

## Questions

---

### Question 1

Given a battery and a light bulb, show how you would connect these two devices together with wire so as to energize the light bulb:



[file 00001](#)

---

### Question 2

Write the three forms of Ohm's Law ( $E = \dots$ ,  $I = \dots$  and  $R = \dots$ ), showing how voltage, current, and resistance relate to one another:

[file 03336](#)

---

### Question 3

Calculate the voltage dropped across a  $1.8 \text{ k}\Omega$  resistor and the power dissipated by that resistor if it is conducting  $20 \text{ mA}$  of current.

$E =$

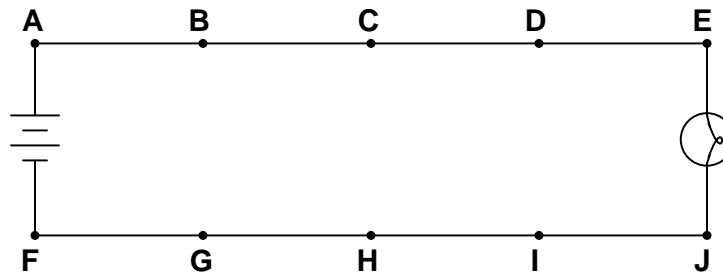
$P =$

[file 03344](#)

---

### Question 4

Identify whether or not there should be voltage between the specified pairs of test points in this simple circuit:



- Between **C** and **H** – *voltage* or *no voltage*?
- Between **A** and **B** – *voltage* or *no voltage*?
- Between **I** and **J** – *voltage* or *no voltage*?
- Between **A** and **F** – *voltage* or *no voltage*?

[file 03353](#)

---

**Question 5**

Choose the proper band colors for a 4-band resistor (assume a tolerance of 5%) that will let 3.7 mA of current through it with 20.72 volts dropped across it:

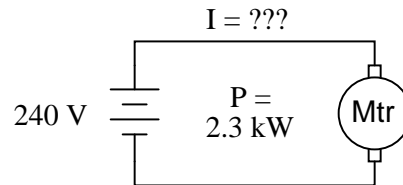
\_\_\_\_\_

file 03346

---

**Question 6**

Calculate the amount of current through a 240 volt DC electric motor as it draws 2.3 kW of electric power from the circuit source:

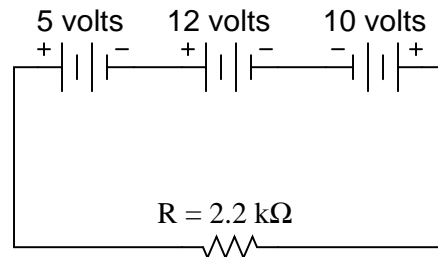


file 03349

---

**Question 7**

Calculate the resistor voltage ( $V_R$ ) and resistor current ( $I_R$ ) in this circuit:



$V_R =$

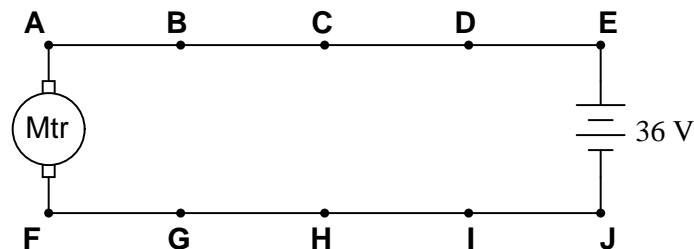
$I_R =$

file 03370

---

**Question 8**

Suppose the motor in this circuit refused to run, despite your voltmeter showing that there is 36 volts between points **E** and **J** at the battery:



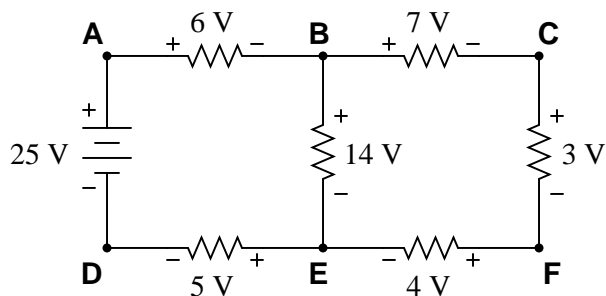
Connecting your voltmeter between points **B** and **G** in the circuit, you measure 36 volts as well. What does this indicate about the location of the fault? Assume there is only *one* thing wrong with this circuit (no multiple faults!).

file 03391

---

**Question 9**

Determine the voltage that a digital voltmeter would register if connected between the specified points in this circuit:



Between points **A** (red lead) and **C** (black lead):

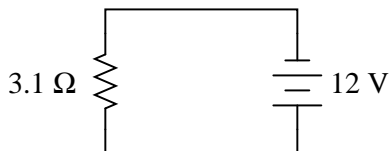
Between points **E** (red lead) and **C** (black lead):

file 03374

---

**Question 10**

Calculate the current in this circuit ( $I$ ), and also the approximate length of time that this 36 amp-hour battery will be able to maintain power to the load before it dies ( $t$ ):



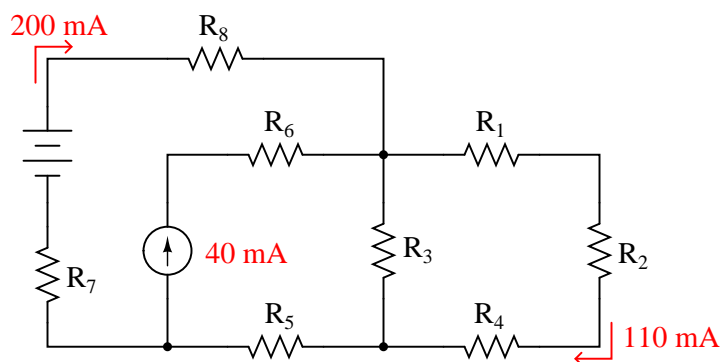
$I =$

$t =$

file 03404

### Question 11

Identify the magnitudes and directions of the specified resistor currents in this circuit:



Note: all arrows point in the direction of *conventional flow notation*.

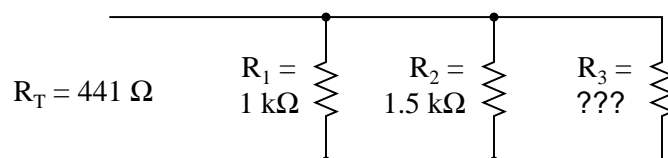
- $I_{R1} = \underline{\hspace{2cm}}$  ; Direction = *to the left* or *to the right*?
- $I_{R5} = \underline{\hspace{2cm}}$  ; Direction = *to the left* or *to the right*?
- $I_{R6} = \underline{\hspace{2cm}}$  ; Direction = *to the left* or *to the right*?
- $I_{R3} = \underline{\hspace{2cm}}$  ; Direction = *up* or *down*?

file 03419

### Question 12

Calculate the value of  $R_3$  necessary to create a total resistance of  $441 \Omega$ :

$R_3 =$

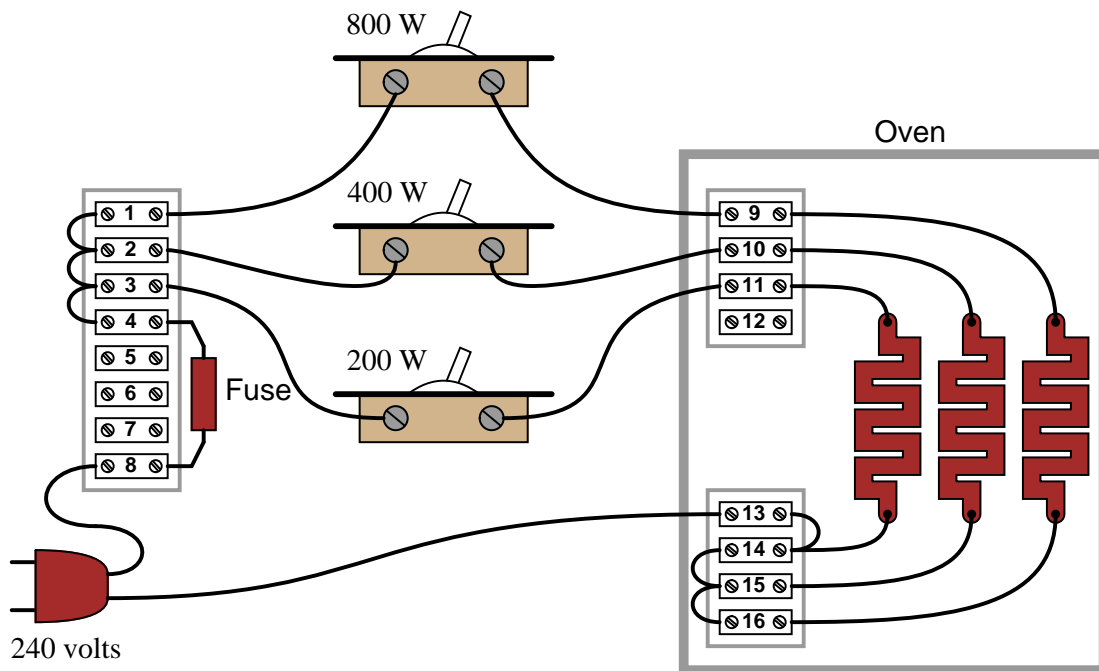


Also, write an equation solving for the value of  $R_3$  in terms of  $R_T$ ,  $R_1$ , and  $R_2$ .

file 03411

### Question 13

The following electric heater seems to have a problem: it heats up slower than usual with all three switches turned "on."



With three differently-sized heating elements (200 watt, 400 watt, and 800 watt), the oven operator can set the power in seven discrete steps by turning on specific combinations of switches: 200 watts, 400 watts, 600 watts, 800 watts, 1000 watts, 1200 watts, and 1400 watts.

You are summoned to diagnose this oven's problem *without turning it off*. You are allowed to turn off any single switch for a few seconds at most, but otherwise you need to leave all three heaters on because the oven needs to heat up as fast as it can! The idea is to figure out where the problem might be, then gather together any parts necessary for repairs while the oven is still being used, and fix the oven as fast as possible when you finally get the chance to turn it off completely.

Using a magnetic "clamp-on" ammeter to measure current without breaking the circuit, you read 4.1 amps through the wire between the power plug and terminal 13 with all three switches in the "on" position. Then, you momentarily turn the "800 watt" switch off and on, watching the current fall from 4.1 amps to 0.8 amps and then return to 4.1 amps.

Based on this data, identify two things:

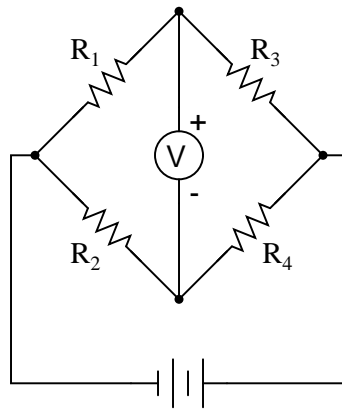
- Two components or wires in the oven circuit that you know must be in good working condition.
- Two components or wires in the oven circuit that could possibly be bad (and thus cause the slow heating problem).

file 03414

---

#### Question 14

Calculate the value of resistor  $R_3$  needed to balance this bridge circuit, given the following resistance values:



- $R_1 = 1.9 \text{ k}\Omega$
- $R_2 = 2.5 \text{ k}\Omega$
- $R_3 =$
- $R_4 = 1 \text{ k}\Omega$

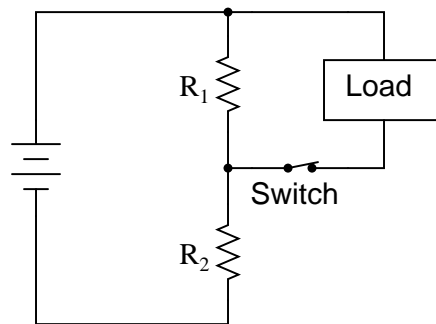
Also, write an equation showing how these four resistor values relate to one another in a condition of balance.

file 03429

---

#### Question 15

Qualitatively determine what will happen to the currents through resistors  $R_1$  and  $R_2$  if the switch conducting power to the load is suddenly opened (turned off):



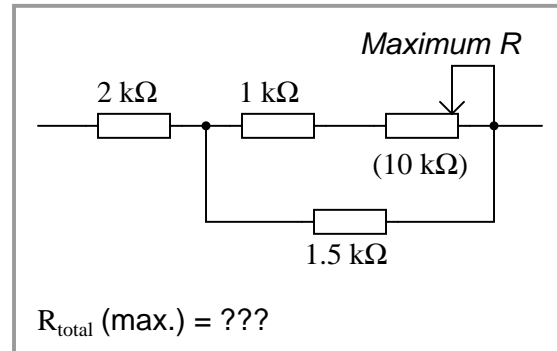
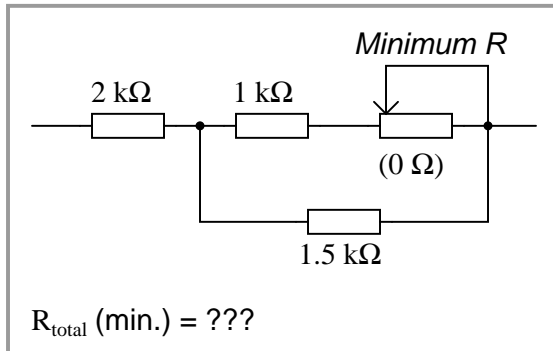
- $I_{R1}$  will *increase, decrease, or stay the same?*
- $I_{R2}$  will *increase, decrease, or stay the same?*

file 03431

---

Question 16

Calculate the total resistance of this network with the potentiometer in minimum and maximum resistance positions (as shown in these two diagrams):

