The following structure is composed of infinitely permeable steel, a block of NdFeB, and an air gap. Your task is ultimately to find the force acting to close the air gap. The NdFeB may be modeled as having an equivalent coercivity of $H'_c = -940 \text{kA/m}$ and a recoil permeability of $\mu_R = 1.05 \mu_0$, where $\mu_0 = 4\pi \times 10^{-7} \text{H/m}$. Depth into the page is 2.5 cm. Other dimensions are as shown, all in centimeters. Equations you may need:

$$R = \frac{\mu}{\mu A}$$

$$(Ni)_{eq} = -H'_d d$$

$$W'_f = \int \lambda di$$

$$f_{fd} = -\frac{\partial W'_f}{\partial x}$$

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a. Draw the magnetic equivalent circuit. Indicate all elements numerically, EXCEPT leave the length of the air gap as “g.”

b. Find the co-energy.

c. Find the force acting to close the gap, $f_{fd}(g)$.

d. Find the force numerically for $g = 2 \text{ mm} = 0.2 \text{ cm}$. 

In the series-connected dc motor depicted in the figure,

1) Back emf can be described as $E_a = K \cdot I_f \cdot \omega_m$.

2) $R_a = 0.6 \, \Omega$, $R_f = 0.4 \, \Omega$, and the supply voltage is 120 V.

a) Find the developed torque by the motor at the speed of 65 rad/s if the armature current is 12 Amps.

b) Find constant $K$.

c) Find the new value for the armature current if the mechanical speed changes to 250 rad/s.
A 3-phase voltage source feeds a 3-phase load connected through lines as shown in the system below. The sources, lines, and loads are balanced, and $V_{ab} = 140\angle 0^\circ$ volts.

1) Calculate the active and reactive power delivered by the source.
2) What is the power factor of the system?
In the following single phase system, the input voltage is 100V. A load of 3+j is connected to a transformer with a ratio of 1:3. A transmission line with an impedance of 1+2j is connecting the transformer to a power source $V_1$. Please calculate: 1. load current $i_1$, 2. transmission line current $i_2$, and 3. source active and reactive power (without considering C).

Assume that a capacitor C is connected to the source to compensate for reactive power. If a source power factor of 1 (unity) is of interest, what is the proper value for capacitor C?
For the following circuit, use repeated source transformation to find the Norton equivalent with respect to terminals $a$ and $b$. 

![Circuit Diagram]
Find the steady-state current \( i(t) \) in the following circuit:
Referring to the transmission line of intrinsic impedance $Z_0 = 50\Omega$ below, the DC source voltage is $V_0$ with an internal resistance of $R_s = 150\Omega$. The switch is turned on at $t = 0^+$. The load resistance is $R_L = 350\Omega$. The length $\ell = 20cm$ and the propagation speed is 20cm/nano-second (that is the transit time= 1 nano-second). Through the use of a proper bounce diagram, plot the value of voltage at the source point as function of time up to 8 times the transit time from the source to the load. What is the steady-state value of the voltage?
Problem #M11  Area: Waves & Devices Code #

Consider a silicon (Si: a Col. IV material) abrupt-junction pn diode with only \( N_{sp}^- = 10^{18} \text{ cm}^{-3} \) on the p side and only \( N_{dn}^+ = 10^{13} \text{ cm}^{-3} \) on the n side. One side is doped with aluminum (Al: a Col. III materials) and the other side is doped with phosphorous (P: a Col. V material). \( T = 300 \text{ K} \). Important physical constants are:

- Boltzmann's constant: \( k = 1.38 \times 10^{-23} \text{ J/K} = 8.62 \times 10^{-5} \text{ eV/K} \)
- Planck's constant: \( h = 4.14 \times 10^{-15} \text{ eV-s} \)
- Carrier Mobilities: \( \mu_n = 1350 \text{ cm}^2/\text{V-s} \) \( \mu_p = 480 \text{ cm}^2/\text{V-s} \)
- Bandgap Energy of Si: \( E_g = 1.11 \text{ eV} \)
- Intrinsic Carrier Concentration: \( n_i = 1.50 \times 10^{10} \text{ cm}^{-3} \) at 300 K

(a) Silicon (Si) is a column IV material on the periodic table and it is in the third row. Neon (Ne) is a column VIII material on the periodic table and it is at the end of the second row. If the electronic configuration for Neon is \( 1s^22s^22p^6 \), state the electronic configuration for Silicon.

(b) Specify which material is the dopant for the respective sides of the diode. Justify.

- p-side of diode: __________
- n-side of diode: __________

Justification:

(c) Calculate the contact potential \( V_o \).

(d) Calculate the equilibrium carrier concentrations on the p-side.

(e) Answer the following multiple-choice questions. Circle the one best answer.

For forward bias, the depletion width is

- Equal to
- Greater than
- Less than

The diode current is primarily

- Holes
- Electrons
- Neither (holes=electrons)
- Insufficient Information
Show all work for full credit, using this page, and the following two blank pages on the exam. Express all answers to an accuracy of at least three decimal places. State all assumptions you make when working the problem.

A system contains 4 blocks connected in series as shown in the figure below

The first block is a signum operator, $\text{sgn}()$. The output of this block is +1 when $x(t)$ is positive, -1 when $x(t)$ is negative, and zero when $x(t)$ is zero.

The lowpass filter (LPF) passes signals from 0 Hz to 8.5 kHz, and perfectly removes all signals above that frequency.

The differentiator $(\frac{d}{dt})$ is ideal.

The highpass filter (HPF) passes all signals above 7.5 kHz, and perfectly removes all signals below that frequency.

What is the rms value of the HPF output, $b(t)$, when the input to the system is

$$x(t) = 34.23 \sin(2000 \pi t + 7.8 \pi)$$
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.