ENGR-2300

Electronic Instrumentation

Quiz 1, Spring 2019

Name: ______**Solution**______

Please write you name on each page

Section: 1 or 2

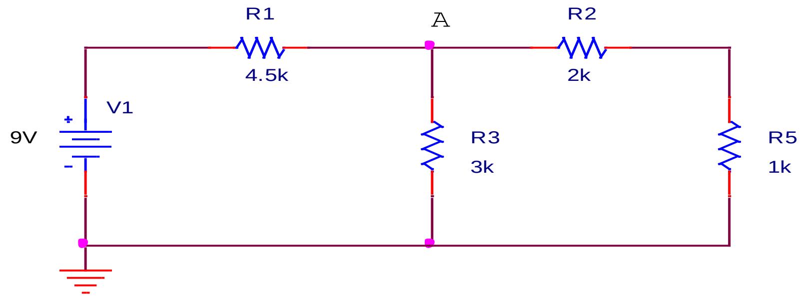
4 Questions Sets, 20 Points Each
LMS Portion, 20 Points

Question Set 1)	**Resistive and Equivalent Circuits**
Question Set 2)	**Resistor Combinations, Loading, and Measurements**
Question Set 3)	**Filters and Transfer Functions**
Question Set 4)	**Phasors, Inductors, Transformers, and More**

On all questions:
SHOW ALL WORK. BEGIN WITH FORMULAS,
THEN SUBSTITUTE VALUES AND UNITS.
No credit will be given for numbers that appear without justification.
Unless otherwise stated in a problem, provide 3 significant digits in answers.
It may be easier to answer parts of questions out of order.

If you need extra room, make it clear in the main problem statement that work is continuing on the back of the page.

Question Set 1) Resistive and Equivalent Circuits (20 pnts)



1.a) (6 pnts) What is the voltage at point A in the circuit above?

R2 and R5 are in series, replace with "R25":

$$R25 = R2 + R5 = 2\ \text{k}\Omega + 1\ \text{k}\Omega = 3\ \text{k}\Omega$$

R25 and R3 are in parallel, replace with "R325":

$$\frac{1}{R325} = \frac{1}{R3} + \frac{1}{R25} \rightarrow R325 = \frac{R3 * R25}{R3 + R25} = \frac{3\ \text{k}\Omega * 3\ \text{k}\Omega}{3\ \text{k}\Omega + 3\ \text{k}\Omega} = 1.5\ \text{k}\Omega$$

Voltage divider of R1 and R325 to find VA:

$$VA = V1 * \frac{R325}{R1 + R325} = 9\ \text{V} \frac{1.5\ \text{k}\Omega}{4.5\ \text{k}\Omega + 1.5\ \text{k}\Omega} = 2.25\ \text{V}$$

1.b) (4 pnts) What is the current through R2?

VA is the voltage across the "resistor" R3 AND R25, the current is the same for any series components; therefore, the current through R25 is equal to the current through R2:

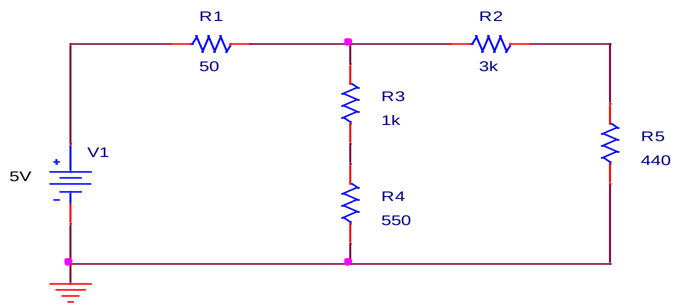
$$I25 = I2 = \frac{VA}{R25} = \frac{2.25\ \text{V}}{3\ \text{k}\Omega} = 7.5 \times 10^{-4}\ \text{A} = 0.75\ \text{mA}$$

OR find voltage across R2 using voltage divider and solve directly for I2

$$VR2 = VA \frac{R2}{R2 + R5} = 2.25\ \text{V} \frac{2\ \text{k}\Omega}{2\ \text{k}\Omega + 1\ \text{k}\Omega} = 1.5\ \text{V}$$

$$I2 = \frac{VR2}{R2} = \frac{1.5\ \text{V}}{2\ \text{k}\Omega} = 0.75\ \text{mA}$$

1.c) (6 pnts) What is the total resistance seen by the source V1 in the circuit below?