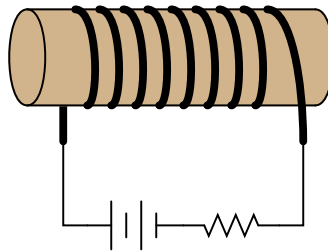


[file 03439](#)

---

Question 17

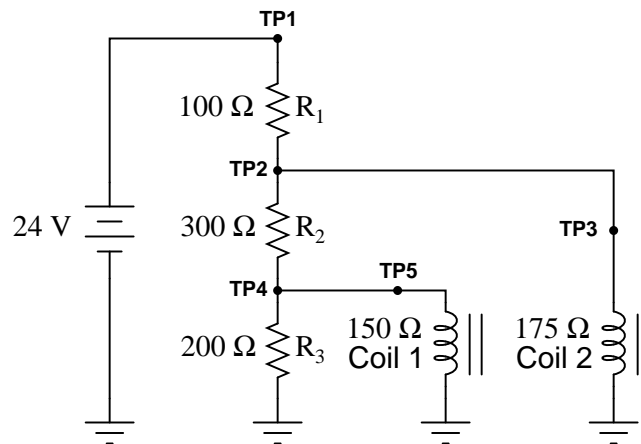
Identify the North and South poles on this electromagnet. Also draw the magnetic lines of flux, showing their paths:



[file 03479](#)

### Question 18

A piece of laboratory equipment uses a voltage divider to reduce voltage to two electromagnet coils from a higher-voltage source. Coil #1 is supposed to receive 2.91 volts and coil #2 is supposed to receive 13.11 volts:



One day, something goes wrong with this circuit. The magnetic field from coil #1 suddenly disappears, yet there is still a magnetic field coming from coil #2. The technician who looked at this problem before you took two voltage measurements and then gave up: 13.55 volts at test point TP3 and 5.42 volts at test point TP4. You left your multimeter back at the shop, which means you cannot take any more voltage measurements. However, since you are more determined than the former technician, you proceed to identify the following from the two measurements already taken:

- Two components or wires in the circuit that you know cannot be failed either open or shorted, besides the 24 volt source which is obviously operational.
- One component or wire in the circuit you think could possibly be bad, and the type of failure it would be (either open or shorted).

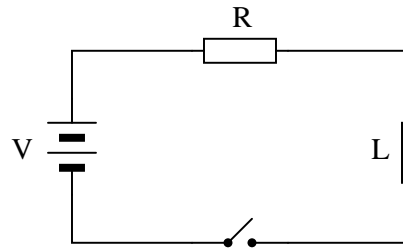
file 03487



---

Question 19

Identify two different component values that could be changed in this circuit to make the time constant *longer* (creating a *slower* circuit response):



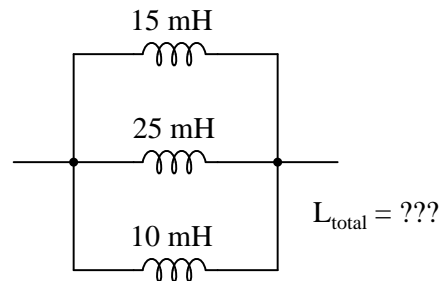
Be sure to identify both the components and the directions their respective values must be changed (*larger* or *smaller*).

file 03519

---

Question 20

Calculate the total inductance in this network:



file 03528

---

Question 21

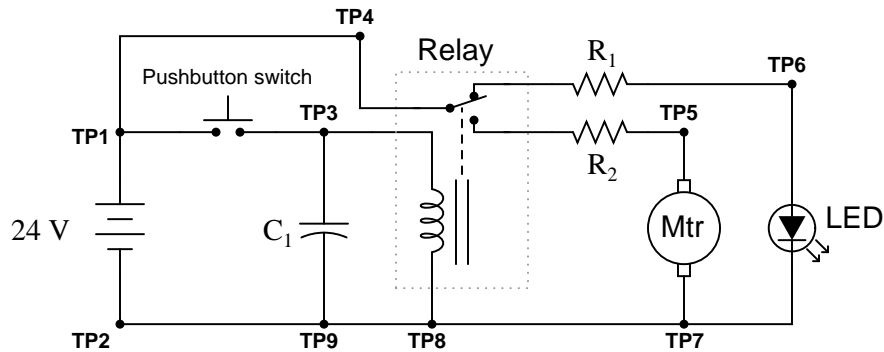
Calculate the voltage across a  $47 \mu\text{F}$  capacitor after charging from a 12 volt source through a total circuit resistance of  $22 \text{ k}\Omega$  for 2 seconds.

$V_C =$

file 03540

## Question 22

In this time-delay relay circuit, the motor will immediately start when the pushbutton is pressed, and continue to run for about 5 seconds after the pushbutton is released. The green light-emitting diode (LED) is supposed to be on whenever the motor is stopped, and off whenever the motor is running:



However, a problem has developed with this circuit. Neither the motor nor the green LED ever energizes, no matter what is done with the pushbutton switch. Strangely enough, the relay *does* make a "click" sound when the pushbutton is pressed, and then another "click" sound about 5 seconds after the switch is released. Based on this information, determine the following:

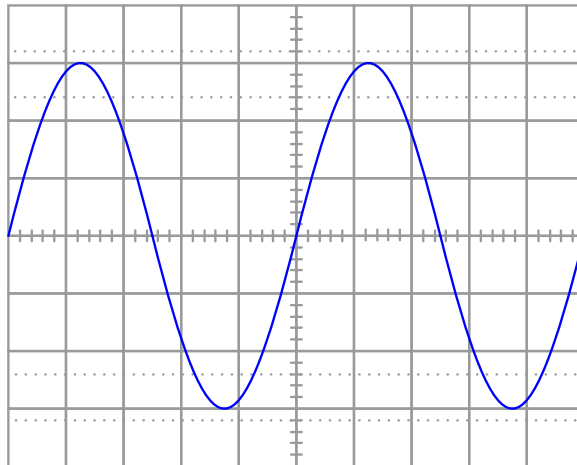
- Two components or wires in the circuit that you know cannot be failed either open or shorted, besides the 24 volt source.
- Two components or wires in the circuit you think could possibly be bad (either one independently capable of causing the problem), and the type of failure each would be (either open or shorted).

file 03534

---

**Question 23**

Determine the following parameters of this AC voltage waveform, assuming a vertical sensitivity of 0.5 volts per division and a timebase of 1 millisecond per division:



V (peak) =

V (RMS) =

Frequency (f) =

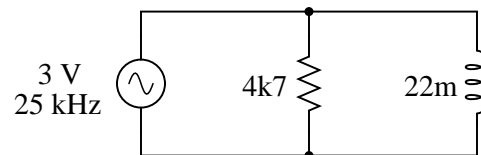
Period =

file 03562

---

**Question 24**

Calculate total impedance ( $Z_{total}$ ), total current ( $I_{total}$ ), resistor current ( $I_R$ ), and inductor current ( $I_L$ ) in the following circuit:



$Z_{total} =$

$I_{total} =$

$I_L =$

$I_R =$

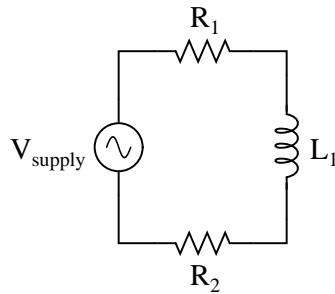
Note: your answers may be simply scalar quantities (no polar or rectangular form necessary)

file 03579

---

Question 25

Determine (qualitatively) what will happen to the following voltages and current in this circuit as *frequency* is increased (assume  $V_{supply}$  remains constant):



$I_{total}$  = increase, decrease, or stay the same?

$V_{R1}$  = increase, decrease, or stay the same?

$V_{L1}$  = increase, decrease, or stay the same?

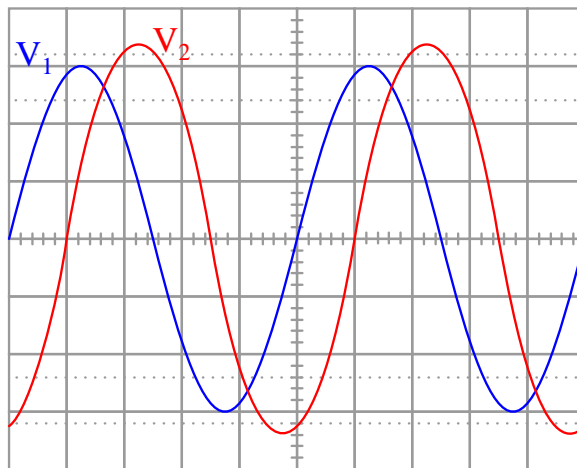
$V_{R2}$  = increase, decrease, or stay the same?

file 03581

---

Question 26

Determine the following parameters of these AC voltage waveforms, assuming a vertical sensitivity of 1 volt per division and a timebase of 2 milliseconds per division:



$V_1$  (peak) =

$V_2$  (peak) =

Frequency (f) =

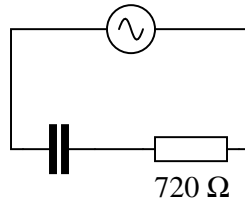
Phase shift ( $\theta$ ) =

file 03598

---

Question 27

Calculate the amount of reactance ( $X_C$ ) in ohms that the capacitor must have to give this circuit a total impedance ( $Z_{total}$ ) of  $1.7\text{ k}\Omega$ , and also its capacitance value ( $C$ ) in Farads if the source frequency is  $2\text{ kHz}$ :



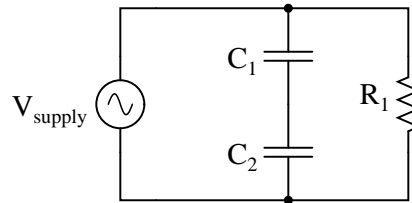
$X_C =$   
file 03609

$C =$

---

Question 28

Determine (qualitatively) what will happen to the following parameters in this circuit as *frequency* is decreased (assume  $V_{supply}$  remains constant):



$I_{total} =$  *increase, decrease, or stay the same?*

$V_{R1} =$  *increase, decrease, or stay the same?*

$I_{C1} =$  *increase, decrease, or stay the same?*

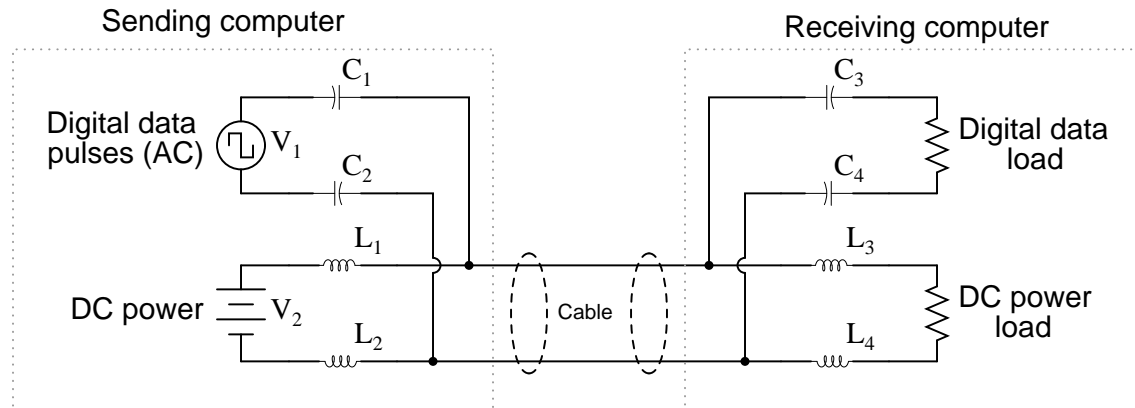
Phase shift ( $\Theta$ ) between  $V_{total}$  and  $I_{total} =$  *increase (approach  $-90^\circ$ ), decrease (approach  $0^\circ$ ), or stay the same?*

file 03606

---

### Question 29

A digital computer network uses a two-conductor cable to send both power (DC) and data (AC pulses) from one computer to another, inductors and capacitors being used to filter the voltages to and from their proper destinations:



The system works fine for a while, but then one day the receiving computer stops receiving data. It still has DC power getting to it, but just no digital data. Identify the following:

- One failed component in the circuit that could possibly account for the problem, and the type of fault (open or short) you suspect that component would have.
- Show where you would connect a voltmeter in the circuit to verify a fault in that one suspect component, and the voltage reading (AC, DC, or both) you would expect to get if indeed that one component had failed.

