

**Math section** – questions 1 through 10

- ☐ (Q1) Ohm's/Joule's Law calculations in simple DC circuits
- ☐ (Q2) Resistor color code and tolerance calculations
- ☐ (Q3) Oscillograph interpretation
- ☐ (Q4) Ohm's Law calculations in simple AC circuits
- ☐ (Q5) Right-triangle distance calculations
- ☐ (Q6) Analog meter interpretation
- ☐ (Q7) Proportions
- ☐ (Q8) Unit conversions
- ☐ (Q9) Manipulating algebraic equations
- ☐ (Q10) Interpreting graphs

**DC circuits section** – questions 11 through 20

- ☐ (Q11) Series or parallel resistor network calculations
- ☐ (Q12) Series-parallel resistor network calculations
- ☐ (Q13) Bridge network calculations
- ☐ (Q14) Qualitative analysis of simple DC circuits
- ☐ (Q15) RC time delay calculations
- ☐ (Q16) LR time delay calculations
- ☐ (Q17) Multi-source network calculations
- ☐ (Q18) Thévenin/Norton equivalent networks
- ☐ (Q19) Voltage divider design
- ☐ (Q20) Time-delay circuit design

**AC circuits section** – questions 21 through 30

- ☐ (Q21) Rectifier circuit calculations
- ☐ (Q22) Series or parallel RLC network calculations
- ☐ (Q23) Series or parallel LC resonant circuit calculations
- ☐ (Q24) Transformer circuit calculations
- ☐ (Q25) Qualitative analysis of simple AC circuits
- ☐ (Q26) Three-phase wye-delta calculations
- ☐ (Q27) Three-phase delta-wye calculations
- ☐ (Q28) AC motor calculations
- ☐ (Q29) Filter circuit design
- ☐ (Q30) Sketch phasor diagrams

**Test and Measurements section** – questions 31 through 40

- ☐ (Q31) Sketch proper multimeter connections in a simple circuit
- ☐ (Q32) Adjusting oscilloscope controls to achieve better display
- ☐ (Q33) Identifying oscilloscope front-panel controls
- ☐ (Q34) Identifying standard electronic test equipment
- ☐ (Q35) Multimeter insertion resistance calculations
- ☐ (Q36) Sketch proper oscilloscope connections in circuits
- ☐ (Q37) Pulse-width-modulation load parameters via oscillograph
- ☐ (Q38) Interpreting curve-tracer graphs
- ☐ (Q39) Using logic tracer to test digital circuits
- ☐ (Q40) Using multimeter to test transistor switching circuits

**Troubleshooting section** – questions 41 through 50

- ☐ (Q41) Identifying possible faults in battery-switch-lamp circuit
- ☐ (Q42) Identifying possible faults in RC or LR time-delay circuit
- ☐ (Q43) Identifying possible faults in an unloaded voltage divider circuit
- ☐ (Q44) Identifying passive filter type and predict effect of component fault
- ☐ (Q45) Identifying possible faults in logic gate circuit
- ☐ (Q46) Identifying possible faults in relay ladder circuit
- ☐ (Q47) Identifying possible faults in semiconductor switching circuit
- ☐ (Q48) Identifying discrete component faults using ohmmeter
- ☐ (Q49) Identify effect of fault in power converter circuit
- ☐ (Q50) Interpreting purpose of a component(s) in a power electronics circuit

Note: this Comprehensive exam borrows many multi-part questions from regular exams offered throughout the EET program. In order to reduce the amount of time necessary to complete this 50-question exam, you will not be required to answer every part of every question. Instead:

- On troubleshooting questions where there is a “possible/impossible” fault table, you need only answer *three* rows in that table and not the entire table. You may choose which three faults to declare as either possible or impossible, but *all* of those answers must be correct in order to count as a correct answer for that question.
- On all other multi-part questions, you need only answer *one* part of that question. Again, if you answer more than one part of any multi-part question, *all* of those answers must be correct in order to count as a correct answer for that question.

**TOTAL SCORE** = \_\_\_\_\_

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**Question 1**

A simple circuit consisting of a voltage source and a resistor connected together with copper wire has the following properties:

- Resistor color code = White, Violet, Brown, Gold
- Wire colors = blue and orange
- Source voltage = 18 Volts
- Total wire length = 2.5 meters

Calculate the amount of power dissipated by the resistor in this circuit as well as the amount of current that will pass through it, assuming the resistor's actual value *precisely* follows its color code (i.e. assume zero error rather than the customary  $\pm 5\%$ ):

$$P =$$

$$I =$$

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**Question 2**

Determine the nominal, low, and high resistance values for the following four-band resistor color codes:

**Brown - Green - Red - Silver**

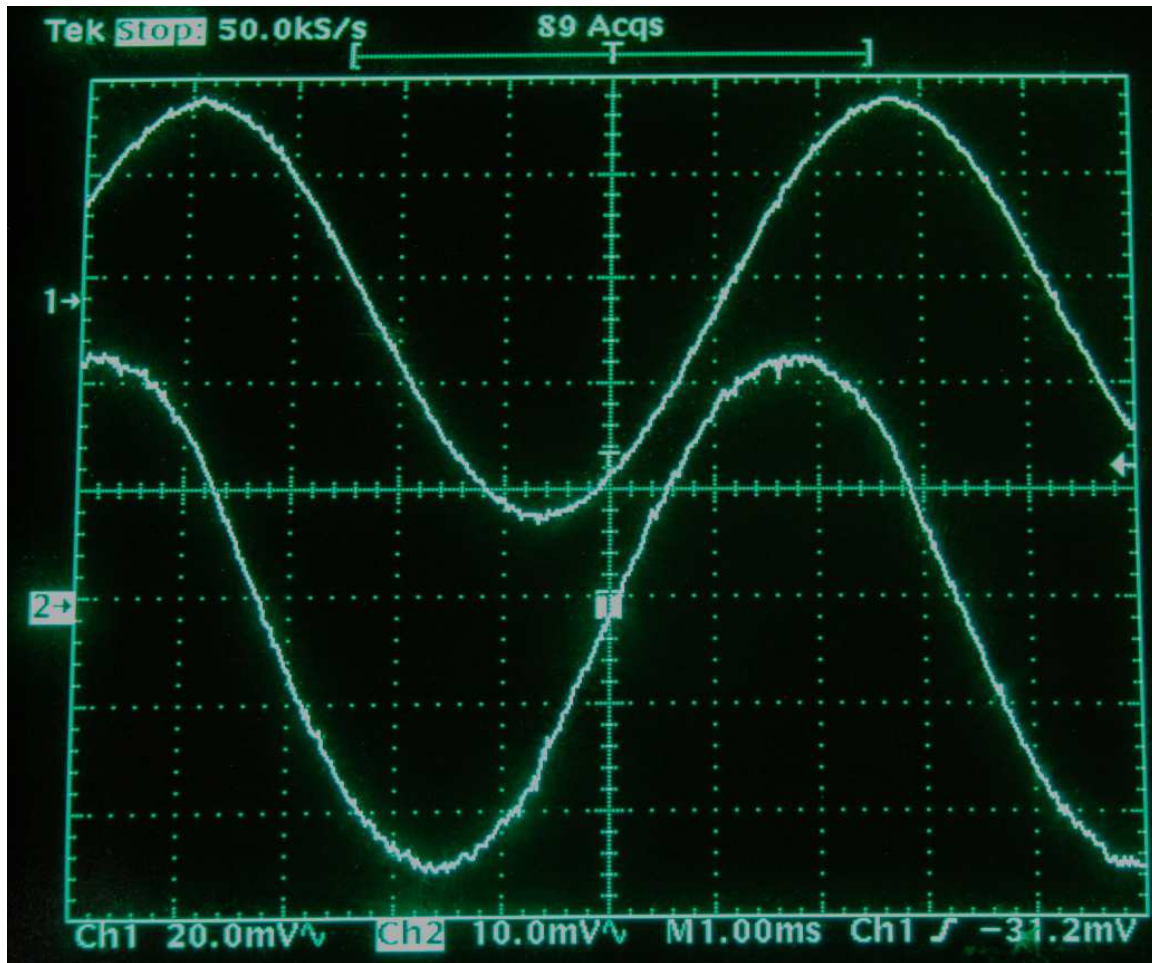
- Nominal (ideal) value = \_\_\_\_\_ Ohms
- Lowest tolerable value = \_\_\_\_\_ Ohms
- Highest tolerable value = \_\_\_\_\_ Ohms

**Orange - Red - Green - Gold**

- Nominal (ideal) value = \_\_\_\_\_ Ohms
- Lowest tolerable value = \_\_\_\_\_ Ohms
- Highest tolerable value = \_\_\_\_\_ Ohms

### Question 3

Identify the following parameters relating to these two voltage waveforms, where Channel 1 is the upper waveform and Channel 2 is the lower waveform. Channel sensitivity, timebase, and trigger settings for the oscilloscope appear immediately below the grid:



- Channel 1  $V_{pk} =$  \_\_\_\_\_
- Channel 2  $V_{pk-pk} =$  \_\_\_\_\_
- Period = \_\_\_\_\_
- Phase shift = \_\_\_\_\_
- Channel 1 leads or lags? Channel 2