R2 and R5 are in series, replace with "R25," and R3 and R4 are in series, replace with "R34":

$$R25 = R2 + R5 = 3\ \text{k}\Omega + 440\ \Omega = 3.44\ \text{k}\Omega$$

$$R34 = R3 + R4 = 1\ \text{k}\Omega + 550\ \Omega = 1.55\ \text{k}\Omega$$

R25 and R34 are in parallel, replace with "Rp":

$$\frac{1}{Rp} = \frac{1}{R34} + \frac{1}{R25} \rightarrow Rp = \frac{R34 * R25}{R34 + R25} = \frac{1.55\ \text{k}\Omega * 3.44\ \text{k}\Omega}{1.55\ \text{k}\Omega + 3.44\ \text{k}\Omega} = 1.07\ \text{k}\Omega$$

R1 and Rp are in series, resulting in the total resistance:

$$Rtot = R1 + Rp = 50\ \Omega + 1.069\ \text{k}\Omega = 1.12\ \text{k}\Omega$$

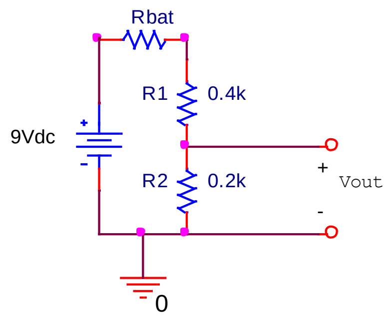
1.d) (4 pnts) Find the voltage across R1.

Use voltage divider:

$$VR1 = V1\frac{R1}{R1 + Rp} = 5\ \text{V}\frac{50\ \Omega}{50\ \Omega + 1.07\ \text{k}\Omega} = 223\ \text{mV}$$

Question Set 2) Resistor Combinations, Loading, and Measurements (20 pnts)

2.a) (4 pnts) Find Vout for the circuit shown below assuming that a Heavy Duty 9V battery is used.



Type	R_{int} (Ω)	V_{oc} (V)	Capacity[a] continuous, to 1V/cell (mAh)	@ (mA)	(mAh)	@ (mA)	Size (in)	Weight (gm)	Connec[b]	Comments
9V "1604"										
Le Clanche	35	9	300	1	160	10	0.65x1x1.9	35	S	
Heavy Duty	35	9	400	1	180	10	"	40	S	
Alkaline	2	9	500	1	470	10	"	55	S	280mAh@100mA
Lithium	18	9	1000	25	950	80	"	38	S	Kodak Li-MnO_2

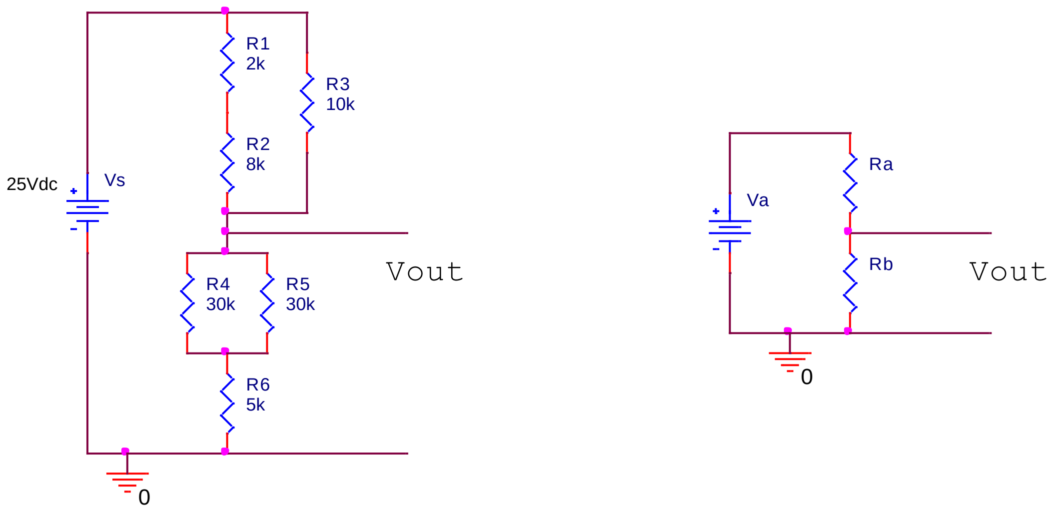
Rbat and R1 are in parallel: (Rbat is 35 Ω from table above)

$$Rtop = Rbat + R1 = 35\ \Omega + 0.4\ \text{k}\Omega = 435\ \Omega$$

Voltage divider to find Vout:

$$Vout = Vbat\frac{R2}{Rtop + R2} = 9\ \text{V}\frac{200\ \Omega}{435\ \Omega + 200\ \Omega} = 2.83\ \text{V}$$

2.b) (4 pnts) For the circuit below-left, reduce the circuit to the form of the circuit shown on the right. In other words, find the values for equivalent resistors Ra and Rb, and the value of Va.