file 03603

---

### Question 30

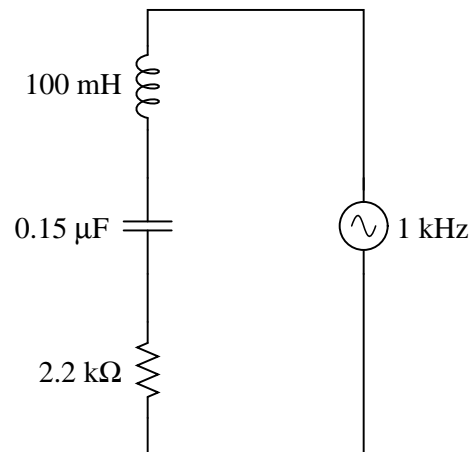
Explain what it means for an inductor-capacitor ( $LC$ ) circuit to be in a state of *resonance*.

file 03616

---

Question 31

Calculate the total impedance of this series RLC circuit and express it in polar form (magnitude and phase angle):

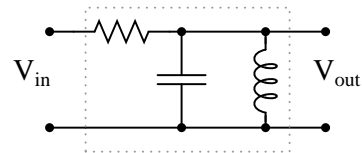
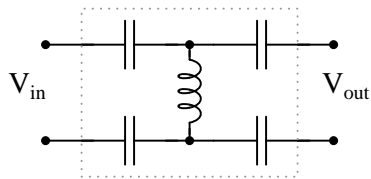
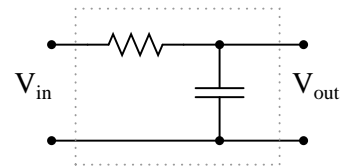
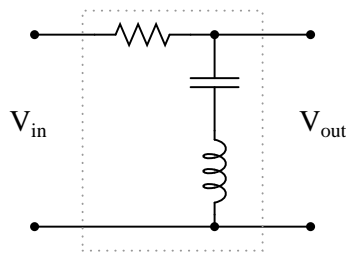


$Z_{\text{total}} =$   
file 03626

---

Question 32

Identify whether each of these filter circuits is a *low-pass*, *high-pass*, *band-pass*, or *band-stop*:

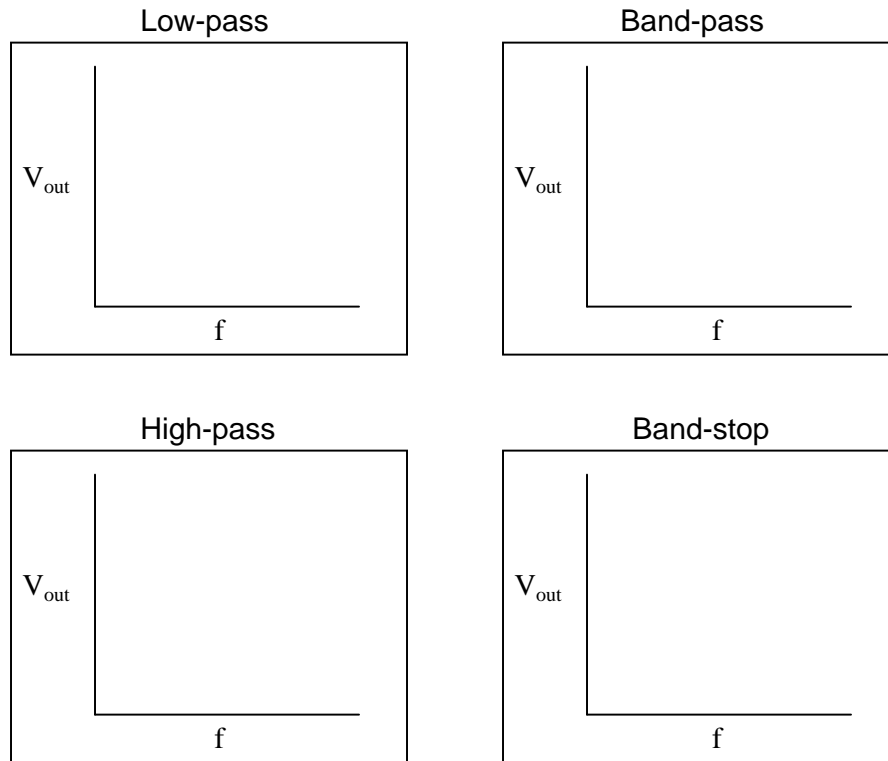


file 03631

---

Question 33

Plot the typical frequency responses of four different filter circuits, showing signal output (amplitude) on the vertical axis and frequency on the horizontal axis:



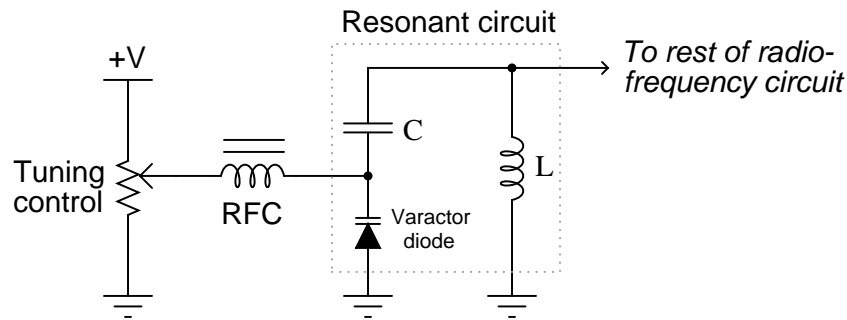
Also, identify and label the *bandwidth* of the filter circuit on each plot.  
[file 03949](#)



---

**Question 34**

A special type of component called a *varactor diode* is used to electronically tune resonant circuits, given its ability to change capacitance with the application of a DC voltage. In the following schematic, the diode, capacitor, and inductor form a resonant circuit; the potentiometer creates a variable DC voltage to impress across the varactor diode (to change its capacitance); and the radio-frequency choke ("RFC") inductor acts as a low-pass filter to block AC from getting to the potentiometer:



The equation for calculating the capacitance of a varactor diode is as follows:

$$C_{diode} = \frac{C_o}{\sqrt{2V + 1}}$$

Where,

$C_{diode}$  = Diode capacitance

$C_o$  = Natural capacitance of diode with zero applied DC voltage

$V$  = Applied DC voltage

Based on this information, determine which direction the potentiometer must be moved to *increase* the resonant frequency of the tuning circuit shown, and also explain why this is so.

[file 03632](#)

---

**Question 35**

Explain why transformers are used extensively in long-distance power distribution systems. What advantage do they lend to a power system?

[file 02213](#)

---

**Question 36**

Calculate the voltage output by the secondary winding of a transformer if the primary voltage is 35 volts, the secondary winding has 4500 turns, and the primary winding has 355 turns.

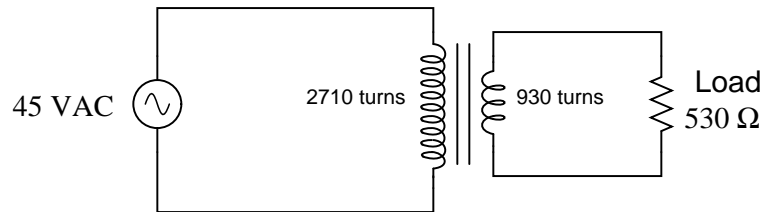
$V_{secondary} =$

[file 02206](#)

---

**Question 37**

Calculate the load current and load voltage in this transformer circuit:



$I_{load} =$

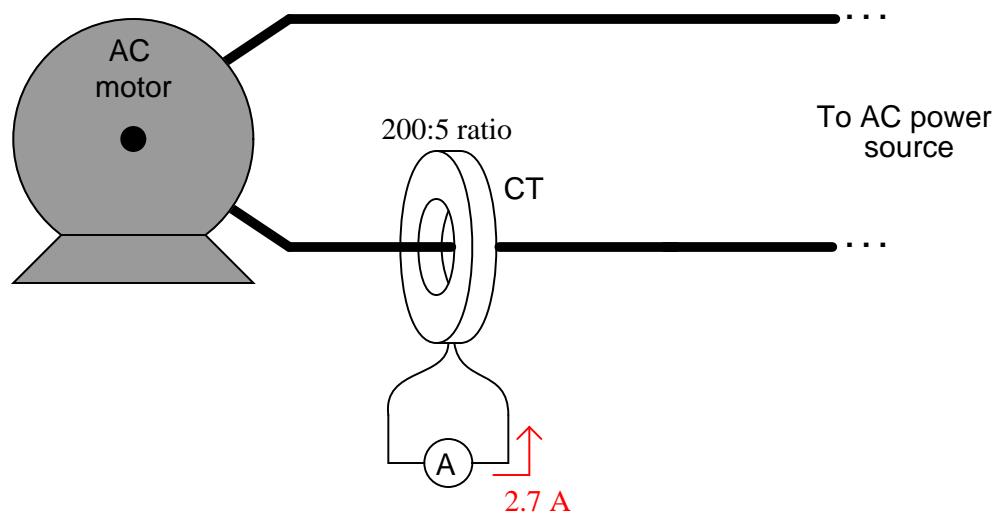
$V_{load} =$

[file 03656](#)

---

**Question 38**

The current feeding a large electric motor is measured by an ammeter connected to a current transformer with a ratio of 200:5. If the ammeter current is 2.7 amps, how much is the motor current?



[file 03659](#)

---

**Question 39**

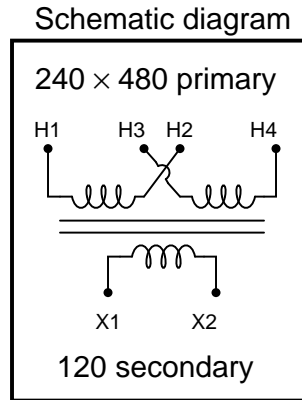
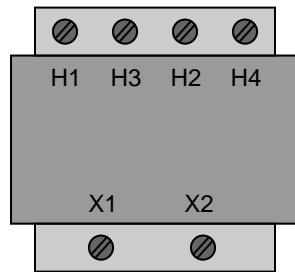
Calculate the number of turns needed in the secondary winding of a transformer to transform a primary voltage of 480 volts down to a secondary voltage of 260 volts, if the primary winding has 1176 turns of wire.

$N_{secondary} =$

[file 03661](#)

#### Question 40

A technician brings a control power transformer into your repair shop for diagnosis. It is a dual-voltage primary unit, and was used on the job site to step 480 volts down to 120 volts:



According to the person who did the field troubleshooting, the transformer is simply "bad." As is typical, you were given no other information to help diagnose the precise fault. Describe how you would test this transformer in your shop for the following faults, noting the transformer terminals you would connect your multimeter to and the type of meter measurement you would expect to see for each specified fault.

##### First (left) primary winding failed open

- Meter connected between:
- Measurement expected for this type of fault:

##### Second (right) primary winding failed open

- Meter connected between:
- Measurement expected for this type of fault:

##### First (left) primary winding shorted to iron core

- Meter connected between:
- Measurement expected for this type of fault:

##### Secondary winding shorted to iron core

- Meter connected between:
  - Measurement expected for this type of fault:
- file 03667

---

**Question 41**

An AC induction motor draws 18 amps of current at a voltage of 480 volts, with current lagging voltage by  $30^\circ$ . Calculate the true power consumed by the motor ( $P$ ), and also its power factor (P.F.):

$$P =$$

file 03680

$$\text{P.F.} =$$

---

**Question 42**

Draw a schematic diagram showing how the windings (coils) of a *Wye* three-phase AC generator are connected together:

Then, calculate the line voltage if the phase voltage in this generator is 7.1 kV. Assume this generator operates in a balanced condition (all phase voltages and currents equal).

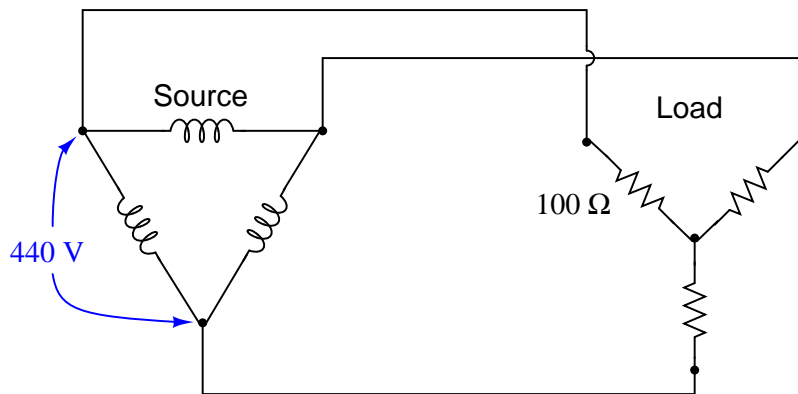
$$V_{line} =$$

file 03683

---

**Question 43**

Calculate the following values in this balanced Delta-Wye system:



$$V_{line} =$$

$$I_{line} =$$

$$V_{phase(load)} =$$

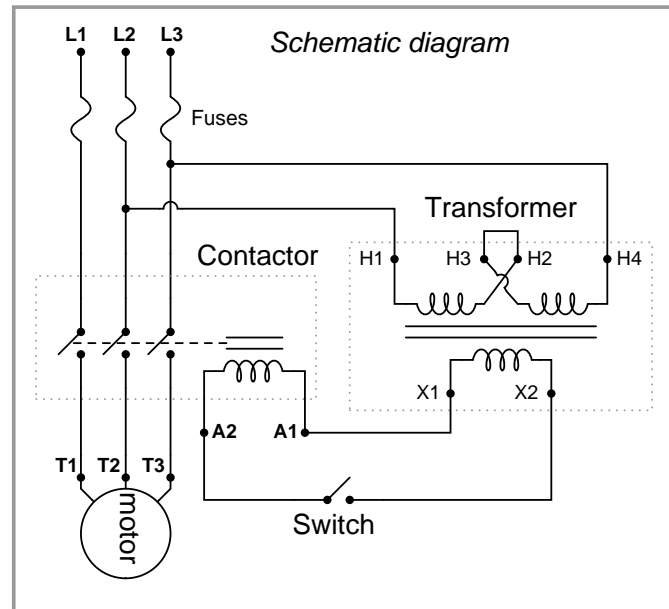
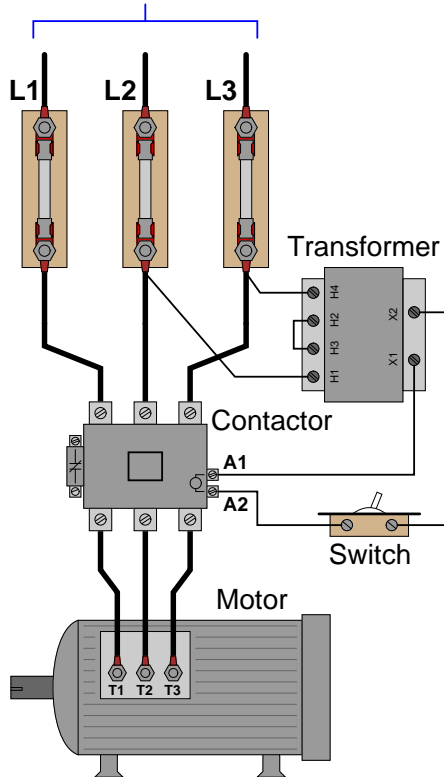
$$P_{total} =$$

file 03689

# Question 44

In this 480 volt AC induction motor control circuit, a three-pole relay (typically called a *contactor*) is used to switch power on and off to the motor. The contactor itself is controlled by a smaller switch, which gets 120 volts AC from a step-down transformer to energize the contactor's magnetic coil. Although this motor control circuit used to work just fine, today the motor refuses to start.

To 3- $\phi$  , 480 volt power source



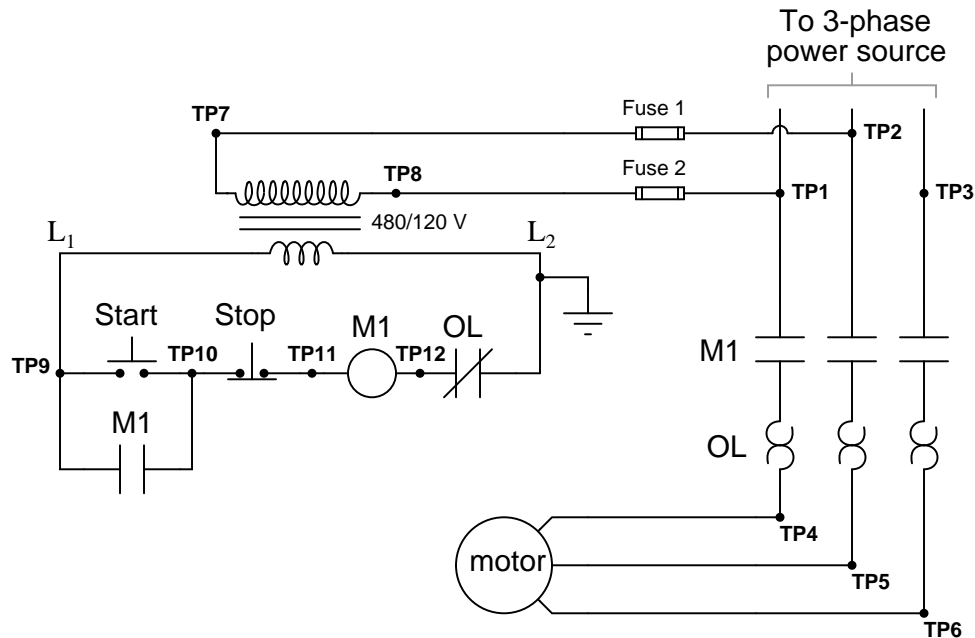
Using your AC voltmeter, you measure 476 volts AC between L1 and L2, 477 volts AC between L2 and L3, and 475 volts AC between L1 and L3. You also measure 477 volts between transformer terminals H1 and H4. With the switch in the "on" position, you measure 0.5 volts AC between terminals X1 and X2 on the transformer. From this information, identify the following:

- Two components or wires in the circuit that you know cannot be failed either open or shorted, besides the 480 volt AC source which is obviously operational.
- Two different component or wire failures in the circuit, either one of which could account for the problem and the measurement values, and the types of failures they would be (either open or shorted).

file 03688

# Question 45

The following motor control circuit has a problem. When the "Start" button is pressed, the motor refuses to start:



Using your digital voltmeter, you measure 120 volts AC between TP10 and Ground when the "Start" switch is pressed, but 0 volts between the same points when the switch is released. From this information, identify two possible faults that could account for the problem and all measured values in this circuit, and also identify two circuit elements that could not possibly be to blame (i.e. two things that you know *must* be functioning properly, no matter what else may be faulted). The circuit elements you identify as either possibly faulted or properly functioning can be wires, traces, and connections as well as components. Be as specific as you can in your answers, identifying both the circuit element and the type of fault.

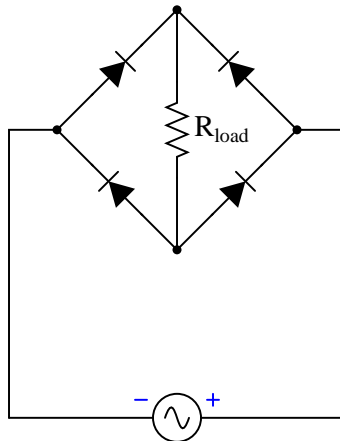
- Circuit elements that are possibly faulted
  - 1.
  - 2.
- Circuit elements that must be functioning properly
  - 1.
  - 2.

file 03212

---

**Question 46**

Trace the current through this rectifier circuit at a moment in time when the AC source's polarity is positive on right and negative on left as shown. Be sure to designate the convention you use for current direction (conventional or electron flow):



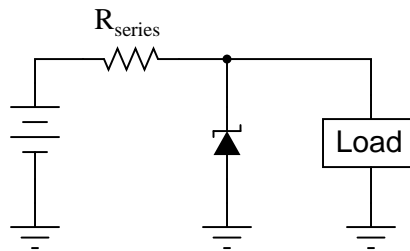
Also, mark the polarity of the voltage drop across  $R_{load}$ .

file 02313

---

**Question 47**

Qualitatively determine what will happen to the series resistor current and the zener diode current in this voltage regulator circuit if the load current suddenly *decreases*. Assume that the zener diode's behavior is ideal; i.e. its voltage drop holds absolutely constant throughout its operating range.



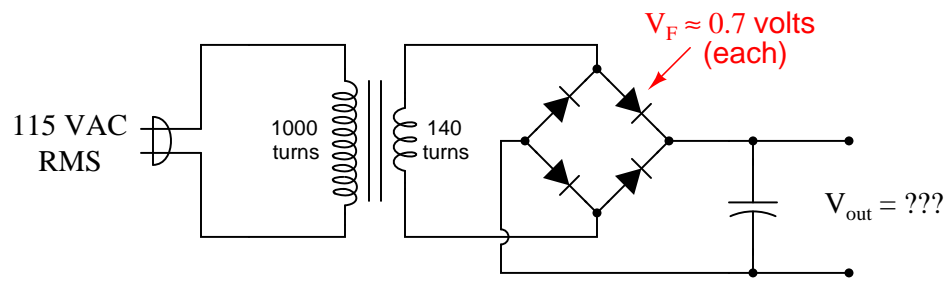
$I_{R_{series}} =$  (*increase, decrease, or unchanged?*)

$I_{zener} =$  (*increase, decrease, or unchanged?*)

file 02315

Question 48

Calculate the approximate DC output voltage of this power supply when it is not loaded:

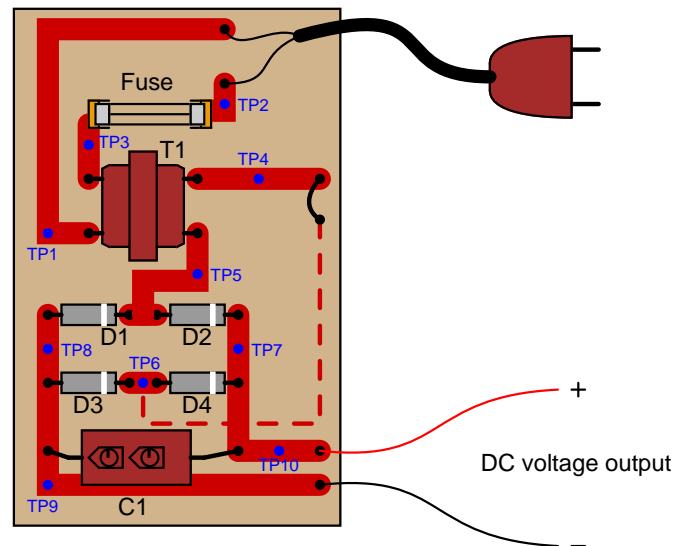


file 02301



### Question 49

A technician is troubleshooting a power supply circuit with no DC output voltage. The output voltage is supposed to be 15 volts DC, but instead it is actually outputting nothing at all (zero volts):



The technician measures 120 volts AC between test points TP1 and TP3. Based on this voltage measurement and the knowledge that there is zero DC output voltage, identify two possible faults that could account for the problem and all measured values in this circuit, and also identify two circuit elements that could not possibly be to blame (i.e. two things that you know *must* be functioning properly, no matter what else may be faulted). The circuit elements you identify as either possibly faulted or properly functioning can be wires, traces, and connections as well as components. Be as specific as you can in your answers, identifying both the circuit element and the type of fault.

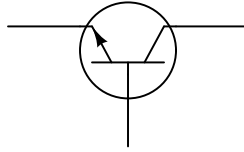
- Circuit elements that are possibly faulted
  - 1.
  - 2.
  
- Circuit elements that must be functioning properly
  - 1.
  - 2.

file 02306

---

Question 50

Examine the following transistor symbol:



Identify the following:

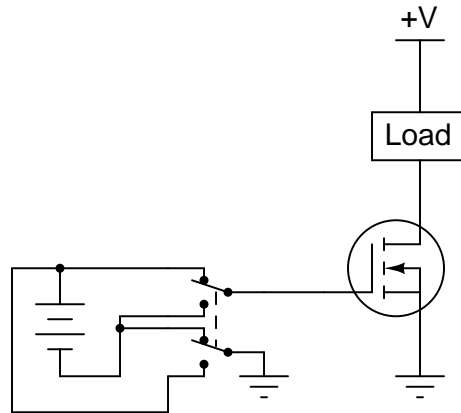
- Type of transistor (*BJT, JFET, or MOSFET*)
- Semiconductor doping (*NPN, PNP ; N-channel, P-channel*)
- Identification of all 3 terminals (*Base, Collector, Emitter ; Gate, Drain, Source*)
- Direction of each terminal's current for proper transistor operation (*be sure to note whether you are using conventional flow or electron flow notation. If current direction is unimportant, or if there is no current at all, be sure to say so!*)

file 02328

---

Question 51

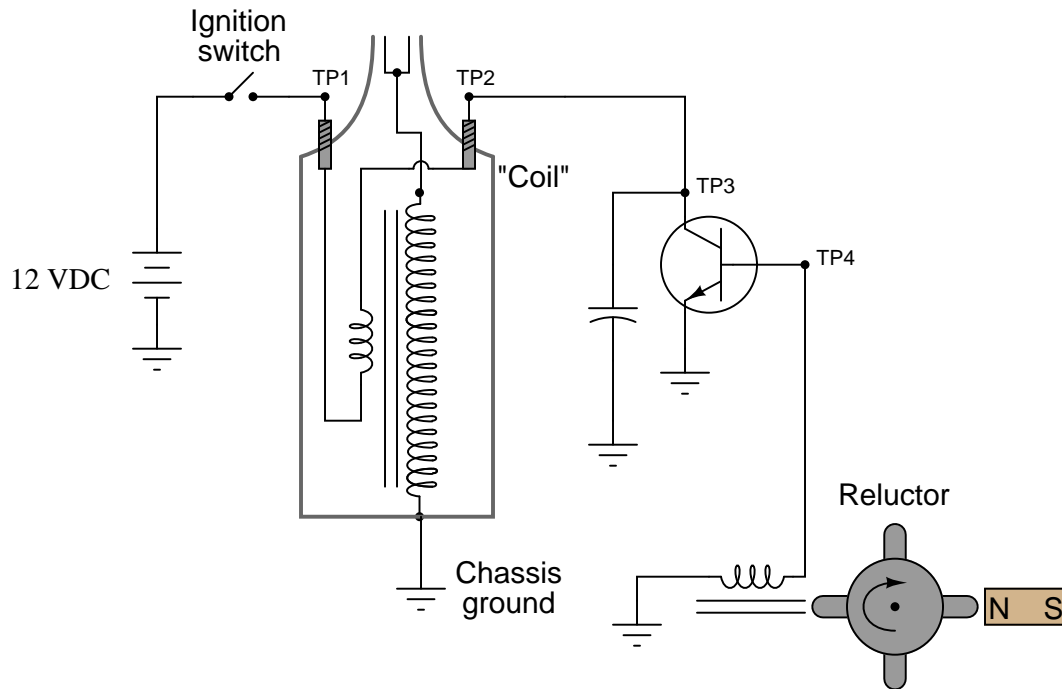
Determine whether the load is energized or de-energized with the switch in the position shown. Also, identify whether the transistor is a *depletion* type or an *enhancement* type:



file 02338

## Question 52

There is a problem somewhere in this electronic ignition circuit. The "coil" does not output high voltage as it should when the reluctor spins. A mechanic already changed the coil and replaced it with a new one, but this did not fix the problem.