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**Question 4**

An 8 milliAmpere RMS AC source with a frequency of 40 Hz connects to a  $3.3 \mu\text{F}$  capacitor. Calculate voltage in this circuit, expressing your answer in either rectangular or polar form, assuming the source is the phase reference (e.g.  $\angle 0^\circ$ ):

$$V = \underline{\hspace{2cm}}$$

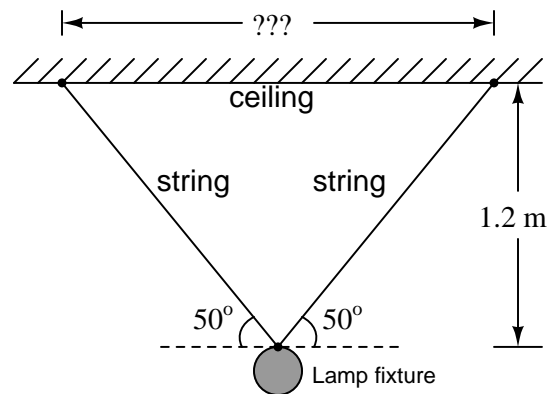
A 16 Volt RMS AC source with a frequency of 1 kHz connects to a 75 mH inductor. Calculate current in this circuit, expressing your answer in either rectangular or polar form, assuming the source is the phase reference (e.g.  $\angle 0^\circ$ ):

$$I = \underline{\hspace{2cm}}$$

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**Question 5**

A lamp fixture suspended by two equal-length strings must hang 1.2 meters below the ceiling. Calculate the total length of string necessary to hang this lamp, and the distance between the two points where the strings attach to the ceiling:



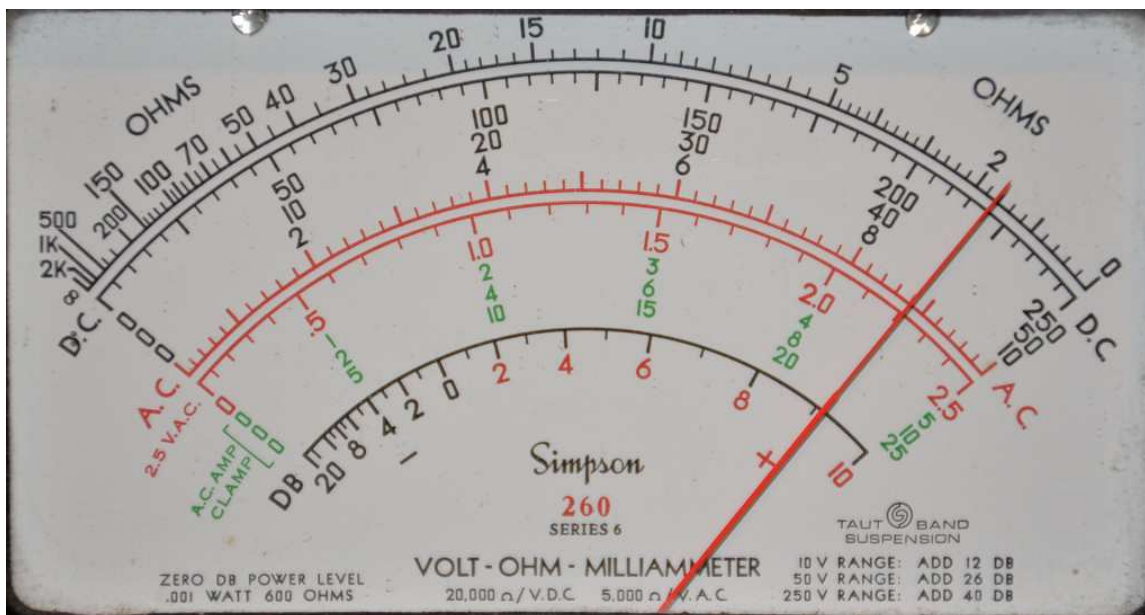
Total string length =                     

Distance between points =

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**Question 6**

Determine the amount of current being registered by this analog VOM (Volt-Ohm-Milliammeter) with its selector switch set on the 100 milliAmpere DC range:



Meter indication = \_\_\_\_\_

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**Question 7**

If a transformer outputs 12.4 Volts AC given a 120 Volt AC supply voltage, how much supply voltage will it require to output 9.5 Volts AC?

$V_{supply} =$  \_\_\_\_\_

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**Question 8**

Convert the temperature rate **30 degrees Rankine per minute** into **Kelvin per hour**. The following equivalents are given as a helpful reference, though you may not need to use all of them:

- 1 Kelvin = 1.8 degrees Rankine
- 1 minute = 60 seconds
- Freezing point of water = 32 degrees Celsius
- 1 hour = 60 minutes

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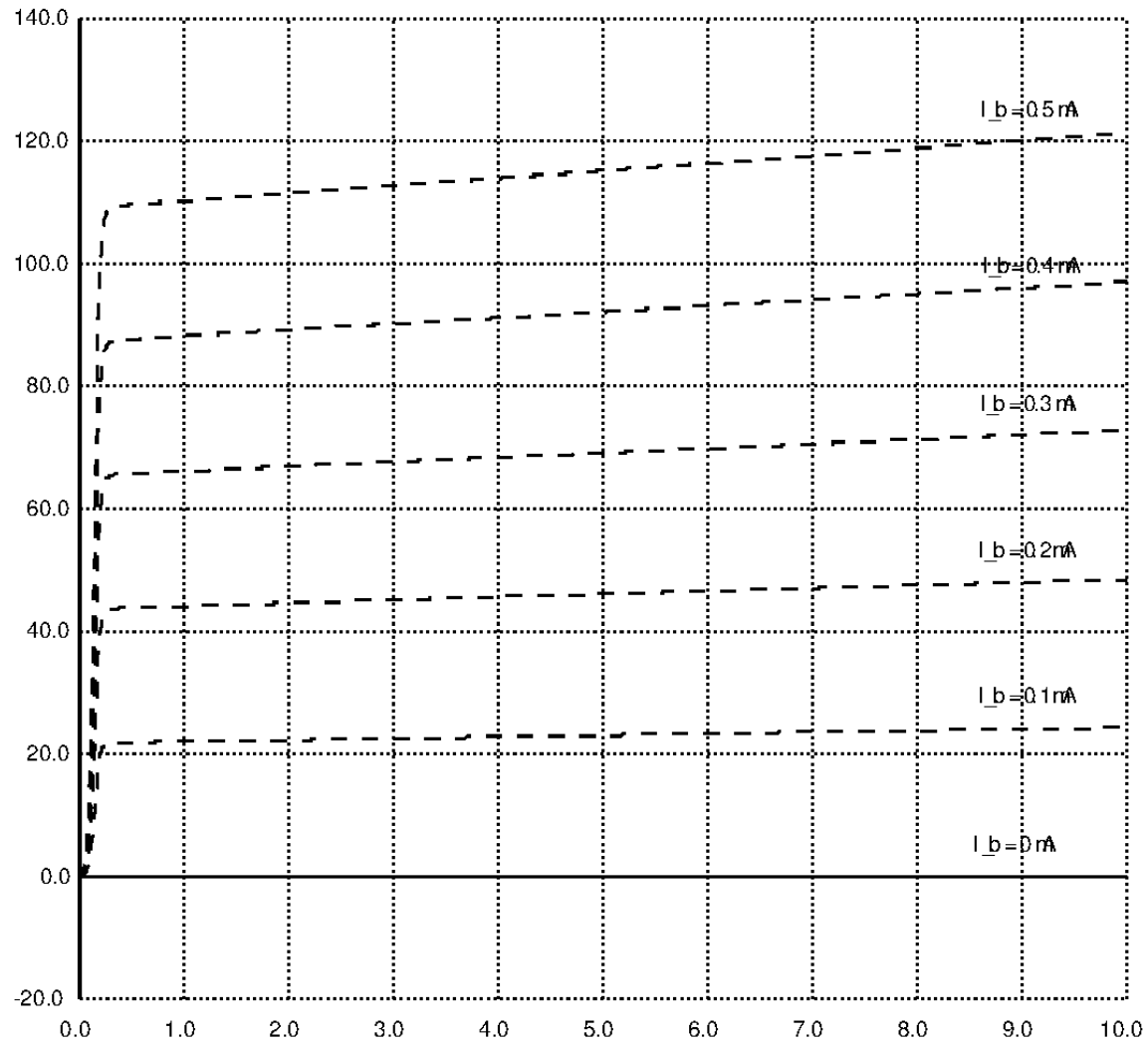
**Question 9**

Solve for  $x$  in this equation:

$$a = \sqrt{bx^2}$$

### Question 10

Identify the approximate collector-emitter voltage across a bipolar junction transistor necessary to drive a collector current of 90 mA at a base current of 0.4 mA, assuming the graph's vertical axis is calibrated in milliAmperes and horizontal axis calibrated in Volts:

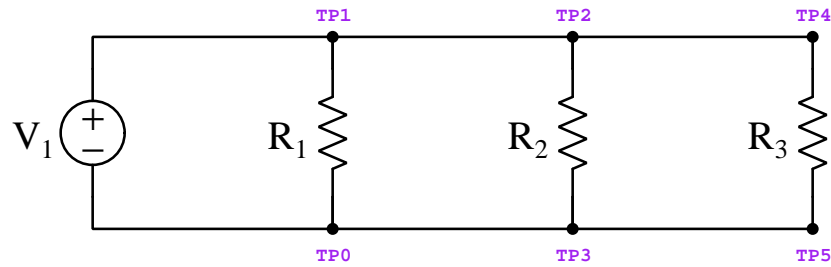


$V_{CE} =$  \_\_\_\_\_

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**Question 11**

Calculate the following parameters for this circuit, assuming  $V_1 = 4.2\text{ V}$ ,  $R_1 = 150\ \Omega$ ,  $R_2 = 25\ \Omega$ , and  $R_3 = 400\ \Omega$ :