R1, R2, and R3 all compose Ra. First find the series total of R1 and R2, then the parallel value including R3:

$$\frac{1}{Ra} = \frac{1}{R1 + R2} + \frac{1}{R3} \rightarrow Ra = \frac{R3(R1 + R2)}{R1 + R2 + R3} = 5\ \text{k}\Omega$$

R3, R5, and R6 all compose Rb. First find the parallel combination of R4 and R5, then add in series with R6:

$$Rb = \frac{R4R5}{R4 + R5} + R6 = 20\ \text{k}\Omega$$

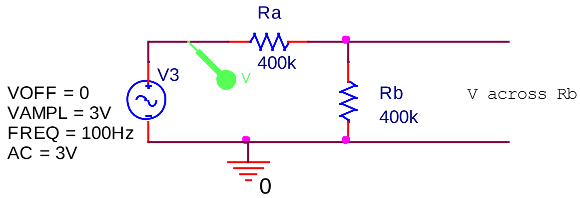
Va is simply Vs, nothing changes.

$$Va = Vs = 25\ \text{V}$$

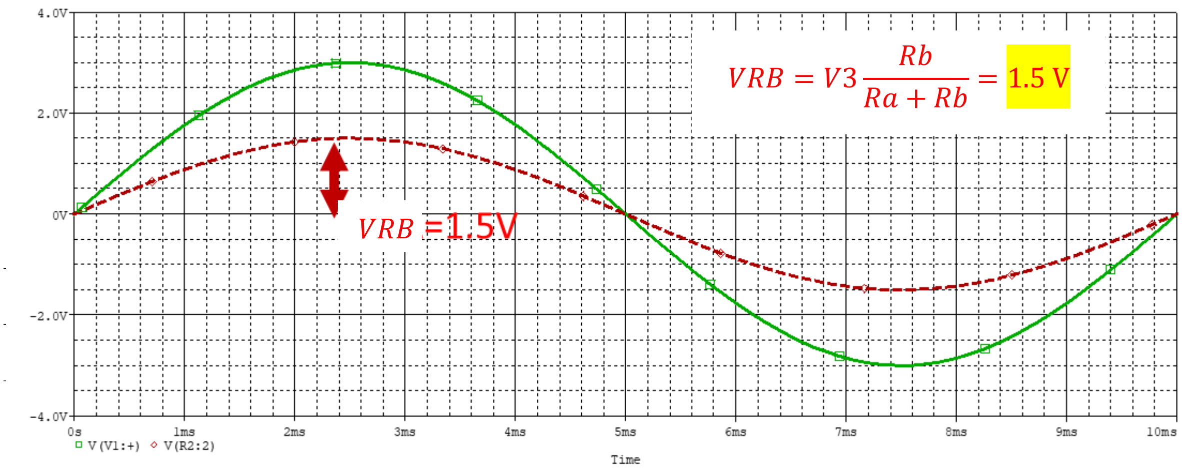
2.c) (2 pnts) What is the value of Vout for the circuit in 2.b?

$$Vout = Va\frac{Rb}{Ra + Rb} = 20\ \text{V}$$

For questions 2.d-2.g: you want to get the time trace of the voltage signal across the load, Rb, as shown in the circuit below.

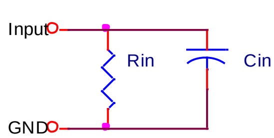


2.d) (5 pnts) Ideal Oscilloscope: The trace below is the signal V3. Sketch V across Rb if you have an ideal oscilloscope, (or ideal Analog Discovery Board). You must label that amplitude of your trace in addition to sketching the curve.



2.e) (2 pnts) You can use an Agilent 54830 Oscilloscope. Using the additional information provided below, what is the input circuit model for this instrument? In other words, what are the values of Rin and Cin for the circuit below?

