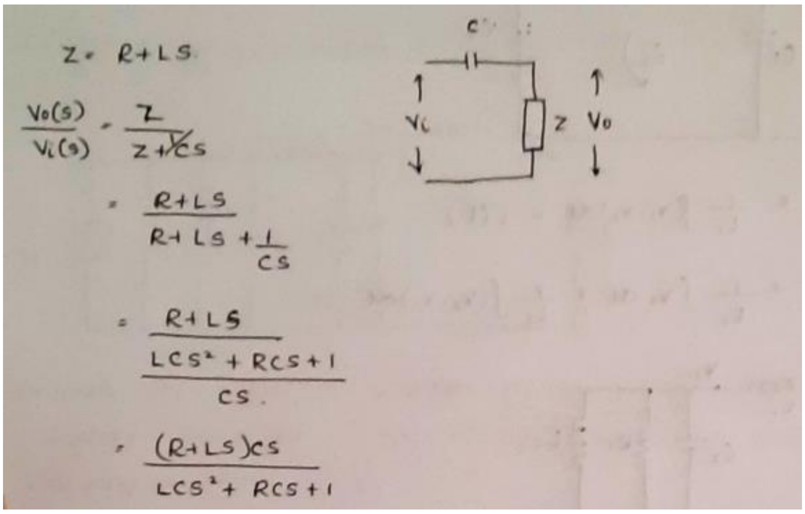
6 Determine the transfer function of the given electrical system.

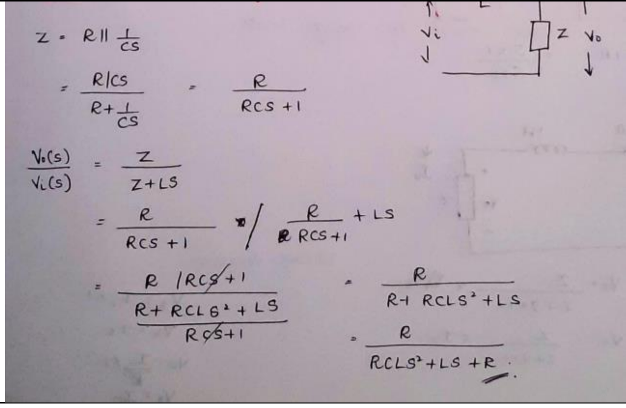


(a)



(b)





7a Compare Open-loop and Closed-loop control systems with an example.

Open loop control system	Closed loop control system
The feedback element is absent.	The feedback element is always
An error detector is not present.	An error detector is always pres
Easy to construct.	Complicated construction.
It is an economical.	It is costly.
Having small bandwidth.	Having large bandwidth.
It is inaccurate.	It is accurate.
Less maintenance.	More maintenance.
It is unreliable.	It is reliable.
Examples: Hand drier, tea maker	Examples: Servo voltage stabili perspiration

7b Explain Synchros as an error detector.

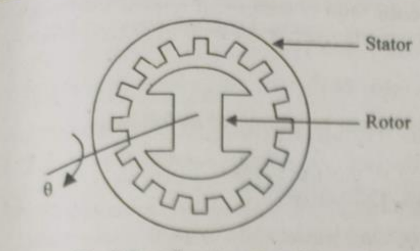


Fig 2.4a : Constructional features.

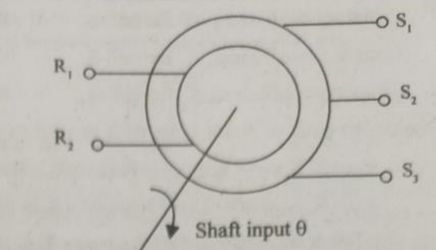
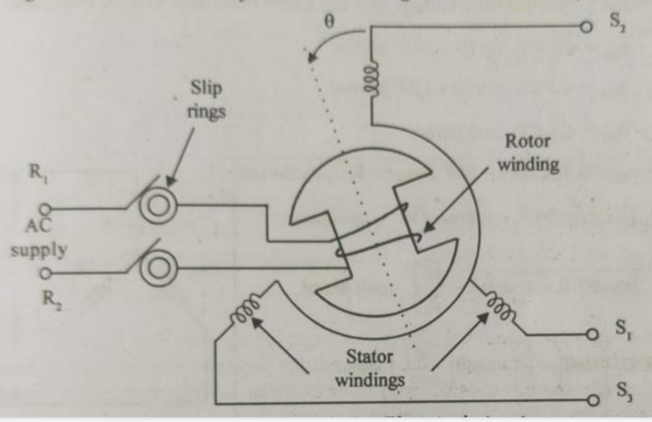


Fig 2.4b : Schematic symbol of a synchro transmitter.



as error detector is shown in fig 2.7.

Initially the shafts of transmitter and control transformer are assumed to be in aligned position. In this position the transmitter rotor will be in electrical zero position and the control transformer rotor will be in null position and the angular separation of both rotor axis in aligned position is 90°. The null position of a control transformer in a servo system is defined as position of its rotor for which the output voltage on the rotor winding is zero with the transmitter in its electrical zero position.

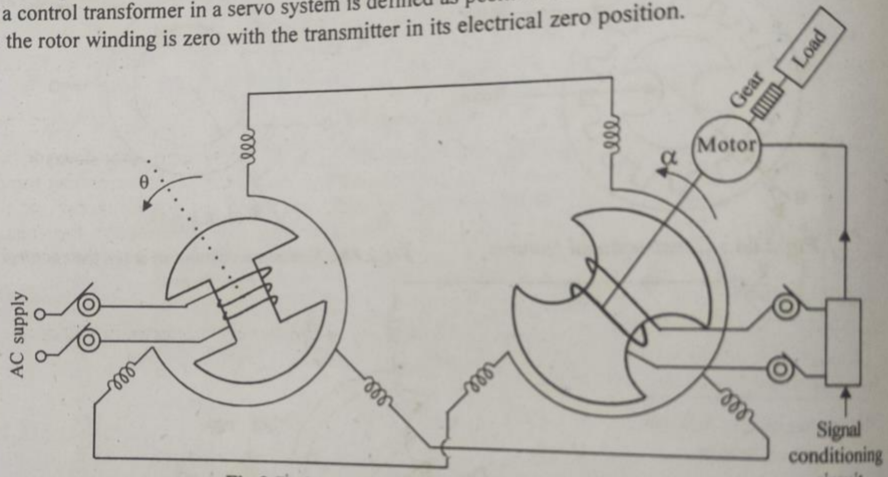


Fig 2.7 : Servo system using synchro error detector.

When, the transmitter rotor is excited, the rotor flux is set-up and emfs are induced in stator coils. These induced emfs are impressed on the stator coils of control transformer. The currents in the stator coils set up flux in control transformer. Due to the similarity in the magnetic construction, the flux patterns produced in the two synchros will be the same if all losses are neglected. The flux patterns are shown in fig 2.8.