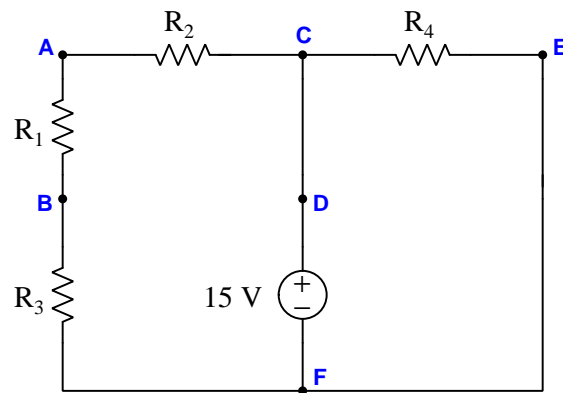


- $I_{R2} =$
- $P_{R3} =$
- $I_{total} =$
- $V_{TP1-TP5} =$

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**Question 12**

Calculate the amount of current through  $R_4$  in this series-parallel circuit, as well as the voltage between points B and D. Annotate the direction of current with an arrow pointing in the direction of conventional flow, and annotate voltage using + and - symbols, both annotations shown in the original diagram. Assume all resistors are  $1\text{ k}\Omega$  in resistance:



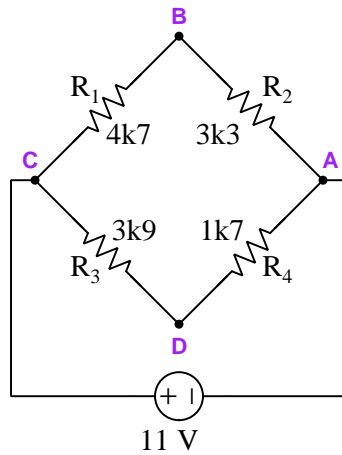
- $I_{R4} =$  (Also draw arrow on diagram)
- $V_{BD} =$  (Also draw + and - polarity marks on diagram)



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**Question 13**

Replace resistor  $R_4$  with one having a value necessary to balance this bridge circuit, then calculate the requested voltages and currents in the balanced circuit:

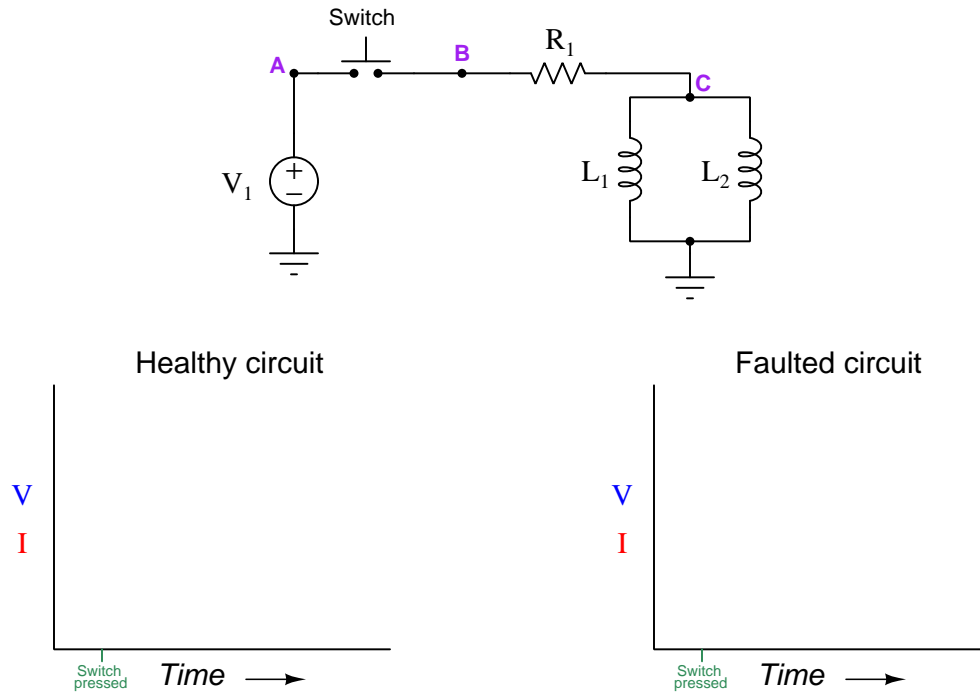


- $R_4 =$
- $V_{DC} =$
- $V_{BD} =$
- $I_{R2} =$
- $I_{source} =$

Be sure to specify whether the voltage values are positive or negative, following the convention that the first subscript represents the voltmeter's red test lead and the second subscript the black test lead (e.g.  $V_{AB}$  = red on A and black on B).

### Question 14

Suppose inductor  $L_1$  fails open in the following circuit:

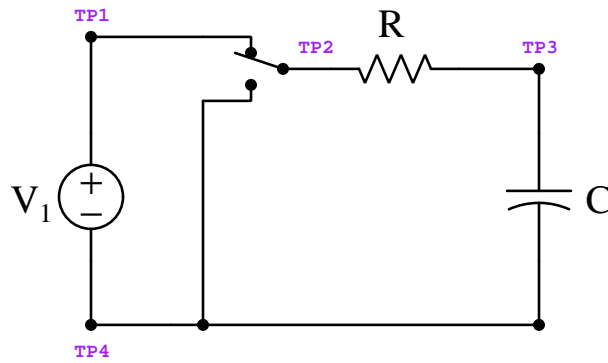


Sketch graphs for  $L_2$  voltage and current in the circuit assuming no faults (left) and again with the failed component (right).

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**Question 15**

Calculate the following parameters for this circuit, assuming  $V_1 = 12\text{ V}$ ,  $C = 820\text{ }\mu\text{F}$ ,  $R = 47\text{ k}\Omega$ , and that the capacitor's voltage happens to be 9.0 Volts at the time the switch is flipped to the “down” position:

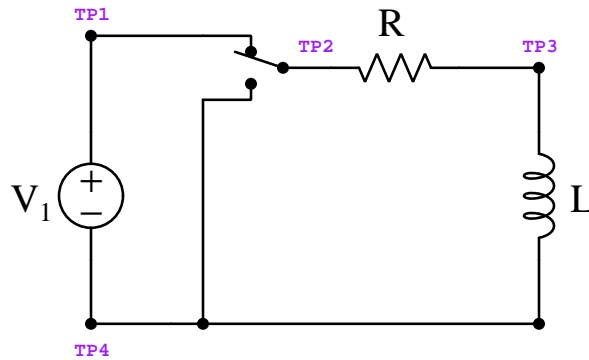


- $V_C$  60 seconds following switch flip =
- $V_{TP4-TP2}$  32 seconds following switch flip =
- $I_R$  70 seconds following switch flip =

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**Question 16**

Calculate the following parameters for this circuit, assuming  $V_1 = 10\text{ V}$ ,  $L = 0.5\text{ H}$ ,  $R = 47\text{ }\Omega$ , and that the inductor's current happens to be 150 mA at the time the switch is flipped to the “down” position:

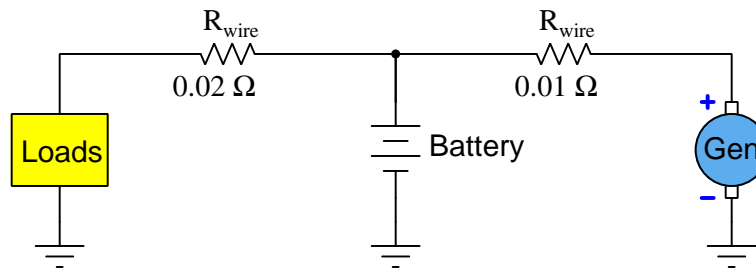


- $V_L$  5 milliseconds following switch flip =
- $V_{TP1-TP2}$  280 milliseconds following switch flip =
- $I_R$  20 milliseconds following switch flip =

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**Question 17**

In this circuit, a generator turned by an automobile engine provides electrical power to various loads in the automobile as well as current to re-charge the automobile's battery. The battery, of course, discharges when needed to provide additional current during "heavy" load conditions. The wires connecting these components together have small amounts of resistance as shown:



Supposing the battery's terminal voltage is 13.3 Volts, and that it is *discharging* (i.e. acting as an electrical energy *source*) with a current of 11.5 Amperes, and the load current is 18.2 Amperes, calculate the following:

$$V_{\text{generator}} =$$

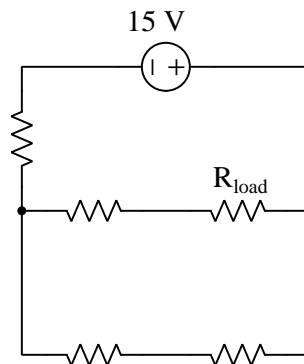
$$V_{\text{loads}} =$$

Also, show the direction of current (conventional flow notation) through both wires and through the battery.

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**Question 18**

Sketch a Thévenin equivalent circuit for this network complete with  $V_{Th}$  and  $R_{Th}$  values, and also calculate load voltage. Assume a load resistance of  $2 \text{ k}\Omega$ , and that all other resistors in the original network have equal values of  $1 \text{ k}\Omega$  each:



- $V_{Th} =$
- $R_{Th} =$
- $V_{\text{load}} =$

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**Question 19**

Design and sketch an unloaded voltage divider circuit powered by a 24 Volt DC source that outputs 4 Volts (with polarity shown) between a pair of terminals in parallel with a resistor that is connected in series with a  $2.2\text{ k}\Omega$  resistor, being sure to specify any necessary component value(s).



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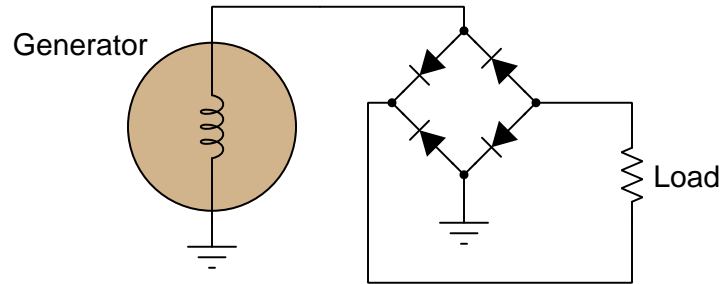
**Question 20**

Design and sketch a circuit where a measured current begins at a value of zero, then inverse-exponentially climbs after toggling a switch, and eventually settles at a maximum of 120 milliAmperes. Be sure to specify *where* in your circuit this current will be measured.