You are then asked to look at the circuit to see if you can figure out what is wrong. Using your multimeter, you measure voltage between TP1 and ground (12 volts DC) and also between TP2 and ground (0 volts DC). These voltage readings do not change at all as the reluctor spins.

From this information, identify two possible faults that could account for the problem and all measured values in this circuit, and also identify two circuit elements that could not possibly be to blame (i.e. two things that you know *must* be functioning properly, no matter what else may be faulted). The circuit elements you identify as either possibly faulted or properly functioning can be wires, traces, and connections as well as components. Be as specific as you can in your answers, identifying both the circuit element and the type of fault.

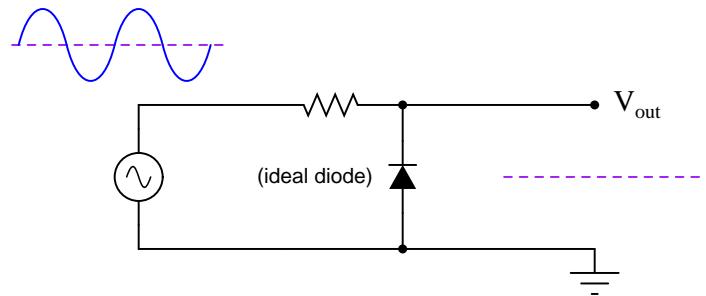
- Circuit elements that are possibly faulted
  - 1.
  - 2.
- Circuit elements that must be functioning properly
  - 1.
  - 2.

file 02343

---

Question 53

Sketch the shape of the output voltage waveform for this "clipper" circuit, assuming an ideal diode with no forward voltage drop:

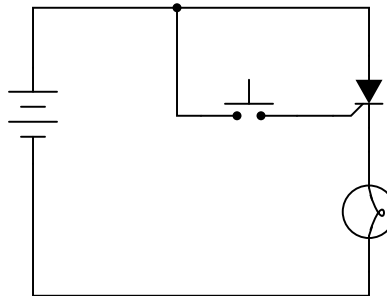


file 02352

---

Question 54

When the pushbutton switch is actuated, the lamp energizes and remains energized even when the switch is released:

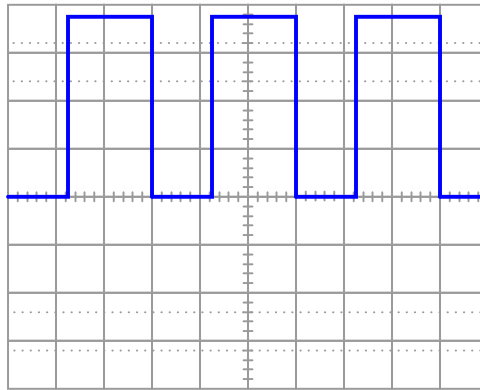


Insert a second switch into the schematic diagram that allows someone to de-energize the lamp once it has been "latched" on by actuating the first switch.

file 02388

Question 55

A resistive DC load receives pulse-width modulated (PWM) power from a controller circuit, and an oscilloscope shows the load voltage waveform as such:



Vertical sensitivity = 1 volt/div

Probe ratio = 10:1

Coupling = DC

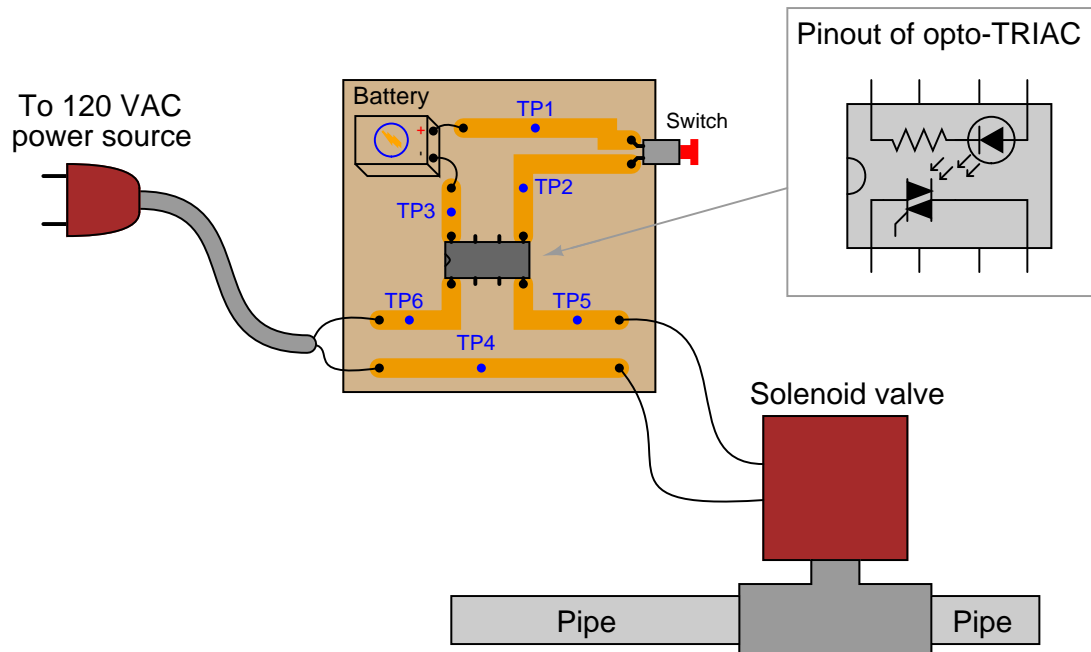
Timebase = 20  $\mu$ s/div

Calculate the duty cycle of this waveform, and also the average power dissipated by the load assuming a load resistance of 10.3  $\Omega$ .

file 02348

### Question 56

A technician is troubleshooting a faulty optically-isolated TRIAC power switching circuit. The solenoid valve is supposed to open up and pass liquid through it whenever the pushbutton switch is pressed, but it remains shut no matter what state the switch is in:



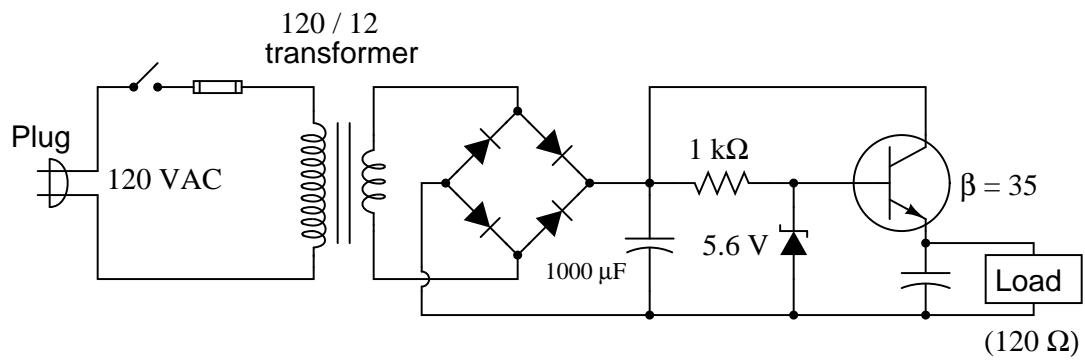
Leaving the switch in its normal ("unpressed") position, the technician measures 120 volts AC between test points TP5 and TP6, and 9 volts DC (normal for the battery) between test points TP1 and TP3. Based on these voltage measurements, identify two possible faults that could account for the problem and all measured values in this circuit, and also identify two circuit elements that could not possibly be to blame (i.e. two things that you know *must* be functioning properly, no matter what else may be faulted). The circuit elements you identify as either possibly faulted or properly functioning can be wires, traces, and connections as well as components. Be as specific as you can in your answers, identifying both the circuit element and the type of fault.

- Circuit elements that are possibly faulted
  - 1.
  - 2.
- Circuit elements that must be functioning properly
  - 1.
  - 2.

file 02402

Question 57

Calculate the DC voltage across the load connected to this regulated power supply circuit, and also the amount of current through the silicon transistor's base terminal, given a load resistance of  $120\ \Omega$ :

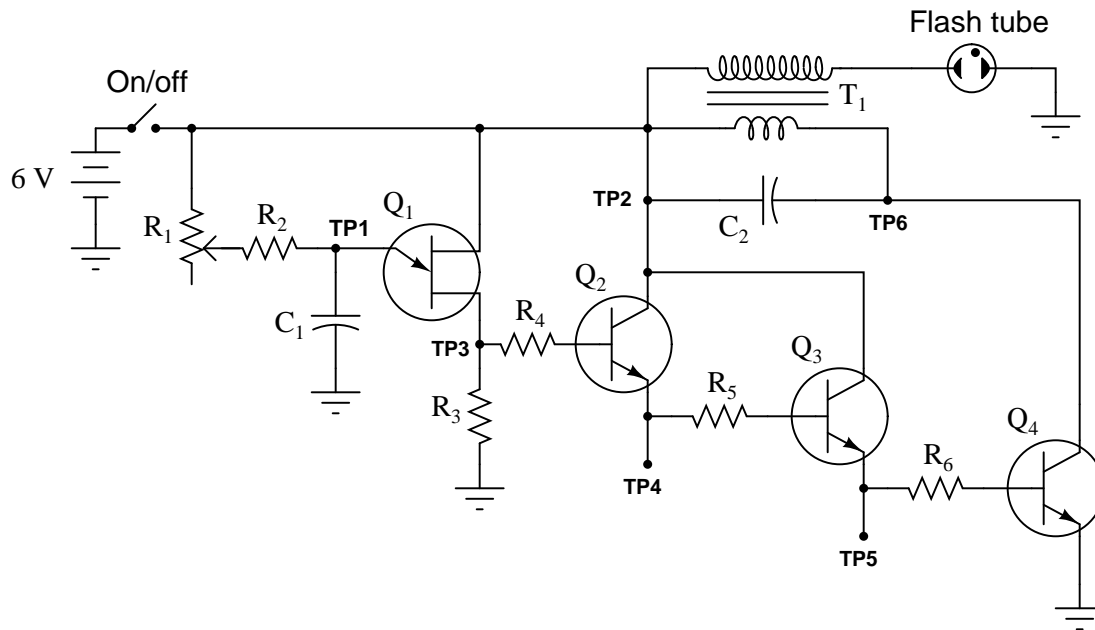


$V_{load} =$   
file 02496

$I_B =$

Question 58

The following strobe light has a problem: the flash tube never flashes.



Turning the flash rate control (rheostat  $R_1$ ) to the slowest position, you take two voltage measurements with a voltmeter: at test point 3 (between TP3 and ground) you measure a voltage rhythmically pulsating between about 1.5 and 4 volts DC. At test point 6 (between TP6 and ground) you measure 6 volts DC all the time.

From this information, identify two possible faults that could account for the problem and all measured values in this circuit, and also identify two circuit elements that could not possibly be to blame (i.e. two things that you know *must* be functioning properly, no matter what else may be faulted) other than the 6 volt battery and the on/off switch. The circuit elements you identify as either possibly faulted or properly functioning can be wires, traces, and connections as well as components. Be as specific as you can in your answers, identifying both the circuit element and the type of fault.

- Circuit elements that are possibly faulted

- 1.
- 2.

