Consider the simplified distribution feeder shown below. The short-circuit positive/negative and zero sequence reactances for the equivalent source are $j0.1$ and $j0.3$ pu respectively. The positive/negative and zero sequence reactances of line B-C are $j0.1$ and $j0.3$ pu respectively. The transformer neutral is grounded through a 0.02 pu reactance. A solid single-line-ground fault occurs on bus C. Compute the line-ground, line-neutral (where appropriate), and line-line voltages at buses A, B, and C.
Problem A.2  Power/Machinery  Code #______

For the system shown below, calculate the critical clearing angle for a solid fault at F which is cleared by opening the lower line.
Problem A.3 Power/Machinery Code #

A Buck converter has the following parameters: $V_{in} = 54$ V, duty cycle = 0.4, and inductor $L = 50 \mu$H. The converter was run at the switching frequency of 30 kHz. The output voltage was measured to be 30 V.

a) (25 pts) Find the peak value of the inductor current.
b) (25 pts) Find the average value of the inductor current.
c) (25 pts) Find the output power.
d) (25 pts) Find the value of the load resistor.
You are tasked with designing a small power supply. The source is a deep-cycle lead-acid battery, which has a useable voltage range of 9-14.5 V. The output is 200 V @ 1.2 A (dc), and must be isolated from the source. (This voltage will then be the input to an inverter.)

a. If you wanted to do this in a single power conversion stage, what topology would be most appropriate?

b. Suppose the customer has specified that you must have a two-stage design. The first stage must be a boost converter with a switching frequency of 150 kHz, and the second stage must be a forward converter with a switching frequency of 35 kHz.

i. Sketch the power circuit schematic.

ii. Choose an intermediate voltage (output of first stage, input of second stage). Why did you choose this voltage?

iii. Determine values for all components in the first stage. Determine current and/or voltage ratings for each component.

iv. Determine the turns ratio(s) for the windings of the transformer in the first stage. Sketch and label the waveforms of the voltage and current of each winding. Determine corresponding voltage ratings for all power semiconductor devices in the second stage (which should correspond to ratings that are commonly available).

v. List the steps involved in designing this transformer. For whatever method you choose, list all of the factors that affect the design (e.g., winding #1 RMS voltage).
Given is the following circuit. It drives a current through a diode, uses an Op-Amp circuit and provides an output voltage. As core parameters for the diode please assume $I_s = 1.5\text{nA}$, $N=1.8$, $R_s=0$.

This is a DC analysis problem.

a) Give the voltage across the diode for a current range from $1\mu\text{A}$ to $10\text{mA}$ (diode forward biased).

b) Calculate the output voltage of the Op-Amp for a current range from $1\mu\text{A}$ to $10\text{mA}$

c) What will happen if the current direction is inverted (diode is now reverse biased, imagine $1\mu\text{A}$ in reverse direction)? What will be the output voltage? Can it be calculated? What further information you may need? How would a real circuit react?
For the buck-boost converter depicted in the figure below assume that i) all of the components are ideal and ii) the converter has reached its steady-state operation.

If $V_i = 30 \, \text{V}$, $d = 0.6$, $R = 15 \, \Omega$, $L = 60 \, \mu\text{H}$, and the switching frequency = 100 kHz, determine:

a) (20 pts) the output voltage,
b) (20 pts) the average value of the diode current,
c) (20 pts) the average value of the inductor current,
d) (20 pts) the minimum value of the inductor current,
e) (10 pts) is the converter operating under continuous conduction mode of operation, and
f) (10 pts) sketch the waveform of the switch current.
Figure (a) shows a strain gauged beam flexure as an accelerometer. Four resistive strain gauges are used with a typical arrangement of two compression gauges and two tension gauges. The purposes of such an arrangement include maximizing the sensitivity and temperature compensation, when the strain gauges are interrogated by a Wheatstone bridge as shown in Figure (b) where $E_{ex}$ is the excitation voltage (a constant) and $e_o$ is the output.

