Consider the figure below. Dimensions are as shown. The total air path is 5 mm, split into two parts of lengths $x$ and $(5\text{mm}-x)$. Depth into the page is 4 cm. The coil has 150 turns. The steel has infinite permeability.

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a. Draw the magnetic equivalent circuit.
b. Solve the circuit for flux and flux-linkage.
c. Determine the co-energy.
d. Determine the force of electric origin acting on the moving member in the $+x$ direction, as a function of current $i$. The only variables allowed to remain in your answer are $x$ and $i$.```
A three-phase, 4-pole induction motor is rated for 575 V, 60 Hz. Its parameters are: \( R_1 = 0.75 \, \Omega \), \( R_2 = 1.2 \, \Omega \), \( X_1 = 3 \, \Omega \), \( X_2 = 3 \, \Omega \), \( X_m = 25 \, \Omega \). It will be operated from an adjustable speed drive, which has a bus voltage of 810 V.

a. If third harmonic injection is used, what is the maximum possible voltage applied to the motor without saturating the PWM process?

b. The motor is now operated at 35 Hz. The ASD uses a linear V/Hz profile with 50 V of boost. What is the applied voltage?

c. For the conditions of (b), draw the equivalent circuit of the motor. Label all impedances NUMERICALLY. Also label the source voltage NUMERICALLY.

d. For the conditions of (b), the speed is 975 RPM. Determine the slip and the total power consumption of the motor.
A 13.8 kV line serves a three-phase load rated 800 kW at 0.92 power factor lagging. What is the three-phase rating of a capacitor bank required to correct the power factor to 0.98 lagging?
In the following system, the generator, motor, and transformers are all solidly grounded.

Generator: 1 MVA, 13.8 kV, \(x_d = x_q = 0.1\) per unit, \(x_0 = 0.05\) per unit
Motor: 1 MVA, 12.5 kV, \(x_d = x_q = 0.1\) per unit, \(x_0 = 0.05\) per unit
Transformer 1: 1 MVA, 138 kV \(Y\) / 13.8 kV \(\Delta\)
Transformer 2: 0.5 MVA, 138 kV \(Y\) / 13.8 kV \(\Delta\)

Draw the per-unit positive sequence equivalent circuit.
Thevenin Equivalent Circuit

Determine Thevenin Equivalent Voltage, $V_{th}$ and Thevenin Equivalent Resistance, $R_{th}$ for the circuit shown below.

Answer

\[
V_{th} = \\
R_{th} =
\]
For the following circuit, find the transfer function: \( H(j\omega) = \frac{V_0}{V_s} \)
For the following amplifier circuit, $\beta = 100$, $R_1 = 20 \, k\Omega$, $R_2 = 10 \, k\Omega$, $R_E = 3 \, k\Omega$, and $V_A = 100 \, V$. Assume $V_{CC}$ has been adjusted such that $I_{CO} = .75 \, mA$. Find the input resistance, $R_i$, as shown, and the small-signal voltage gain, $A_v = \frac{v_o}{v_i}$. Assume the transistor is in the forward active mode, and recall that $r_x = \frac{V_T}{I_{CO}}$, $g_m = \frac{I_{CO}}{V_T}$, and $r_o = \frac{V_A}{I_{CO}}$. 
Consider the TTL gate shown. The parameters for the diodes and transistors are shown in the table to the right.

\[ \begin{align*}
V_T &= 0.7V \\
V_{BE\text{(on)}} &= 0.7V \\
V_{BE\text{(sat)}} &= 0.8V \\
V_{CE\text{(sat)}} &= 0.1V \\
\beta_F &= 25 \\
\beta_R &= 0.1
\end{align*} \]

Let \( V_x = V_y = 5V \). Find \( V_{B0}, V_{B2}, V_{B1}, I_{B1}, I_{B2}, V_{B3}, I_{R2}, I_{E2}, I_{RB}, \) and \( I_{B0} \).

Answers: \( V_{B0} = \ldots \), \( V_{B2} = \ldots \), \( V_{B1} = \ldots \), \( I_{B1} = \ldots \), \( I_{B2} = \ldots \),

\( V_{B3} = \ldots \), \( I_{R2} = \ldots \), \( I_{E2} = \ldots \), \( I_{RB} = \ldots \), \( I_{B0} = \ldots \).
Consider the following discrete-time system

\[ x(k + 1) = \begin{bmatrix} 1 & T \\ 0 & 1 \end{bmatrix} x(k) + \begin{bmatrix} \frac{T^2}{2} \\ T \end{bmatrix} u(k) \]

where \( T \) is the sampling interval. Determine a state feedback gain matrix \( K \) such that the response to an arbitrary initial condition is deadbeat.
Use the Routh-Hurwitz test to find the range of $K$ for which the following characteristic equation is stable.

$$ s^5 + 2s^4 + 2s^3 + 4s^2 + Ks + 4 = 0 $$
Find the complex exponential Fourier Series coefficients for

\[ x(t) = sgn \{ sgn [20 \cos(2\pi 10t) + 10\sqrt{2}] \} + 20 \]

Where \( sgn() \) is the signum function, defined as

\[ sgn(y) = \begin{cases} 
-1 & \text{for } y < 0 \\
0 & \text{for } y = 0 \\
+1 & \text{for } y > 0 
\end{cases} \]

Show your work for full credit. If you think it is impossible to find the Fourier Series coefficients for \( x(t) \), explain why it is impossible.
Problem M22  Communications  Code # ________

Prove that the impulse response, $h(n)$ of a causal, linear, time invariant, discrete-time system has no non-zero values for $n < 0$. 
A standard (non-adaptive) delta modulator is to be used to transmit the message signal \( m(t) = 3 \cos 500\pi t \) volts.

(20%) a) From the choices below, select an appropriate sampling interval. (Circle one.) Explain the reason for your choice.

Answer (Circle one): \( T_s = 0.15 \text{ ms} \quad T_s = 1.5 \text{ ms} \quad T_s = 15 \text{ ms} \)

Explain your answer: 

(20%) b) Find the maximum slope of \( m(t) \).

Answer: \( \left| \frac{dm(t)}{dt} \right|_{\text{max}} = \) 

(15%) c) Using the \( T_s \) you selected in a), find the smallest step size, \( \delta_0 \), that will prevent slope overload.

Answer: \( \delta_0 = \)

(15%) d) What is the bit rate of this design?

Answer: \( R = \)

(15%) e) If this design results in quantization levels that are too coarse then you must make \( \delta_0 \) smaller. What effect will this have on \( T_s \) (still preventing slope overload)?

(Circle the best answer.)

1) \( T_s \) will have to become larger.
2) \( T_s \) can stay the same.
3) \( T_s \) will have to become smaller.

(15%) f) Based on your answer to e), how will the bit rate change?

(Circle the best answer.)

1) The bit rate will be lower.
2) The bit rate will not change.
3) The bit rate will be higher.
A set of symbols $S = \{a, b, c, d, e\}$ is found in a discrete source with the probability of occurrence being $P = \{0.1, 0.15, 0.30, 0.16, 0.29\}$.

1. What is the self-information of each symbol?

2. What is the entropy of the discrete source?

3. Use Huffman Coding to encode the symbols.

4. Compute the average coding length of the resulting Huffman code and compare it with the entropy.