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**Question 21**

Calculate voltage across the load as well as the direction of current in this circuit at the exact instantaneous moment in time when the generator's voltage reaches 60 Volts (– on top terminal, + on ground terminal), assuming the use of a standard silicon rectifying diode:



$$V_{load} = \underline{\hspace{2cm}}$$

$$I_{load} = \text{(sketch arrow in the direction of conventional flow)}$$

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**Question 22**

Calculate the following parameters for a series resistor-inductor-capacitor circuit given the following component values:

- $V_{source} = 5$  Volts RMS
- $f_{source} = 200$  Hz
- $R = 150\ \Omega$
- $L = 40$  mH
- $C = 27\ \mu\text{F}$

$$Z_{total} = \underline{\hspace{2cm}}$$

$$I_C = \underline{\hspace{2cm}}$$

$$V_R = \underline{\hspace{2cm}}$$

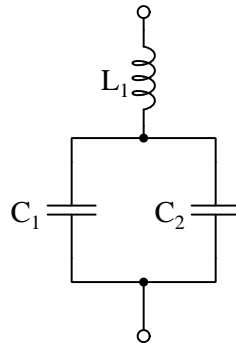
$$Z_L = \underline{\hspace{2cm}}$$

All answers must be shown as phasor (i.e. complex-number) quantities in polar form.

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**Question 23**

Choose the necessary value for  $C_1$  to make this network resonate at a frequency of 7 kHz assuming  $L_1$  is 0.8 mH and  $C_2$  is  $0.33 \mu\text{F}$ , and determine whether the total impedance at that resonant frequency will be extremely high or extremely low:



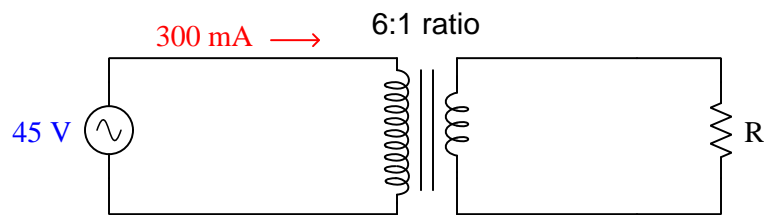
$$C_1 = \underline{\hspace{2cm}}$$

$$Z_{total} \text{ @ resonance} = \textit{high / low}$$

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**Question 24**

Calculate the load voltage and resistance in this transformer circuit. Assume an ideal transformer with no power losses at all:



$$V_{load} =$$

$$R_{load} =$$

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**Question 25**

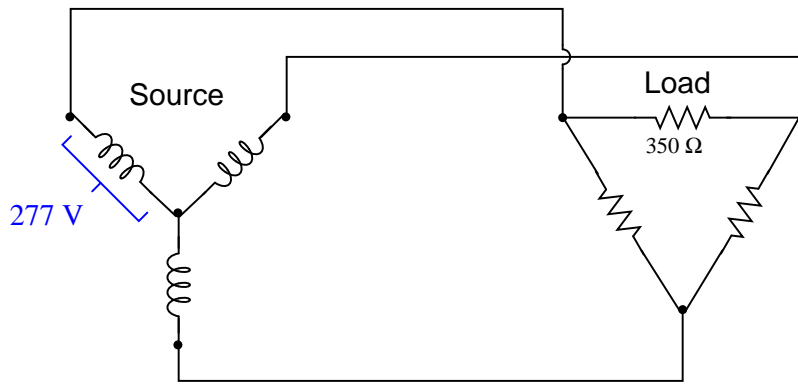
Predict the effects on the following voltages and currents in a series RL network with constant source voltage if the inductor is replaced with another having a smaller value (i.e. fewer milliHenrys):

- Current through source (*increases, decreases, or remains the same*)
- Voltage across  $L$  (*increases, decreases, or remains the same*)
- Voltage across  $R$  (*increases, decreases, or remains the same*)

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**Question 26**

Calculate the following parameters in this balanced 3-phase power system, assuming a source phase voltage of 277 VAC and a load phase resistance of 350 Ohms:



$$I_{line} = \text{_____} \text{ Amperes}$$

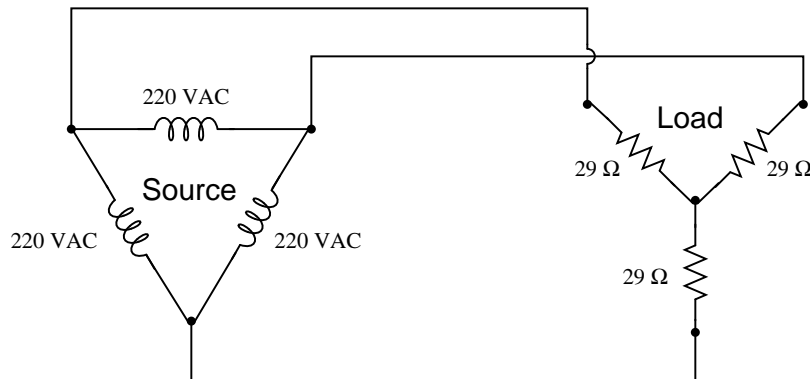
$$V_{line} = \text{_____} \text{ Volts}$$

$$I_{phase} \text{ (load)} = \text{_____} \text{ Amperes}$$

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**Question 27**

Calculate the following parameters in this balanced 3-phase power system, assuming a source phase voltage of 220 VAC and a load phase resistance of 29 Ohms:



$$V_{line} = \text{_____} \text{ Volts}$$

$$I_{line} = \text{_____} \text{ Amperes}$$

$$I_{phase} \text{ (source)} = \text{_____} \text{ Amperes}$$



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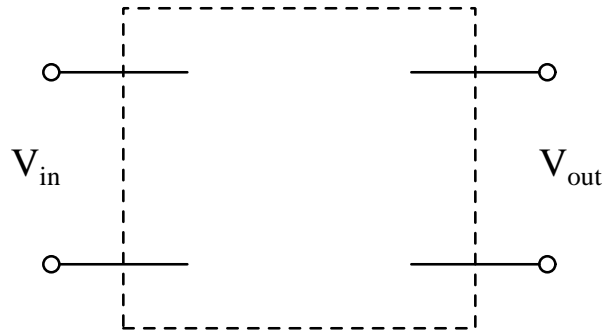
**Question 28**

A three-phase electric motor running on a line voltage of 480 Volts draws 9.3 Amperes of current. Calculate the horsepower output of this motor at this line current, assuming 100% efficiency and a perfect power factor (1.0).

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**Question 29**

Design a low-pass filter with a cutoff frequency of 4 kHz, using either a 250 mH, 110 mH, or 90 mH inductor. Sketch the components between the terminals shown below:



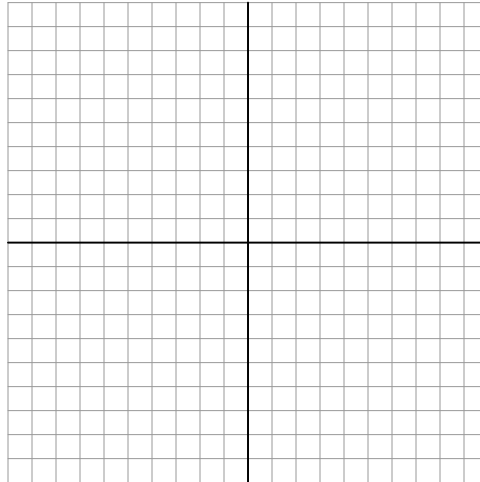
Be sure to show all component values within your diagram.

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**Question 30**

Sketch a phasor diagram for all impedances in a simple series resistor-capacitor circuit given the following component values:

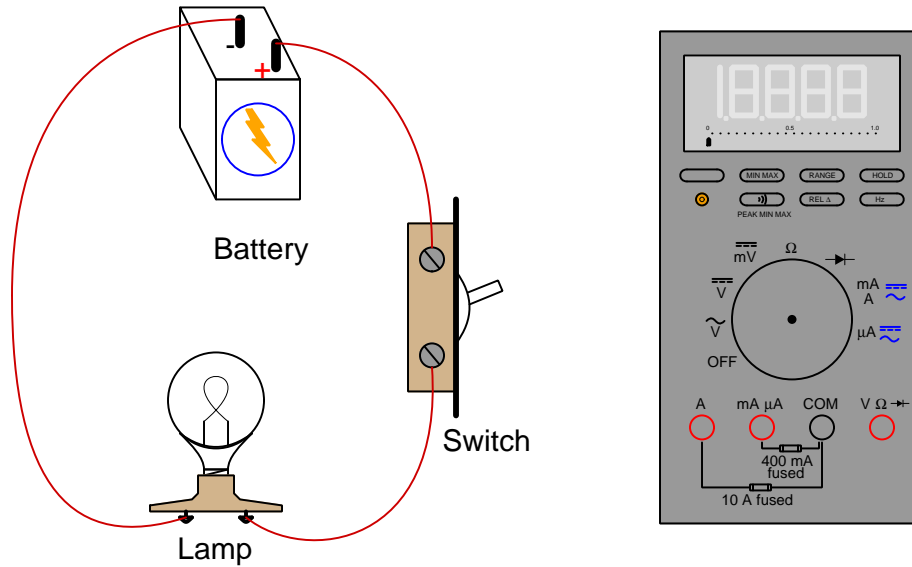
- $V_{source} = 50$  Volts RMS  $\angle 0^\circ$
- $f_{source} = 60$  Hz
- $R = 30\ \Omega$
- $C = 68\ \mu\text{F}$



Draw the phasor lengths and angles as close to scale as you can, being sure to document your calculated values for the phasor quantities (i.e. show your work!).