Vertical : Analog Channels	54830B, 54831B, 54832B, 54830D, 54831D and 54832D	54845B and 54846B
Input Channels	54830B: 2 analog 54830D: 2 analog + 16 digital 54831B/54832B: 4 analog 54831D/54832D: 4 analog + 16 digital	4 analog
Analog Bandwidth @50 Ω (-3 dB)*1	54830B/D, 54831B/D: 600 MHz 54832B/D: 1 GHz	**54845B: 1.5 GHz** **54846B: 2.25 GHz**
Calculated Rise Time2 @50 Ω	54830D/B, 54831B/D: 583 ps 54832B/D: 350 ps	54845B: 233 ps 54846B: 178 ps
Input Impedance*	1 MΩ ± 1% (13 pF typical),	1 MΩ ± 1% (12 pF typical),
Sensitivity3	1 mV/div to 5 V/div (1 MΩ) 1 mV/div to 1 V/div (50 Ω)	2 mV/div to 2 V/div (1 MΩ) 1 mV/div to 1 V/div (50 Ω)



Rin = 1 MΩ Cin = 13 pF

2.f) (4 pnts) Ignore Cin for now. The Agilent 54830 is used to measure the voltage across Rb, (circuit from 2.d) On the plot for 2.d, add a sketch of the trace that this instrument would measure. You must label the amplitude.

Rin and Cin are now in parallel with Rb, ignoring Cin:

Combine Rin and Rb in parallel, then voltage divider:

$$Reff = \frac{Rb\ Rin}{Rb + Rin} = 286\ \mathrm{k\Omega}$$

$$VRB = V3\frac{Reff}{Ra + Reff} = 1.25\ \mathrm{V}$$

Add applicable trace to 2.d

2.g) (2 pnts) For this measurement it was proper to ignore Cin of the Agilent 54830. Why?

Hint: Calculate the magnitude of Z for Cin for this experiment and justify why this value means Cin can be ignored.

$$\omega = 2\pi \times frequency = 2\pi\ 100\ \mathrm{Hz} = 628\ \mathrm{Hz}$$

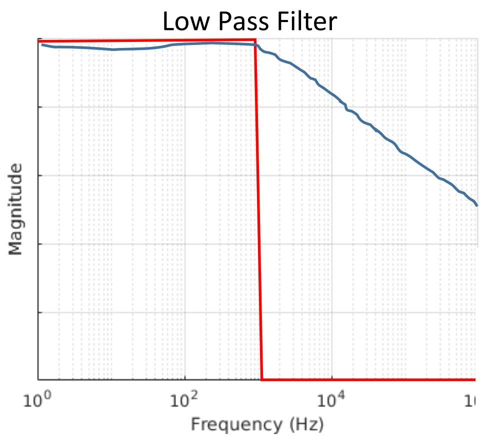
$$Zcin = \frac{1}{\mathrm{j}\omega Cin} = \frac{-\mathrm{j}}{628\ \mathrm{Hz} \times 13\ \mathrm{pF}} = -122\mathrm{j}\ \Omega$$

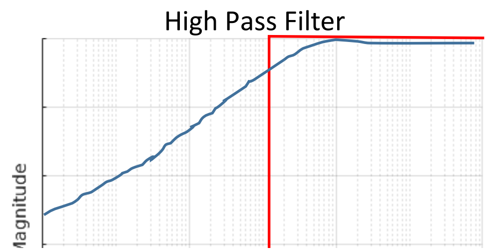
$$|Zcin| = 122\ \Omega \gg Rin, Rb$$

Zcin is significantly larger than both Rin and Rb, causing negligible current to propagate through it as compared to Rin and Rb and thereby causing a negligible change to the operation of the circuit.

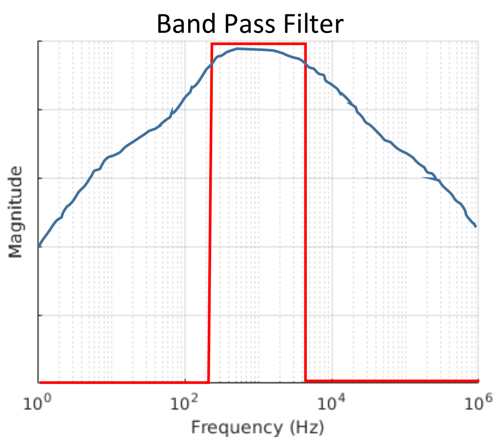
Question Set 3) Filters and Transfer Functions (20 pnts)