- Circuit elements that must be functioning properly (besides battery and on/off switch)

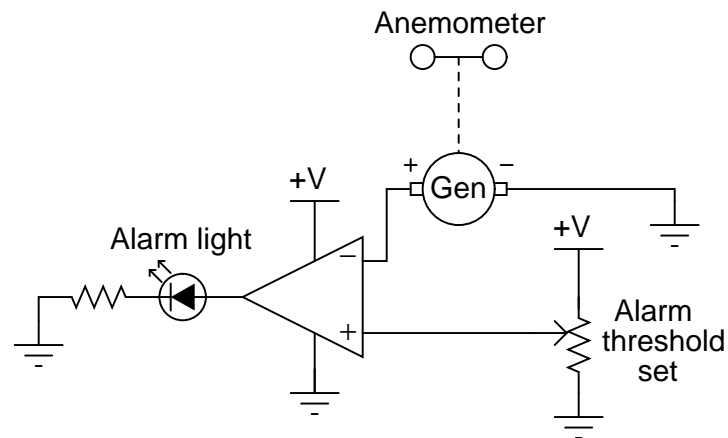
- 1.
- 2.

file 02630



Question 59

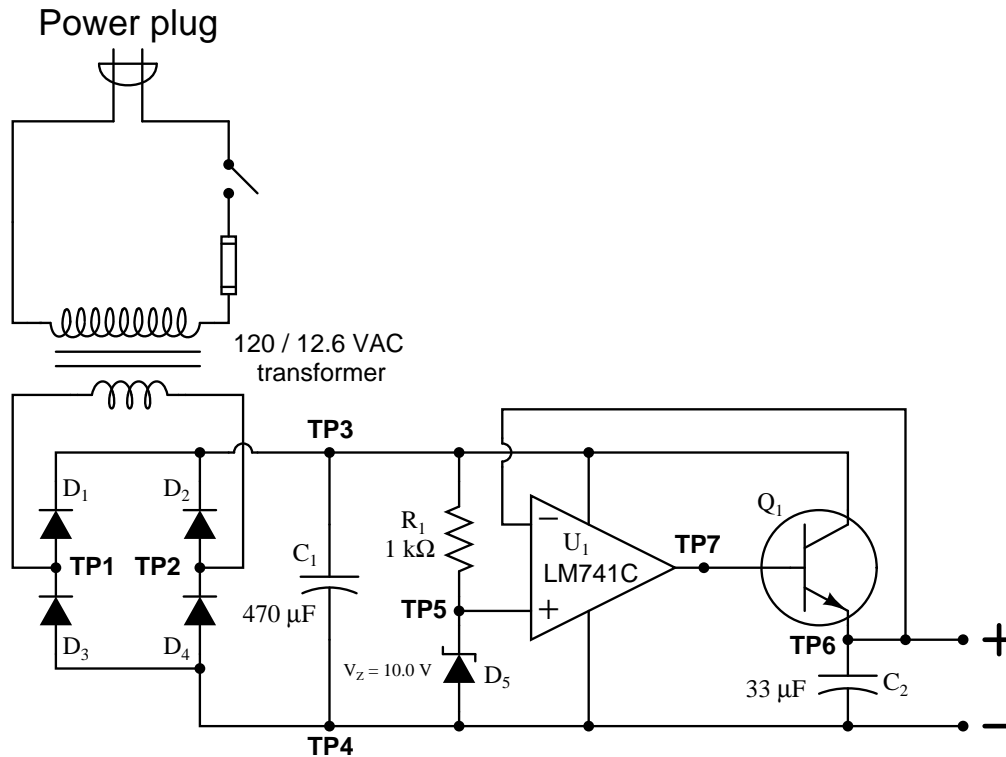
The following comparator circuit was built by an avid kite flyer, who wanted a circuit to alert him to abnormal wind conditions. Is this circuit configured to act as a *high* wind speed alarm, or a *low* wind speed alarm? Also, show which way the potentiometer wiper would have to be moved in order to obtain a higher wind speed alarm point.



file 02664

# Question 60

Something is wrong with this regulated DC power supply circuit. The output is supposed to be +10.0 volts, but instead it measures only about 1 volt:



Using your digital multimeter, you measure 15.3 volts between test points TP7 (red test lead) and TP4 (black test lead). Note that  $V_Z$  shown in the schematic is a *specification* for the zener diode, and not an actual voltmeter measurement. From this information, identify two possible faults that could account for the problem and all measured values in this circuit, and also identify two circuit elements that could not possibly be to blame (i.e. two things that you know *must* be functioning properly, no matter what else may be faulted) other than the 120 volt AC power source, on/off switch, and fuse. The circuit elements you identify as either possibly faulted or properly functioning can be wires, traces, and connections as well as components. Be as specific as you can in your answers, identifying both the circuit element and the type of fault.

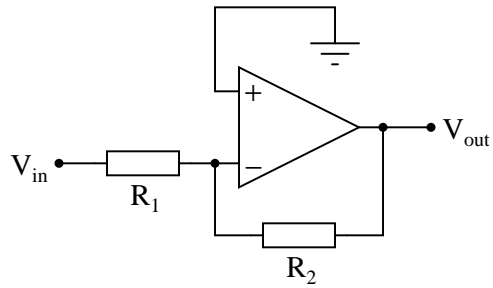
- Circuit elements that are possibly faulted
  - 1.
  - 2.
- Circuit elements that must be functioning properly (besides 120 volt AC source, switch, and fuse)
  - 1.
  - 2.

file 02660

---

Question 61

Is this opamp circuit *inverting* or *noninverting*?

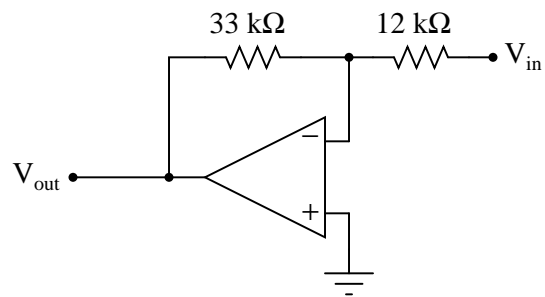


file 02710

---

Question 62

Calculate the voltage gain of this opamp circuit (as a ratio, not decibels):

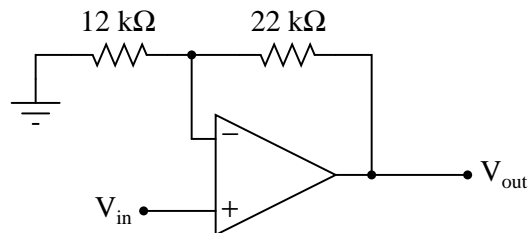


file 02715

---

Question 63

Calculate the voltage gain of this opamp circuit (as a ratio, not decibels):

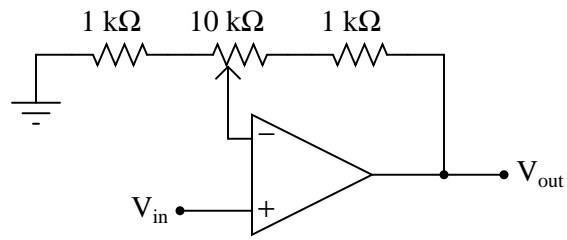


file 02718

---

Question 64

Determine the minimum and maximum voltage gains possible with this circuit:



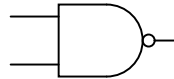
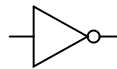
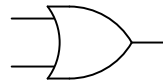
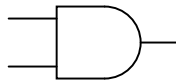
$A_{V(min)} =$   
file 02734

$A_{V(max)} =$

---

Question 65

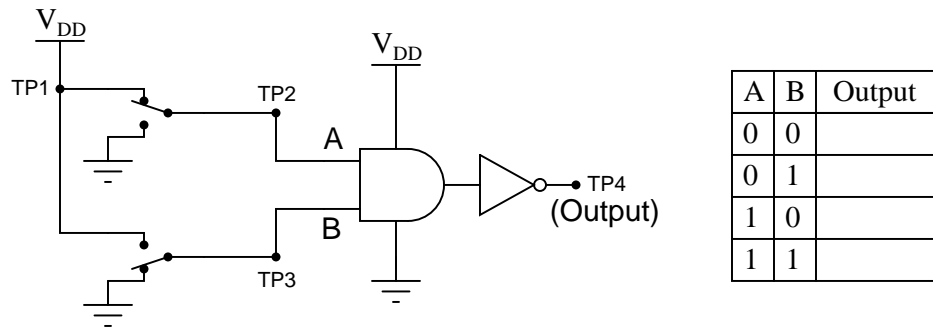
Identify the names of the following logic gates:



file 02874

### Question 66

Determine the logic state (high or low) of each test point with the input switches in the positions shown, and also complete the truth table for the gate:

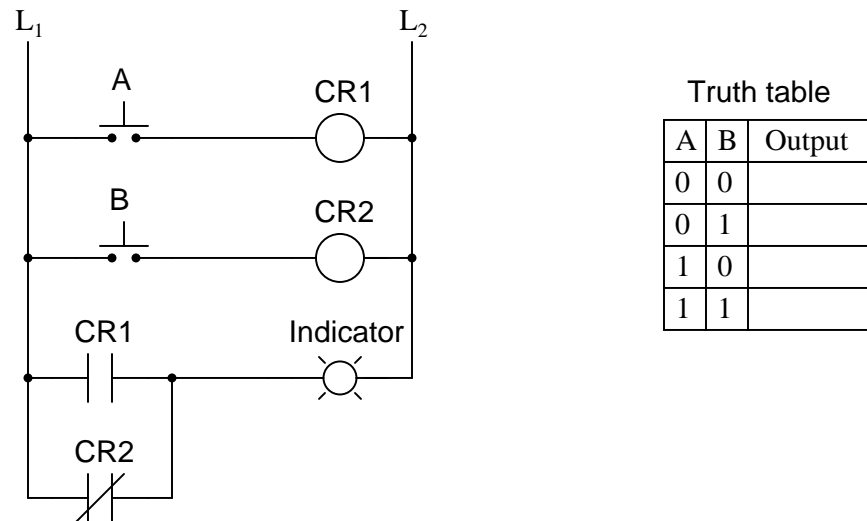


- TP1 = (*high* or *low*)
- TP2 = (*high* or *low*)
- TP3 = (*high* or *low*)
- TP4 = (*high* or *low*)

file 03976

### Question 67

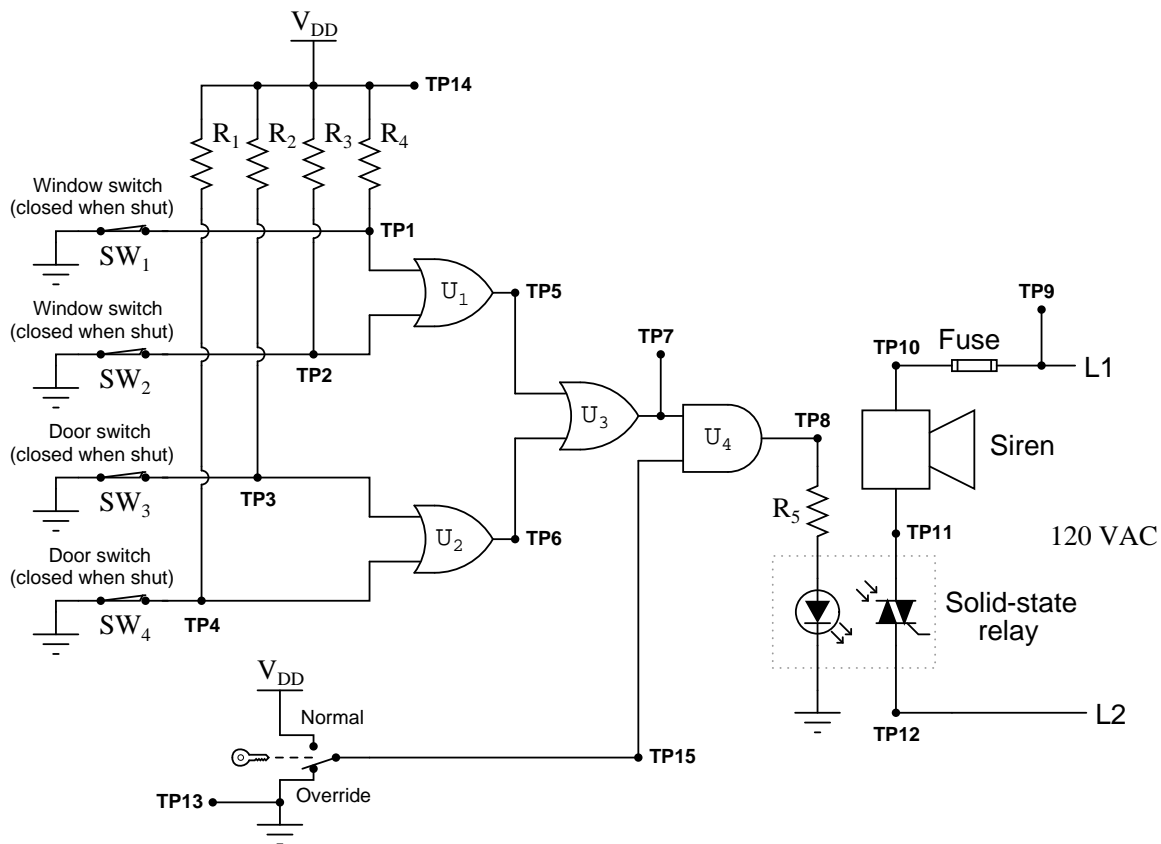
Complete the truth table for the following relay logic circuit:



file 02878

### Question 68

Something is wrong with this building alarm system circuit. The alarm siren energizes even when all the windows and doors are shut. The only way to silence the alarm is to use the "override" key switch:



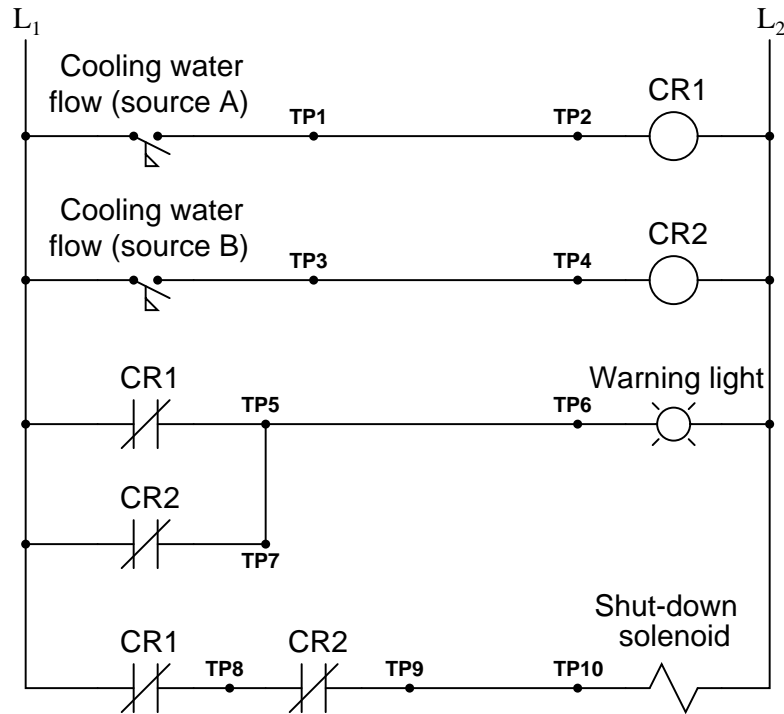
Using your logic probe, you measure a high signal at TP7 and a low signal at TP6 with all windows and doors shut, and with the key switch in the "override" position. From this information, identify two possible faults that could account for the problem and all measured values in this circuit. Then, choose one of those possible faults and explain why you think it could be to blame. The circuit elements you identify as possibly faulted can be wires, traces, and connections as well as components. Be as specific as you can in your answers, identifying both the circuit element and the type of fault.