### Question 31

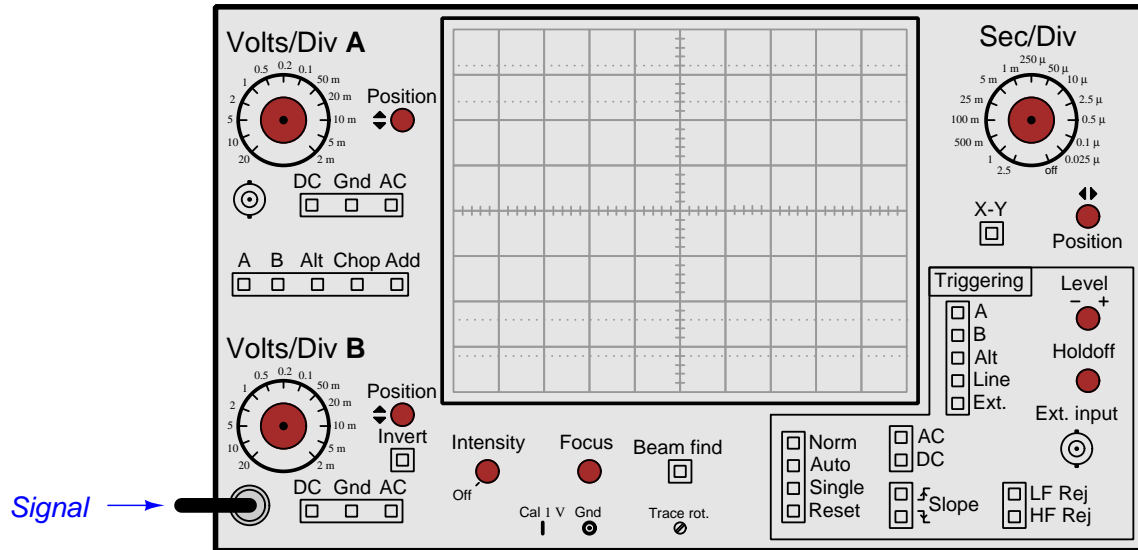
Show how this digital multimeter should connect to the circuit in order to measure the **lamp's voltage**, such that the meter will register a positive quantity, anticipating between 12 Volts and 15 Volts. If you must break continuity anywhere in the circuit, please mark each broken connection with an "X" symbol:



- Sketch proper connections for the red and black test leads
- Show proper setting of the meter's rotary selector

### Question 32

This oscilloscope displays nothing at all even when there is a known signal applied to Channel B. Identify the front-panel control(s) on this oscilloscope you *might* use to view the waveform:



### Question 33

Identify the front-panel control(s) on this oscilloscope you would use to alter the vertical size of the displayed waveform for Channel 2:



### Question 34

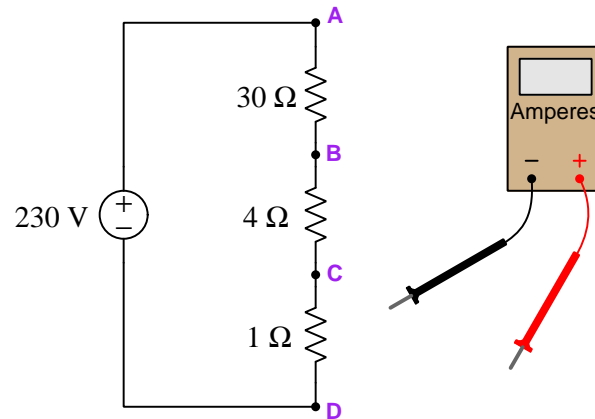
Identify the purpose of this test instrument, and also identify one practical application for it:



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**Question 35**

Sketch how to connect this digital multimeter (DMM) to measure current passing through point **B** in this circuit so that it will register a negative value. If you need to break any existing wire connections to do so, mark those breaks with “X” symbols.



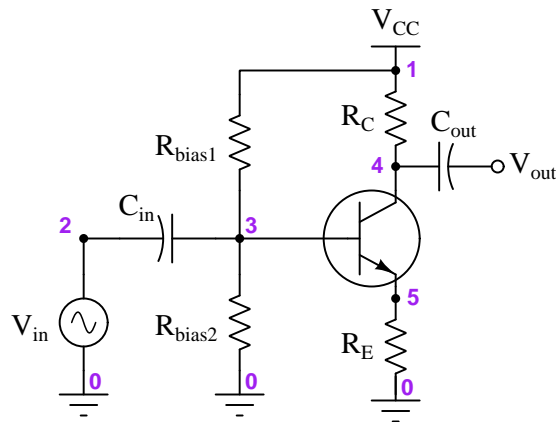
Next, determine how much current this DMM will register when connected between those points, assuming the meter has an internal (insertion) resistance of  $12\ \Omega$ .

Current measurement = \_\_\_\_\_ Amperes

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**Question 36**

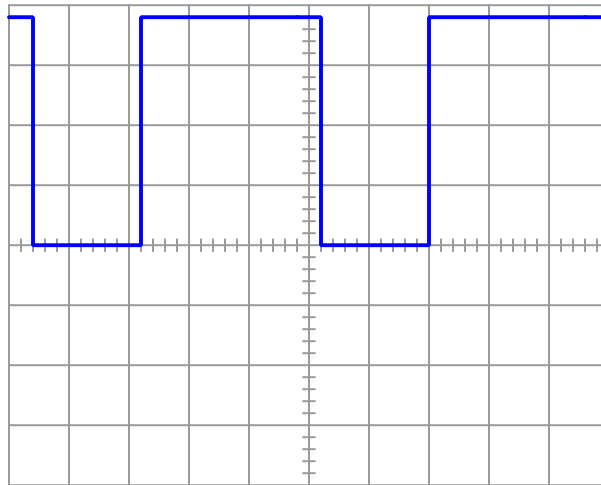
Identify where an oscilloscope probe could be connected in this circuit to measure its *output voltage*:



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**Question 37**

An oscilloscope measures pulsed DC current through a  $22\ \Omega$  load resistance that is known to be dissipating an average power of 129 Watts. Determine the peak current of this PWM waveform:



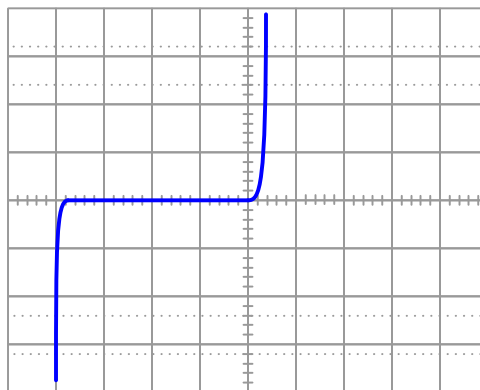
$$I_{pk} = \underline{\hspace{2cm}}$$

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**Question 38**

Interpret this display shown by a *curve tracer* instrument which works by exciting a component with an AC or “swept” DC voltage (horizontal axis) and measuring device current (vertical axis), yielding a current/voltage characteristic curve for the device under test.

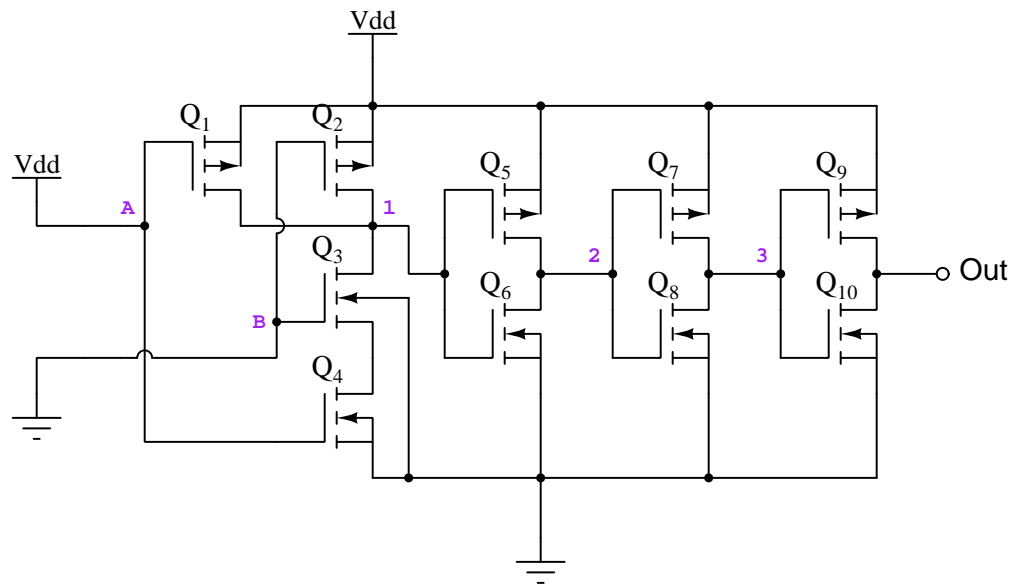
Identify both the component connected to this curve tracer as well as any defects in that component as evidenced by the instrument’s display:





### Question 39

Determine the states that would be measured at various test points in this digital circuit using a logic probe:



Logic state at test point 1 = (high) or (low)