![Diagram of Strain Gauge Accelerometer](image1)

![Diagram of Wheatstone Bridge](image2)

**Figure (a). Strain gauged accelerometer**  
**Figure (b). Wheatstone bridge**

A resistive strain gauge changes its resistance in response to the strain. The gauge factor ($F$) of a strain gauge is defined as:

$$F = \frac{\Delta R}{R \varepsilon}$$

where $\varepsilon$ is the applied strain which is defined as the relative deformation: $\varepsilon = (\delta L)/L$, where $\delta L$ is the change of the length and $L$ is the original length.

Assume the four strain gauges used in the accelerometer have the same resistance, and the strain is relatively small, $\varepsilon_i << 1$ (or $\Delta R_i << R_i$, $i = 1,2,3,4$). Also assume that the four gauges have the same gauge factor of $F$.

(a) Derive the transfer function of the measurement system, i.e., express the output of the bridge ($e_o$) as a function of the strains seen by the four gauges ($\varepsilon_1, \varepsilon_2, \varepsilon_3, \varepsilon_4$), the excitation voltage ($E_{ex}$), and the gauge factor ($F$).

(b) How will you arrange your strain gauges to maximize your sensitivity? Show the corresponding strain gauge placement ($R_1, R_2, R_3, R_4$) in the drawing of the accelerometer.

(c) Normally, strain gauge has strong temperature dependence. This means that the strain ($\varepsilon$) may include both the mechanical strain ($\varepsilon_m$) and the thermal strain ($\varepsilon_t$), $\varepsilon = \varepsilon_m + \varepsilon_t$. If you have only two strain gauges available instead of four, how can you arrange your two strain gauges so that you will have maximum sensitivity and also achieve temperature compensation?
Two mismatched solar panels, A and B, are to be wired together to produce power. Panel A is made of 3 x 9 silicon solar cells (that is: the panel is made with 3 cells in parallel and 9 cells in series) with I-V (current-voltage) characteristics shown in Figure A. Here the maximum power point is labeled as \((I_m, V_m) = (3 \text{ amp, } 4.68 \text{ volt})\). \(I_{sc} = 3.2 \text{ amp}\) is the short-circuit current and \(V_{oc} = 5.85 \text{ volt}\) is the open circuit voltage. The ratio, \((I_m \times V_m) / (I_{sc} \times V_{oc}) = (3 \times 4.68) / (3.2 \times 5.85) = 0.75\) is an indicator (the fill factor) on how rectangular the I-V curve is. Thus, the value of \(I_m \times V_m = 3 \text{ amp} \times 4.68 \text{ volt} = 14.04 \text{ watts}\) is the power rating of the panel A. Similarly, for Panel B (Figure B), it is made of 3 x 8 silicon solar cells with a slightly better quality. \(I_{sc} = 3.3 \text{ amp}\) and \(V_{oc} = 5.2 \text{ volt}\). Here \(I_m = 3.15 \text{ amp}\) and \(V_m = 4.358 \text{ volt}\), with a fill factor at around 0.8. That means the second panel has I-V curve that is more rectangular than that of panel A. The power rating is \(3.15 \text{ amp} \times 4.358 \text{ volt} = 13.728 \text{ watts}\).

**Questions:** If the two panels are to be wired in “Series”:

(a) Sketch the combine I-V curve of the two panels and show the values of \(I_{sc}\) and \(V_{oc}\) of the combined panel.
(b) Where is now the maximum power point? For example, what would be the values of \(I_m\) and \(V_m\)?
(c) Would the total power produced now be equal to \(14.04 + 13.728 = 27.768 \text{ watts}\)?

Please answer yes or no for this question and explain why.

**Combined Panel**
Consider the following two antennas that are directly pointed at each other. Antenna \#1 is linearly polarized with an electric field vector given by \((5\hat{a}_x + \hat{a}_y)\). Antenna \#2 is elliptically polarized with its \(x\)- and \(y\)-directed electric field components being 90\(^\circ\) out of (time) phase and with the relative magnitude of one component being three times the other.

1. Write one possible expression for the polarization unit vector of antenna \#2.

2. Write all possible expressions for the polarization unit vector of antenna \#2 for obtaining maximum polarization loss factor (PLF), given by \(PLF = |\hat{p}_w \cdot \hat{p}_a|^2\), where \(\hat{p}_w\) and \(\hat{p}_a\) are the polarization unit vectors of antenna \#1 and \#2, respectively.