- Circuit elements that are possibly faulted
  - 1.
  - 2.
- Explanation of *why* you think one of the above faults could be to blame

file 02882

Question 69

A water-cooled generator at a power plant has two sources of cooling water flow, each source equipped with a flow switch that returns to its normally-open status if the water flow through the pipe stops. If either water source ceases supplying cooling water to the generator (for whatever reason), that flow switch will de-actuate and turn the warning light on. This is all that is required, as the generator will still receive adequate cooling from only one source. If both water sources cease supplying water, however, a "trip" solenoid will energize to shut down the generator before it overheats:



One day the warning light comes on, but there is still cooling water to the generator so it does not shut down. You are asked to determine what the problem is. Using your voltmeter, you measure 115 volts AC between TP2 and L2, and 0 volts AC between TP4 and L2. From this information, identify two possible causes that could account for the warning light status and all measured values in this circuit. Then, choose one of those possible causes and explain why you think it could be to blame. The possible causes you identify can be non-electrical as well as electrical in nature. Be as specific as you can in your answers.

- Possible causes
  - 1.
  - 2.
- Explanation of *why* you think one of the above possibilities could be to blame

file 02924

# Question 70

Draw the necessary wire connections to build the circuit shown in this ladder diagram:

Ladder diagram:

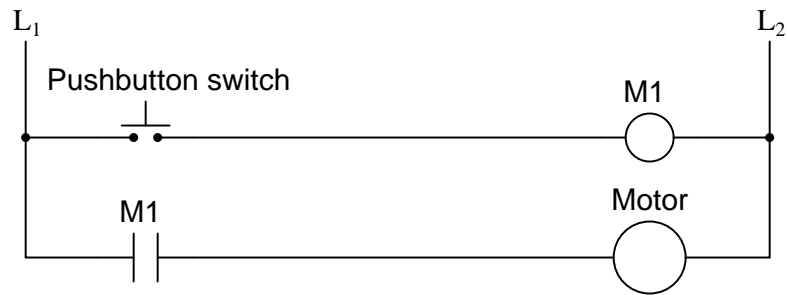
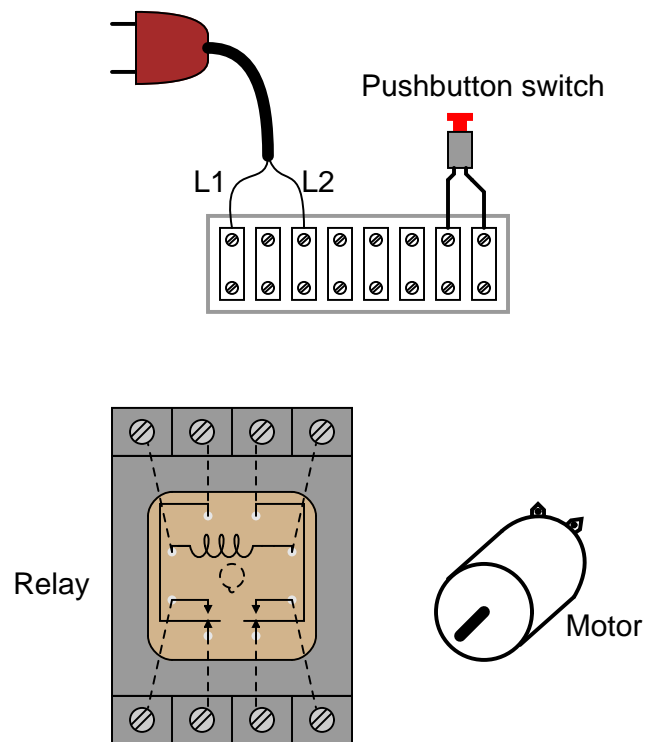


Illustration showing components:



*(Dashed lines represent connections between relay terminals and socket screw lugs, hidden from sight)*

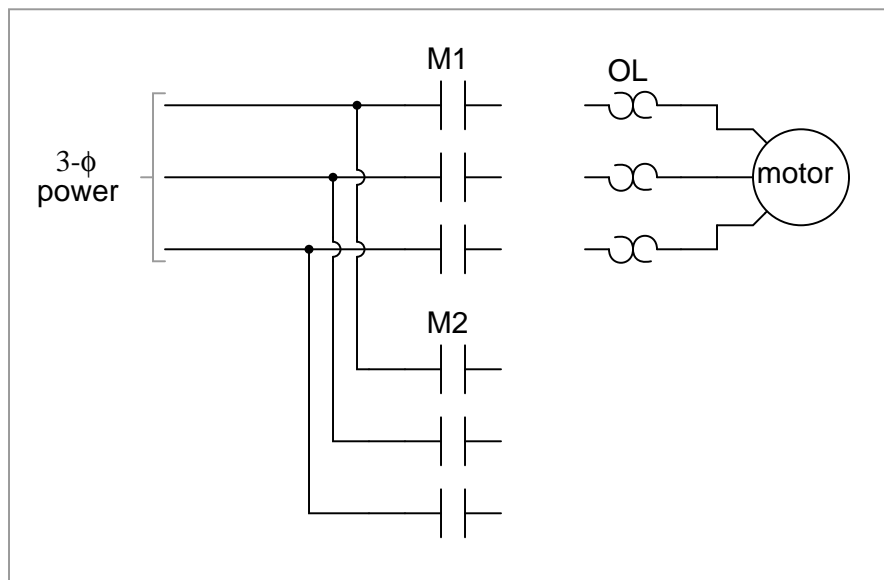
file 03209



---

Question 71

Complete this ladder diagram for a forward/reverse three-phase motor control circuit, complete with interlock contacts to prevent both M1 (forward) and M2 (reverse) contactors from simultaneously energizing:



Be sure to include all these details:

- Proper placement of M1 (forward) and M2 (reverse) coils
- Proper placement of overload contact (OL)
- Proper placement of interlock contacts
- Proper wiring of M1 and M2 contacts to motor

[file 03211](#)

---

Question 72

Convert the octal number 344 to decimal form.

[file 02965](#)

---

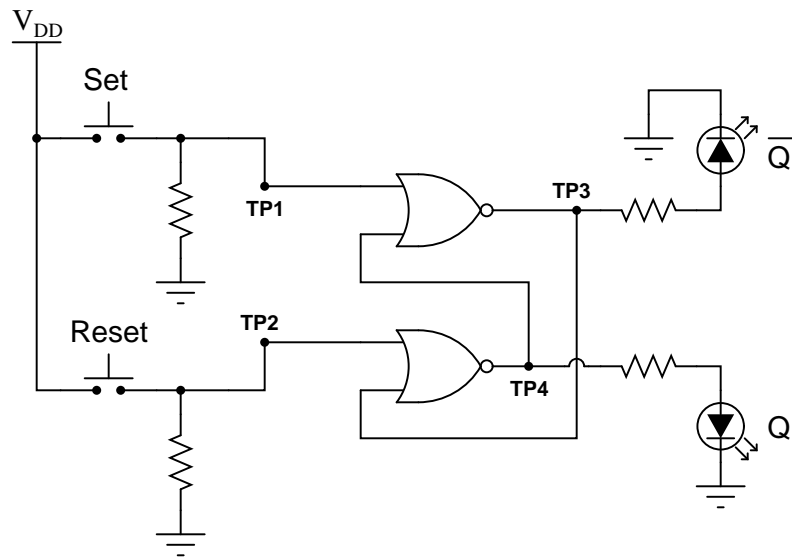
Question 73

Convert the decimal number 35 to hexadecimal form.

[file 02968](#)

### Question 74

Identify the logic states of all four test points (TP1 through TP4) when the correct pushbutton switch is pressed to *reset* the latch circuit:



TP1 =

TP3 =

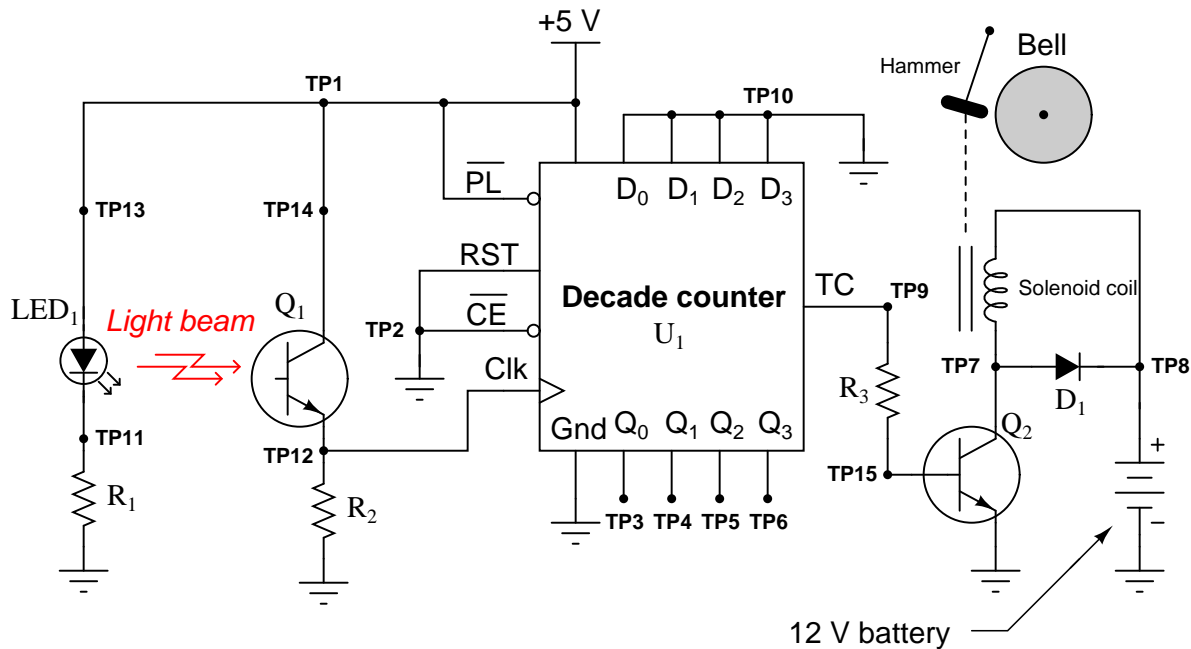
TP2 =

TP4 =

file 03019

# Question 75

An electronic counter is installed at the entrance doorway of a large convention room to count the number of people entering. As each person passes through the doorway, their body interrupts a light beam from an infra-red LED to a matching phototransistor, sending a pulse to the counter IC (LED light striking the phototransistor  $Q_1$  turns it on, and the absence of LED light turns it off). Every tenth person that enters is supposed to win a prize, so the job of this circuit is to ring a bell for every tenth person who enters (at the "terminal count" state). The problem is, the bell was working just fine a few hours ago, but hasn't rung ever since. Some of the convention attendees are starting to get angry, demanding door prizes.



You begin troubleshooting by taking voltage measurements while people randomly enter the room (breaking the light beam as they do). Using your voltmeter, you measure a constant +5 volts at TP3 with respect to ground. This voltage measurement does not change, no matter how many people pass through the light beam. You then connect your voltmeter between TP12 and ground, measuring approximately 0 volts all the time whether or not someone is passing through the doorway.

From this information, identify two possible causes that could account for the problem and all measured values in this circuit. Also, identify the next logical test point(s) from those shown on the schematic that you would check with a voltmeter, and why you would check there. Note that there may be more than one correct answer to this part of the question!

- Possible causes of the problem

- 1.
- 2.

- Next logical test point(s) to check, with reason why you would check there

Next point(s):

Reason:

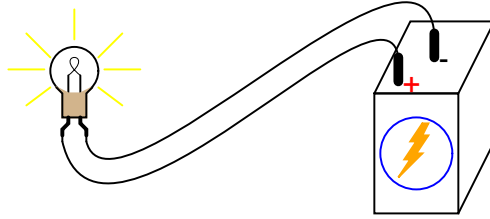
file 03097

## Answers

---

Answer 1

This is the simplest option, but not the only one.