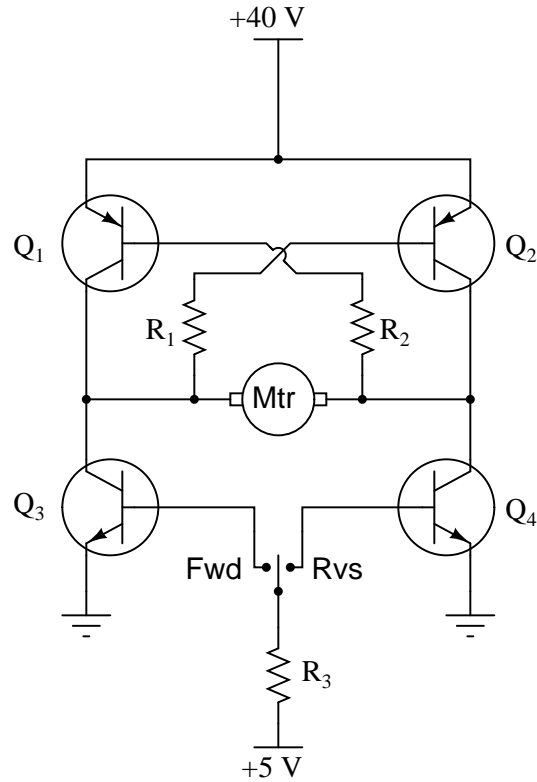
Logic state at test point 3 = (high) or (low)

Logic state at output = (high) or (low)

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**Question 40**

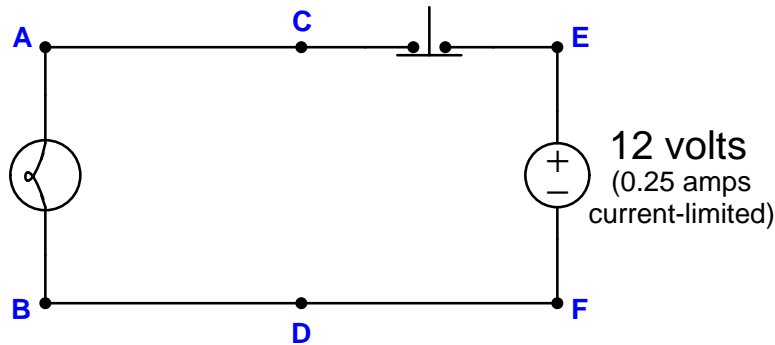
This set of transistors controls the direction of a DC electric motor:



Identify where at one of the transistor terminals you could connect a multimeter to measure motor *inrush current* at the moment in time when the SPDT switch moves to the appropriate position to spin the motor the “reverse” direction. It is important that the meter only register motor current, and not any additional current, during this test! In addition to identifying the connection points, also specify which function (voltage, current, resistance) the multimeter should be configured for during this test.

### Question 41

Suppose the lamp refuses to light up regardless if the pushbutton switch is pressed or not. A voltmeter registers 0 Volts between test points **A** and **D** in the circuit while the pushbutton is released (not pressed):



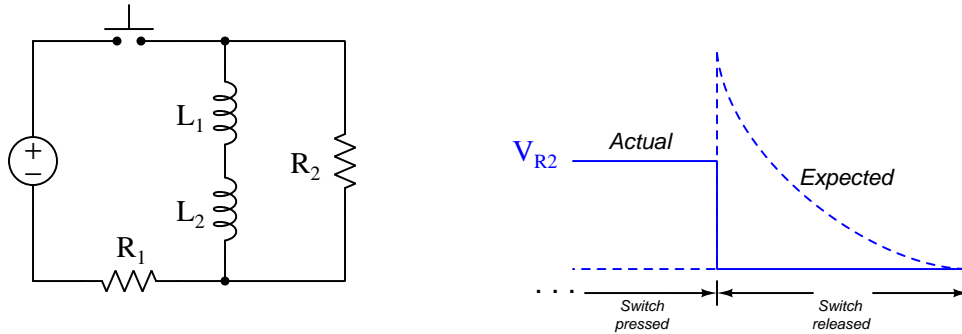
Note that a “current-limited” voltage source behaves like a normal voltage source when the load draws less than its current rating (i.e. constant voltage), but when faced with a load that would draw more current than its rating it switches into current-source mode and limits current to that rated value while letting the voltage sag below its normal value. For example, when shorted, a current-limited source will output its rated current at zero Volts.

Identify the likelihood of each specified fault. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault is compatible with *all* measurements and symptoms in this system.

Fault	Possible	Impossible
Open wire between A and C		
Open wire between B and D		
Open wire between D and F		
Lamp failed open		
Switch failed open		
Lamp failed shorted		
Switch failed shorted		

### Question 42

Suppose the voltage dropped across resistor  $R_2$  when the pushbutton switch is released follows a “step” pattern rather than an inverse-exponential decays it should, as shown in the graph to the right of the schematic diagram. The dashed graph shows what the circuit ought to do, while the solid graph shows what it actually does:



Identify the likelihood of each specified fault. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault is compatible with *all* measurements and symptoms in this system.

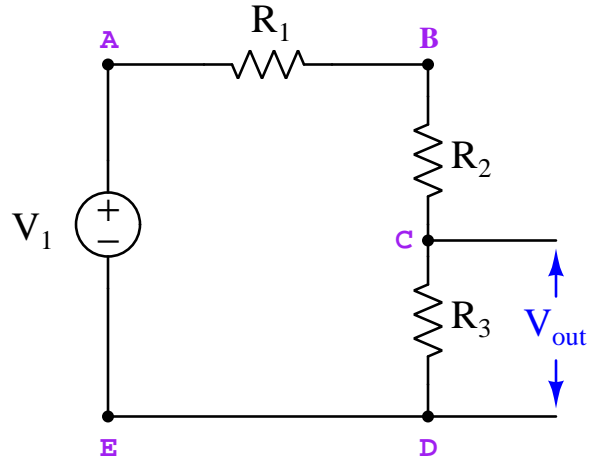
Fault	Possible	Impossible
Resistor $R_1$ failed open		
Resistor $R_2$ failed open		
Inductor $L_1$ failed open		
Inductor $L_2$ failed open		
Inductor $L_1$ failed shorted		
Inductor $L_2$ failed shorted		

### Question 43

The following voltage divider circuit has a problem, as it is found to output 0 Volts. The components are rated as follows:

- $V_1 = 30$  Volts
- $R_1 = 7.1$  k $\Omega$
- $R_2 = 7.1$  k $\Omega$
- $R_3 = 7.1$  k $\Omega$

A diagnostic test performed using a voltmeter registers 30 Volts between test points **B** and **C**.

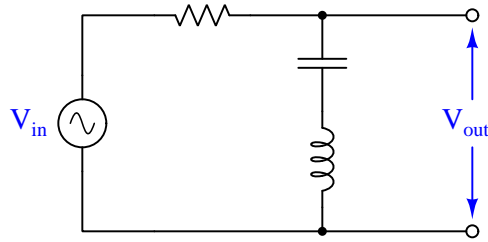


Identify the likelihood of each specified fault. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault is compatible with *all* measurements and symptoms in this system.

Fault	Possible	Impossible
Open wire between E and D		
R1 failed open		
R2 failed open		
R3 failed open		
R1 failed shorted		
R2 failed shorted		
R3 failed shorted		
Voltage source dead		

### Question 44

Identify the type of filtering behavior of the circuit shown in this diagram:

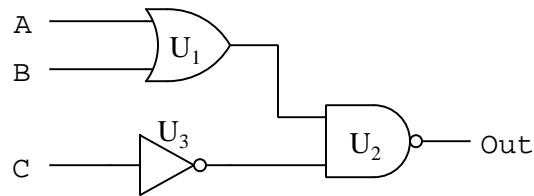


Next, identify the filtering behavior of this same circuit supposing the inductor fails *shorted*. Place two check-marks in the table below to identify each filtering characteristic (one check-mark identifying the healthy circuit's characteristic and another check-mark identifying the faulted circuit's characteristic):

Filter type	Healthy circuit	Faulted circuit
Low-pass		
High-pass		
Band-pass		
Band-stop		
Passes all frequencies		
Blocks all frequencies		

### Question 45

The following logic gate circuit has a problem. Its output state is always low (0) regardless of the input states:

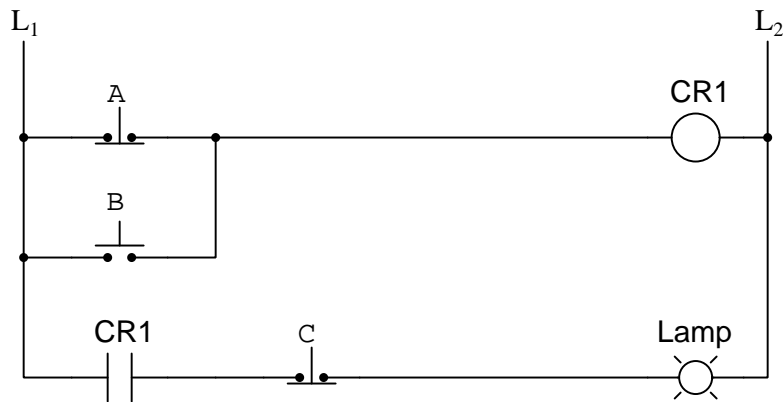


Identify the likelihood of each specified fault. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault is compatible with *all* measurements and symptoms in this system.

Fault	Possible	Impossible
$U_1$ output failed low		
$U_1$ output failed high		
$U_2$ output failed low		
$U_2$ output failed high		
$U_3$ output failed low		
$U_3$ output failed high		

### Question 46

The following relay ladder logic circuit has a problem. The lamp energizes every time pushbutton C is released, regardless of the other switch states:



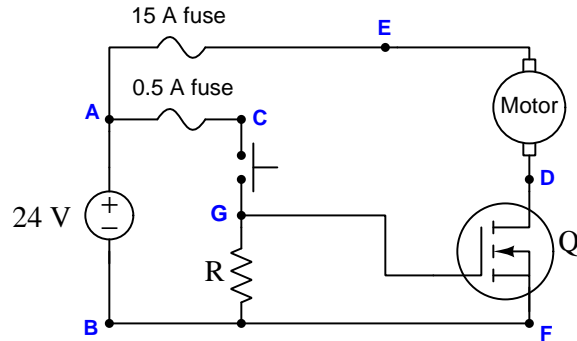
Identify the likelihood of each specified fault. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault is compatible with *all* measurements and symptoms in this system.