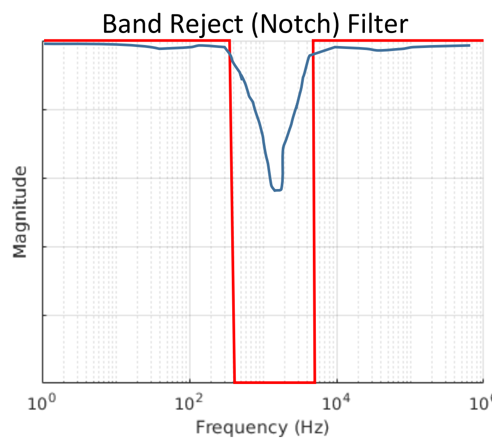
3.a) (4 pnts) Below are four axes with the names of filter types above them. For each axes, draw in both an IDEAL and REALISTIC transfer function **magnitude** shape for a filter that matches the type. In the "pass" frequency range, the filter should have a unity gain (output = input). Note that there is no one correct answer for this problem as there is not enough information to produce one specific transfer function. Make sure to label IDEAL versus REALISTIC, as well as the y axis. Assume a LOGRITHMIC y-axis.





IDEAL, REALISTIC, Main points of focus:
-Ideal versions are correct filter type and have sharp cutoffs
-Realistic matches Ideal's magnitude in part/most of passband
-Realistic has a consistent decay away from the cutoff frequencies
-If decays in realistic filter are not obviously logarithmic, minor penalty





3.b) (2 pnts) Does either of the REALISTIC Low or High pass filters you drew above have a resonance shown? If yes, which ones?

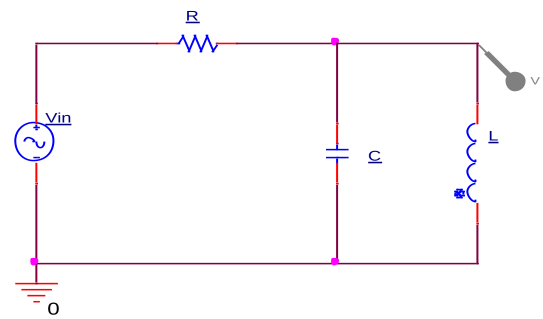
Depends on the Student's drawing. If there is a peak above the passband near the corner frequency, then YES, otherwise: NO.

3.c) (2 pnts) Circle the series component* arrangements listed below that will produce a resonance.

RC	CR	RLC	LCR
RL	LR	RLR	CRC
LC	CL	CLC	LCL

Resonances are produced by the combination of L and C components.

Given the circuit in the schematic to the right, answer the following questions below. Assume that each of the given components is ideal and that Vout is the gray probe and Vin is the input.

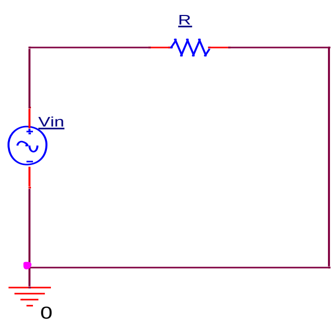


3.d) (4 pnts) Find the transfer function of the circuit, simplified such that there are no fractions in the numerator or denominator of the transfer function.

$$Z_{load} = \frac{1}{\frac{1}{j\omega L} + j\omega C} = \frac{j\omega L}{1 - \omega^2 LC}$$

$$H(j\omega) = \frac{V_{out}}{V_{in}} = \frac{Z_{load}}{R + Z_{load}} = \frac{\frac{j\omega L}{1-\omega^2 LC}}{R + \frac{j\omega L}{1-\omega^2 LC}} = \frac{j\omega L}{j\omega L + R(1 - \omega^2 LC)}$$

3.e) (2 pnts) Redraw and simplify the circuit, assuming operation at low and high frequencies.



Low and High are the same. At low frequency, C is open, L is short. At high frequencies, C is short, L is open.

3.f) (4 pnts) Find the magnitude and phase of the transfer function found in d) above for both low and high frequencies.

$$LOW: \frac{j\omega L}{R} \rightarrow Mag = \frac{\omega L}{R}, Phase = 90^\circ$$

$$HIGH: \frac{j\omega L}{-\omega * 2 * RLC} = \frac{-j}{\omega RC} \rightarrow Mag = \frac{1}{\omega RC}, Phase = -90^\circ$$

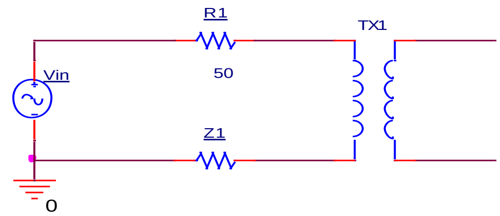
3.g) (1 pnts) Does the answer in 3.f) match what you drew in 3.e)? Why or why not?