Fault	Possible	Impossible
Switch <i>A</i> failed open		
Switch <i>A</i> failed shorted		
Switch <i>B</i> failed open		
Switch <i>B</i> failed shorted		
Switch <i>C</i> failed open		
Switch <i>C</i> failed shorted		
CR1 contact failed open		
CR1 contact failed shorted		

---

**Question 47**

Suppose this DC electric motor refuses to run when the pushbutton switch is pressed. A voltmeter subsequently connected between test points **D** and **F** in this circuit registers 0 Volts when the switch is pressed:



Identify the likelihood of each specified fault. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault is compatible with *all* measurements and symptoms in this system.

Fault	Possible	Impossible
Pushbutton switch failed open		
Pushbutton switch failed shorted		
Motor failed open		
Resistor failed open		
15 amp fuse blown		
0.5 amp fuse blown		

---

**Question 48**

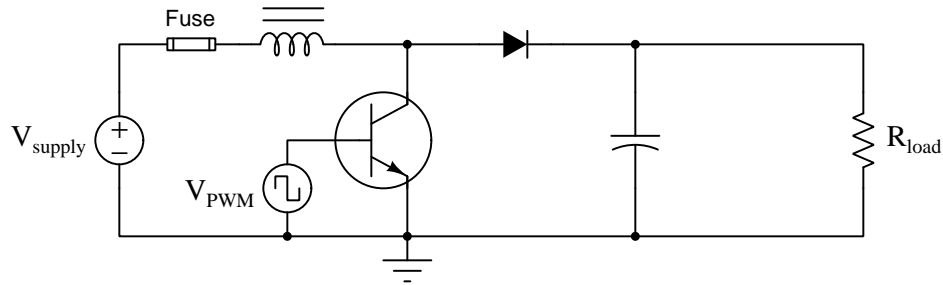
A resistor with color code Yel-Vio-Org-Sil measures 44,500 Ohms when tested with an ohmmeter. Determine whether or not this resistor's resistance is within tolerance.



---

**Question 49**

Identify the effects of a *failed-shorted inductor* in this boost converter circuit:



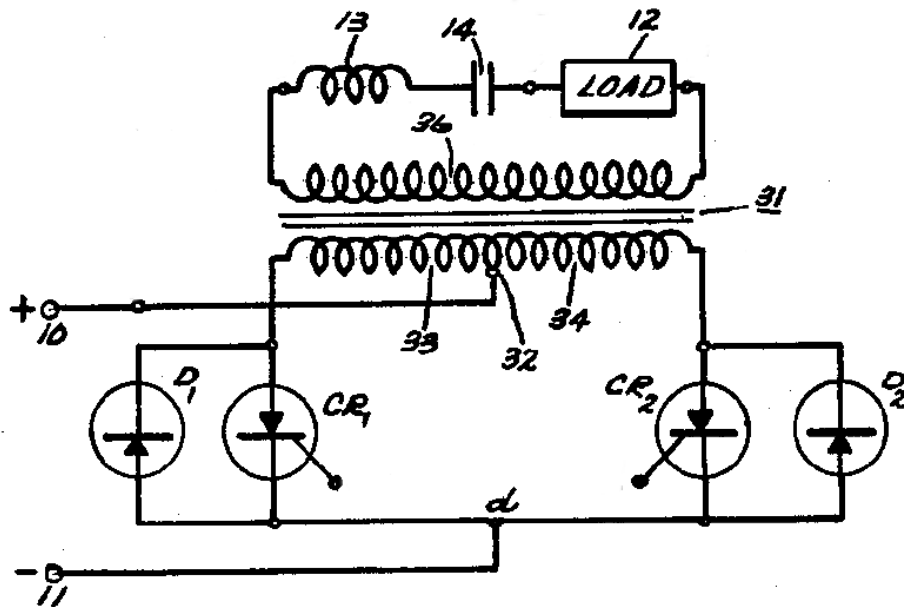
Assume the PWM signal's duty cycle remains constant before and after the fault (i.e. no automatic adjustment in an attempt to regulate load voltage or current).

- Fuse will blow (*yes* or *no*?)
- Load voltage (*increase* or *decrease* or *unchanged*?)
- Supply current (*increase* or *decrease* or *unchanged*?)

---

**Question 50**

Identify the component(s) responsible for controlled switching of DC power in this partial DC-AC converter circuit schematic:



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---

**Answer 1**

Resistor color code = White, Violet, Brown, Gold =  $970\ \Omega$

$$P = 334.03\ \text{mW}$$

$$I = 18.557\ \text{mA}$$

---

**Answer 2****Brown - Green - Red - Silver**

- Nominal (ideal) value = 1,500 Ohms
- Lowest tolerable value = 1,350 Ohms
- Highest tolerable value = 1,650 Ohms

**Orange - Red - Green - Gold**

- Nominal (ideal) value = 3,200,000 Ohms
  - Lowest tolerable value = 3,040,000 Ohms
  - Highest tolerable value = 3,360,000 Ohms
- 

**Answer 3**

*Note: allow for  $\pm 10\%$  tolerance on all answers ( $\pm 10^\circ$  on phase) to account for uncertainties of the display.*

- Channel 1  $V_{pk} = \underline{41\ \text{mV}}$
  - Channel 2  $V_{pk-pk} = \underline{47\ \text{mV}}$
  - Period = 6.6 ms
  - Phase shift =  $50^\circ$
  - Channel 1 lags Channel 2
- 

**Answer 4**

$$V = 9.6458\ \text{V} \angle -90^\circ \quad 0 - j9.6458\ \text{V}$$

$$I = 33.953\ \text{mA} \angle -90^\circ \quad 0 - j33.953\ \text{mA}$$

---

**Answer 5**

Total string length = 3.1330 meters

Distance between points = 2.0138 meters

---

**Answer 6**

(Answer rounded to the nearest minor division)

Meter indication = 88 mADC

---

**Answer 7**

$$V_{supply} = \underline{91.935\ \text{VAC}}$$

---

---

Answer 8

30 degrees Rankine/minute = 1000 Kelvin/hour

---

Answer 9

$$x = \sqrt{\frac{a^2}{b}}$$

---

Answer 10

$V_{CE} = \underline{3 \text{ Volts}}$  (any answer between 1 V and 5 V is acceptable)

---

Answer 11

- $I_{R2} = 168.0 \text{ mA}$
  - $P_{R3} = 44.1 \text{ mW}$
  - $I_{total} = 206.5 \text{ mA}$
  - $V_{TP1-TP5} = 4.2 \text{ V}$
- 

Answer 12

$I_{R4} = 15 \text{ mA}$  – arrow pointing right, from C to E

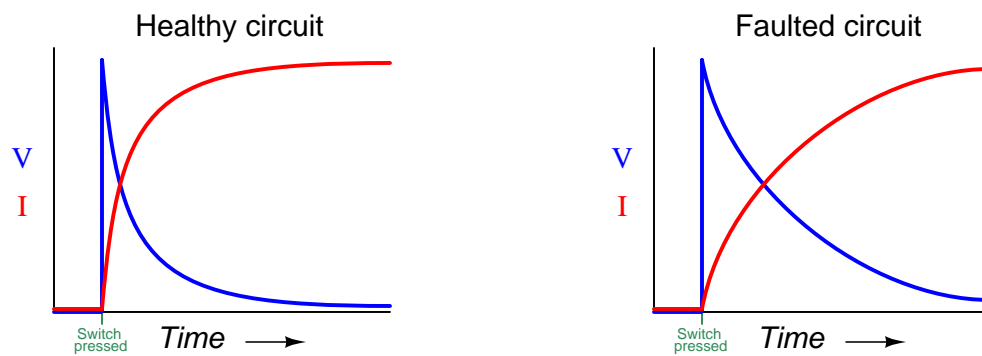
$V_{BD} = 10 \text{ V}$  – B negative (–) and D positive (+)

---

Answer 13

- $R_4 = 2738.30 \, \Omega$
  - $V_{DC} = -6.4625 \text{ V}$
  - $V_{BD} = 0.0000 \text{ V}$
  - $I_{R2} = 1.375 \text{ mA}$
  - $I_{source} = 3.032 \text{ mA}$
- 

Answer 14



---

**Answer 15**

- $V_C$  60 seconds following switch flip = **1.897 V**
- $V_{TP4-TP2}$  32 seconds following switch flip = **0 V**
- $I_R$  70 seconds following switch flip = **31.14  $\mu\text{A}$**

---

**Answer 16**

- $V_L$  5 milliseconds following switch flip = **4.406 V**
- $V_{TP1-TP2}$  280 milliseconds following switch flip = **10 V**
- $I_R$  20 milliseconds following switch flip = **22.89 mA**

---

**Answer 17**

$$V_{generator} = \mathbf{13.367 \text{ Volts}}$$

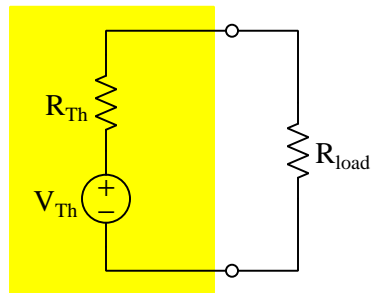
$$V_{loads} = \mathbf{12.936 \text{ Volts}}$$

Current from **right to left** through both wires ; current **up** through the battery.

---

**Answer 18**

*Thevenin equivalent network*



- $V_{Th} = 10 \text{ Volts}$
- $R_{Th} = 1.6667 \text{ k}\Omega$
- $V_{load} = 5.4545 \text{ V}$

---

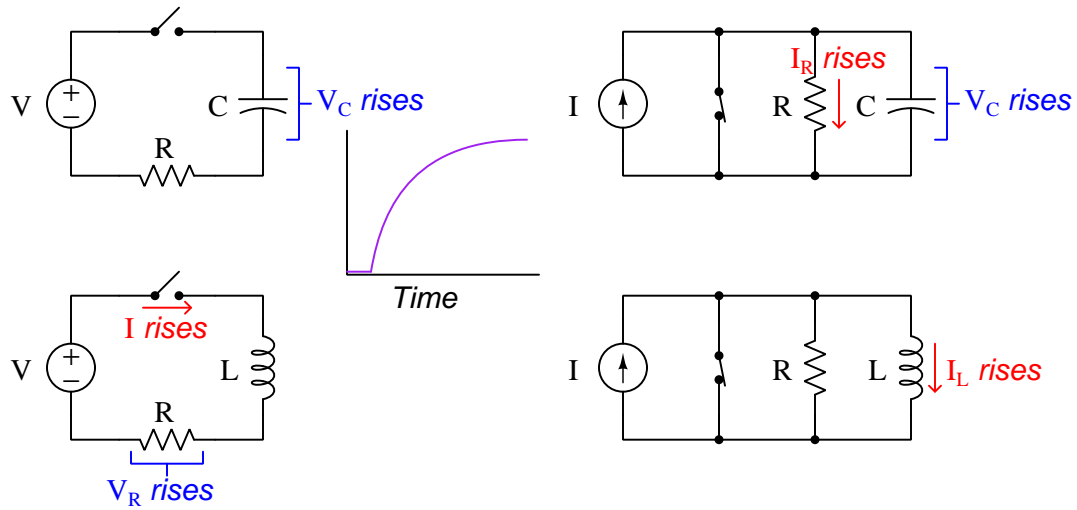
**Answer 19**

The resistor with the output terminals must be  $440 \text{ }\Omega$ , connected in series with the  $2.2 \text{ k}\Omega$  resistor.

---

**Answer 20**

Variables that **rise** in inverse-exponential fashion  
when switch is toggled to the opposite state



---

**Answer 21**

$$V_{load} = \underline{58.6 \text{ V}}$$

$I_{load}$  = **up** through load, through upper-right diode, **down** through source, through lower-left diode

---

**Answer 22**

$$Z_{total} = \underline{151.434 \Omega \angle 7.8918^\circ}$$

$$I_C = \underline{33.0176 \text{ mA} \angle -7.8918^\circ}$$

$$V_R = \underline{4.95265 \text{ V} \angle -7.8918^\circ}$$

$$Z_L = \underline{50.2655 \Omega \angle 90^\circ}$$

---

**Answer 23**

$$C_1 = \underline{0.31618 \mu\text{F}}$$

$$Z_{total} \text{ @ resonance} = \underline{\text{low}}$$

---

**Answer 24**

$$V_{load} = 7.5 \text{ V}$$

$$R_{load} = 4.167 \Omega$$

---

**Answer 25**

- Current through source **increases**
- Voltage across  $L$  **decreases**
- Voltage across  $R$  **increases**

---

**Answer 26**

$$I_{line} = \underline{2.3743} \text{ Amperes}$$

$$V_{line} = \underline{480} \text{ Volts}$$

$$I_{phase} \text{ (load)} = \underline{1.3708} \text{ Amperes}$$

---

**Answer 27**

$$V_{line} = \underline{220} \text{ Volts}$$

$$I_{line} = \underline{4.380} \text{ Amperes}$$

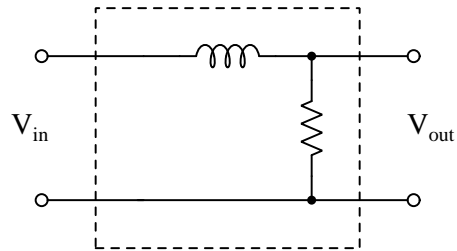
$$I_{phase} \text{ (source)} = \underline{2.529} \text{ Amperes}$$

---

**Answer 28**

$$P = 10.36 \text{ horsepower}$$

---

**Answer 29**

$$L = 250 \text{ mH} ; R = 6.283 \text{ k}\Omega$$

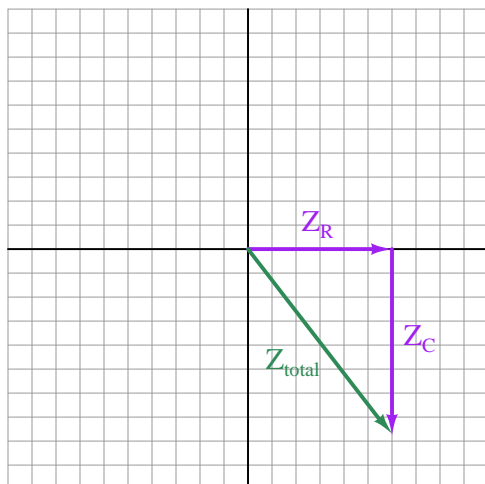
$$L = 110 \text{ mH} ; R = 2.765 \text{ k}\Omega$$

$$L = 90 \text{ mH} ; R = 2.262 \text{ k}\Omega$$

---

**Answer 30**

Note: the order of the phasors is arbitrary, but the resultant (shown as a green vector) is not.



$$Z_R = 30.0000 \, \Omega \angle 0^\circ$$

$$Z_C = 39.0086 \, \Omega \angle -90^\circ$$

$$Z_{total} = 49.2104 \, \Omega \angle -52.4375^\circ$$

---

**Answer 31**

- Sketch proper connections for the red and black test leads
  - Red ( $V\Omega D$ ) to right lamp terminal, Black ( $COM$ ) to left lamp terminal
  - NOTE: any similar connections parallel to the lamp are acceptable
- Show proper setting of the meter's rotary selector
  - Set to DC V position

---

**Answer 32**

Possible controls to manipulate include the Intensity knob (also the power knob), the Beam Find button (to locate where the waveform might be displaced), and the Triggering controls (be sure to set to Channel B, Auto mode).

---

**Answer 33**

The "VOLTS/DIV CH 2" knob.

---

**Answer 34**

This is a *function generator* or *signal generator*, used as a source of voltage signals with variable frequency, amplitude, and/or waveshape. One practical application for it is to drive the input of an amplifier circuit.



---

**Answer 35**

Break the circuit at test point **B**, then connect the red probe to the bottom of that break and the black probe to the top of that break.

Current measurement = 4.89362 Amperes

---

**Answer 36**

Connect the probe tip to the Out terminal (or test point 4) and the ground clip to test point 0.

---

**Answer 37**

$t_{on} = 3 \text{ div}$        $t_{off} = 1.8 \text{ div}$       Duty cycle = 62.5%       $P_{pk} = 206.4 \text{ W}$

$I_{pk} =$  3.0630 Amperes

---

**Answer 38**

This curve matches the characteristics of a *zener diode*, and it appears to be healthy. Alternatively, it could be a regular rectifying diode that is breaking down prematurely in reverse-bias mode.

---

**Answer 39**

Logic state at test point 1 = high

Logic state at test point 3 = high

Logic state at output = low

---

**Answer 40**

Measure DC current at  $Q_1$ 's collector terminal, with the switch moving to the *reverse* position to trigger current through  $Q_1$  and to the motor.

---

**Answer 41**

Fault	Possible	Impossible
Open wire between A and C	✓	
Open wire between B and D		✓
Open wire between D and F	✓	
Lamp failed open		✓
Switch failed open	✓	
Lamp failed shorted	✓	
Switch failed shorted		✓

---

**Answer 42**

Fault	Possible	Impossible
Resistor $R_1$ failed open		✓
Resistor $R_2$ failed open		✓
Inductor $L_1$ failed open	✓	
Inductor $L_2$ failed open	✓	
Inductor $L_1$ failed shorted		✓
Inductor $L_2$ failed shorted		✓

---

**Answer 43**

Fault	Possible	Impossible
Open wire between E and D		✓
R1 failed open		✓
R2 failed open	✓	
R3 failed open		✓
R1 failed shorted		✓
R2 failed shorted		✓
R3 failed shorted		✓
Voltage source dead		✓

---

**Answer 44**

Filter type	Healthy circuit	Faulted circuit
Low-pass		✓
High-pass		
Band-pass		
Band-stop	✓	
Passes all frequencies		
Blocks all frequencies		

---

**Answer 45**

Fault	Possible	Impossible
$U_1$ output failed low		✓
$U_1$ output failed high		✓
$U_2$ output failed low	✓	
$U_2$ output failed high		✓
$U_3$ output failed low		✓
$U_3$ output failed high		✓

---

**Answer 46**

Fault	Possible	Impossible
Switch <i>A</i> failed open		✓
Switch <i>A</i> failed shorted	✓	
Switch <i>B</i> failed open		✓
Switch <i>B</i> failed shorted	✓	
Switch <i>C</i> failed open		✓
Switch <i>C</i> failed shorted		✓
CR1 contact failed open		✓
CR1 contact failed shorted	✓	

---

**Answer 47**

Fault	Possible	Impossible
Pushbutton switch failed open		✓
Pushbutton switch failed shorted		✓
Motor failed open	✓	
Resistor failed open		✓
15 amp fuse blown	✓	
0.5 amp fuse blown		✓

---

**Answer 48**

Yel-Vio-Org-Sil should be 47000 Ohms  $\pm$  10%, allowing for a range of 42300 Ohms to 51700 Ohms. Thus 44500 Ohms is **within tolerance**.

---

**Answer 49**

- Fuse will blow (**yes**)
- Load voltage (**decrease**)
- Supply current (**increase** then **decrease**)

---

**Answer 50**

- SCR  $CR_1$  (*must* include this component!)
- SCR  $CR_2$  (*must* include this component!)

**Credit for schematic:**

US Patent 3,120,633 (“Series Inverter Circuit Having Controlled Rectifiers With Power Diodes In Reverse Parallel Connection”) by Luther L. Genuit.