No, because in f, the inductor and capacitor still exist. In e, Vout is 0, whereas it is non zero in f

Grading: Use best judgement if answered YES. Could construe that they are effectively the same when assuming omega =0 and inf.

Question Set 4) Phasors, Inductors, Transformers, and More (20 pnts)

Assuming TX1 in the circuit to the right is an ideal transformer with $L_{Primary} = 20\text{ mH}$, $L_{secondary} = 125\text{ mH}$, $V_{in} = 10\text{ V}$, and the voltages across the resistor and Z1 are measured to be $V_{R1} = 2.45\text{ V} \angle 42.74°$ and $V_{Z1} = 10.95\text{ V} \angle 106.20°$, answer questions a)-f) below. Operating frequency is 1 kHz. It is unknown what is connected to the secondary of the transformer.



4.a) (2 pnts) What are the values the voltages across R1 and Z1 (V_{R1} and V_{Z1}) in Cartesian form?

VR1 = 1.80 + 1.66j V

VZ1 = -3.05 + 10.52j V

4.b) (2 pnts) What would be the measured voltage across the primary coil of the transformer?

Vin = VR1 + Vprimary + VZ1 -> Vprimary = Vin – VR1 – VZ1

Vprimary = 11.25 – 12.18j V

4.c) (2 pnts) What is the current through the primary coil of the transformer? Please answer in mA.

Current through R1, primary and Z1 all the same since they are in series:

VR1 = IR1*R1 -> IR1 = VR1/R1 = 36 + 33.2j mA

4.d) (2 pnts) What is the load impedance presented by the primary coil of the transformer?

V = IZ -> Zprimary = Vprimary / IR1 = - 338.57j Ω

4.e) (2 pnts) What is the load impedance attached across the secondary coil of the transformer?

$a = \sqrt{L_{secondary}/L_{primary}} = 2.5$

$Z_{primary} = Z_{secondary}/a^2$ $\quad Z_{secondary} = Z_{primary}a^2 =$ -2116j Ω

4.f) (2 pnts) Assuming there are at most 2 components (R, L, or C) connected in series to the secondary coil, what are they (or is it) and what are their values (or its value)?

A single capacitor since it is purely imaginary and negative.

$Z_{cap} = 1/j\omega C$ -> $C = 1/j\omega Z_{cap}$ = 75.2 nF

4.g) (3 pnts) Consider a coil built on the entire length of a 6 cm long, 0.5 cm radius hollow plastic tube. It's inductance was measured to be 25 µH. One quarter of the coil was then cut off and the coil was pulled slightly to again cover the whole length of the tube. What is it's new inductance?

Essentially just removed 1/4 of the turns while leaving the rest of the LONG COIL equation inputs alone, lumped together as the constant A_L below:

$$L = \frac{\mu N^2 \pi r_c^2}{d} = A_L N^2$$

$$L_{original} = A_L N_{original}^2 \text{ -> } A_L = L_{original}/N_{original}^2$$

$$L_{new} = A_L N_{new}^2 = \frac{L_{original} N_{new}^2}{N_{original}^2}, N_{new} = 0.75\ N_{original}$$

$$L_{new} = L_{original} 0.75^2 = 14.1\ \mu\text{H}$$

4.h) (2 pnt) A resistor has the color bands yellow-green-red in order on it with no other markings. What are it's two possible values?

yellow-green-red is $45\text{x}10^2$ = 4.5 kΩ

red-green-yellow is $25\text{x}10^4$ = 250 kΩ

4.i) (1 pnt) What is a "decade" in terms of logarithmic scales?

It is a full jump in an order of magnitude, for example, 10^2 to 10^3 is a decade, so is $5\text{x}10^5$ to $5\text{x}10^6$

4.j) (1 pnt) Name at least two staff members (faculty or TA/USA) supporting EI, either section.

Elmo and Cookie Monster?

Check out the footer...

4.k) (1 pnt) What is your favorite activity when not doing work?

I bet the most popular answer is "Sleeping," or maybe a sarcastic (or not sarcastic) "nothing, I'm always doing work"