---

Answer 2

$$E = IR \quad I = \frac{E}{R} \quad R = \frac{E}{I}$$

---

Answer 3

$$E = 36 \text{ volts} \quad P = 0.72 \text{ watts}$$

---

Answer 4

- Between **C** and **H** – *voltage*
- Between **A** and **B** – *no voltage*
- Between **I** and **J** – *no voltage*
- Between **A** and **F** – *voltage*

---

Answer 5

Green      Blue      Red      Gold

---

Answer 6

$$I = 9.5833 \text{ amps}$$

---

Answer 7

$$V_R = 7 \text{ volts} \quad I_R = 3.182 \text{ mA}$$

---

Answer 8

The fault must be somewhere to the *left* of points **B** and **G**.

---

Answer 9

Between points **A** (red lead) and **C** (black lead): *+13 volts*

Between points **E** (red lead) and **C** (black lead): *-7 volts*

---

Answer 10

$$I = 3.871 \text{ A} \quad t = 9.3 \text{ hours}$$

---

Answer 11

- $I_{R1} = \underline{110 \text{ mA}}$  ; Direction = *to the right*
- $I_{R5} = \underline{240 \text{ mA}}$  ; Direction = *to the left*
- $I_{R6} = \underline{40 \text{ mA}}$  ; Direction = *to the right*
- $I_{R3} = \underline{130 \text{ mA}}$  ; Direction = *down*

---

Answer 12

$$R_3 = 1.664 \text{ k}\Omega$$

$$R_3 = \frac{1}{\frac{1}{R_T} - \left(\frac{1}{R_1} + \frac{1}{R_2}\right)}$$

---

Answer 13

The data suggests something failed open in the 400 watt heater circuit. All wires and components conducting current to the 200 watt and 800 watt heaters must be good.

---

Answer 14

$$R_3 = 760 \text{ }\Omega$$

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

---

Answer 15

- $I_{R1}$  will *increase*
- $I_{R2}$  will *decrease*

---

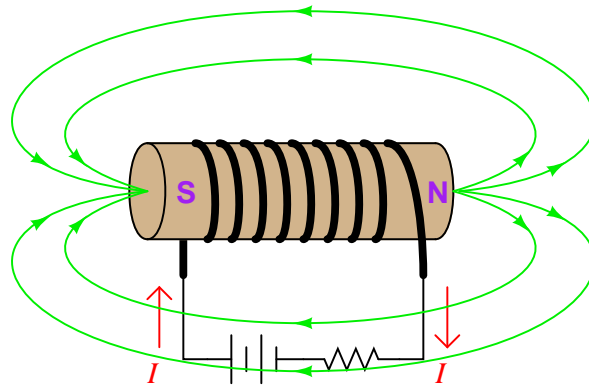
Answer 16

$$R_{total} \text{ (min.)} = 2.6 \text{ k}\Omega$$

$$R_{total} \text{ (max.)} = 3.32 \text{ k}\Omega$$

---

Answer 17



---

Answer 18

**Components known to be in good working condition:**

- Wire from battery to  $R_1$
- Wire from TP2 to TP3
- $R_1$
- $R_2$
- $R_3$
- Coil #2

**Components which could possibly be faulted:**

- Wire from TP4 to TP5 broken (open)
- Coil #1 failed open

---

Answer 19

Make  $R$  *smaller*.          Make  $L$  *larger*.

I recommend assigning two points to each properly identified component, and two points for each proper direction of change.

---

Answer 20

$$L_{total} = 4.839 \text{ mH}$$

---

Answer 21

$$V_C = 10.27 \text{ V}$$

---

Answer 22

**Components known to be in good working condition:**

- Pushbutton switch
- Capacitor
- Relay coil

**Components which could possibly be faulted:**

- Wire from TP1 to TP4 broken (open)
- Wire from TP4 to relay broken (open)
- Wire from TP7 to TP8 broken (open)
- Relay reed burnt so it cannot contact either "throw."

---

Answer 23

$$V_{peak} = 1.5 \text{ volts}$$

$$V_{RMS} = 1.061 \text{ volts}$$

$$f = 200 \text{ Hz}$$

$$\text{Period} = 5 \text{ milliseconds}$$

---

Answer 24

$$Z_{total} = 2.784 \text{ k}\Omega$$

$$I_{total} = 1.078 \text{ mA}$$

$$I_L = 868.1 \text{ }\mu\text{A}$$

$$I_R = 638.3 \text{ }\mu\text{A}$$

---

Answer 25

$$I_{total} = \textit{decrease}$$

$$V_{R1} = \textit{decrease}$$

$$V_{L1} = \textit{increase}$$

$$V_{R2} = \textit{decrease}$$

---

Answer 26

$$V_1 (\text{peak}) = 3 \text{ volts}$$

$$V_2 (\text{peak}) = 3.4 \text{ volts}$$

$$f = 100 \text{ Hz}$$

$$\Theta = 72^\circ$$

---

Answer 27

$$X_C = 1540 \text{ }\Omega$$

$$C = 51.67 \text{ nF}$$

---

Answer 28

$$I_{total} = \textit{decrease}$$

$$V_{R1} = \textit{stay the same}$$

$$I_{C1} = \textit{decrease}$$

$$\text{Phase shift } (\Theta) \text{ between } V_{total} \text{ and } I_{total} = \textit{decrease} \text{ (approach } 0^\circ)$$

---

Answer 29

**Possible component faults, and their respective validating tests**

- Source  $V_1$  failed (no signal); measure 0 AC voltage directly across its terminals.
  - Problem with receiving computer circuitry (digital data load "resistor" failed open); measure full AC voltage directly across its terminals.
  - Capacitor  $C_1$  failed open; measure full AC voltage directly across its terminals.
  - Capacitor  $C_2$  failed open; measure full AC voltage directly across its terminals.
  - Capacitor  $C_3$  failed open; measure full AC voltage directly across its terminals.
  - Capacitor  $C_4$  failed open; measure full AC voltage directly across its terminals.
- 

Answer 30

Resonance is that state where the inductive and capacitive reactances are precisely equal to one another:

$$X_L = X_C$$

---

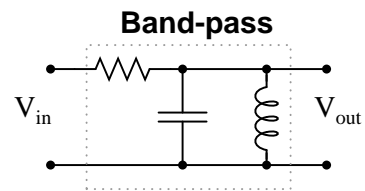
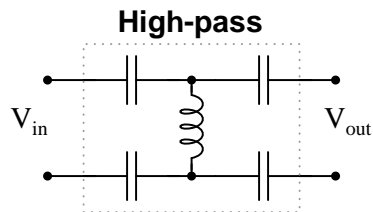
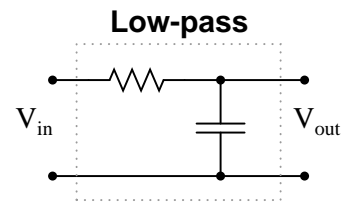
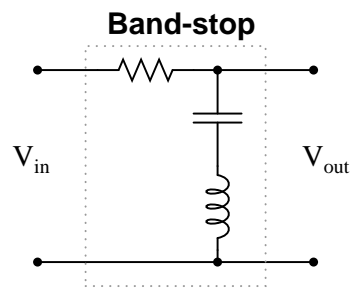
Answer 31

$$\mathbf{Z_{total} = 2.242\text{ k}\Omega \angle -11.13^{\circ}}$$

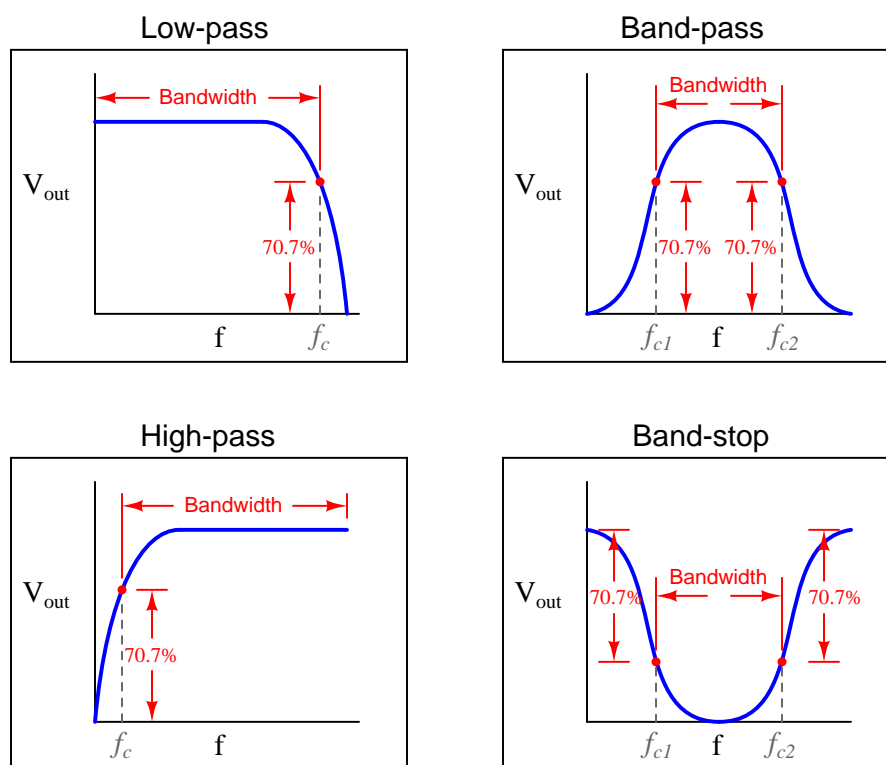
I recommend assigning 4 points to the correct magnitude and 4 points to the correct angle.

---

Answer 32








---

Answer 34

Moving the pot wiper *up* increases the DC voltage across the varactor, which decreases its capacitance, which increases the resonant frequency of the LC circuit.

---

Answer 35

Transformers are used to step voltage up for efficient transportation over long distances, and used to step the high voltage down again for point-of-use circuits.

---

Answer 36

$$V_{secondary} = 443.7 \text{ volts}$$

---

Answer 37

$$I_{load} = 29.14 \text{ mA}$$

$$V_{load} = 15.44 \text{ V}$$

---

Answer 38

$$I_{motor} = 108 \text{ amps}$$

---

Answer 39

$$N_{secondary} = 637 \text{ turns}$$

---

Answer 40

First (left) primary winding failed open

- Meter connected between:  $H1$  and  $H2$
- Measurement expected for this type of fault: *Infinite resistance*

Second (right) primary winding failed open

- Meter connected between:  $H3$  and  $H4$
- Measurement expected for this type of fault: *Infinite resistance*

First (left) primary winding shorted to iron core

- Meter connected between: *Either  $H1$  or  $H2$ , and metal frame/core of transformer*
- Measurement expected for this type of fault: *Low resistance*

Secondary winding shorted to iron core

- Meter connected between: *Either  $X1$  or  $X2$ , and metal frame/core of transformer*
- Measurement expected for this type of fault: *Low resistance*

---

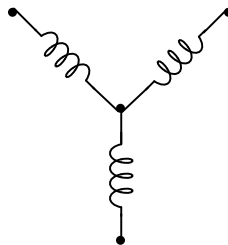
Answer 41

$$P = 7.482 \text{ kW}$$

$$\text{P.F.} = 0.866, \text{ or } 86.6\%$$

---

Answer 42



$$V_{line} = 12.3 \text{ kV}$$

---

Answer 43

$$V_{line} = 440 \text{ volts}$$

$$I_{line} = 2.54 \text{ amps}$$

$$V_{phase(load)} = 254 \text{ volts}$$

$$P_{total} = 1.936 \text{ kW}$$

---

Answer 44

**Components known to be in good working condition:**

- The center (L2) and right (L3) fuses
- All wires from fuses to transformer primary

**Components which could possibly be faulted:**

- Transformer primary winding(s) failed open
- Transformer secondary winding failed open or failed shorted
- Jumper wire from H2 to H3 failed open
- Contactor coil failed shorted

---

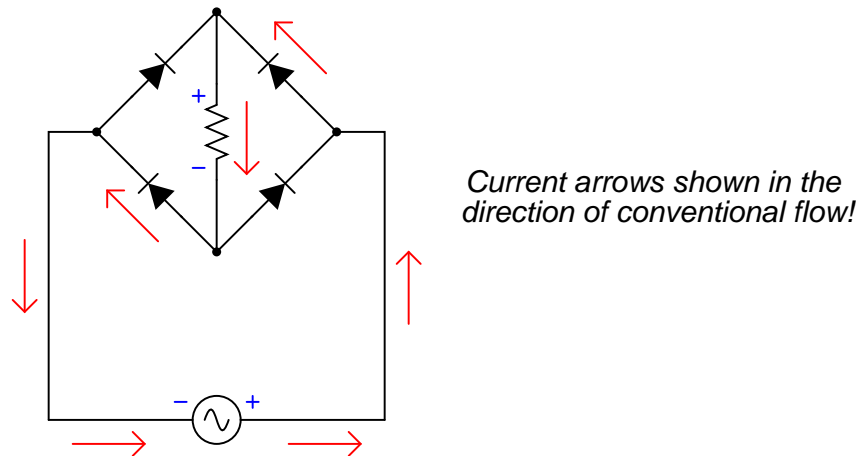
Answer 45

Note: the following answers are not exhaustive. There may be more circuit elements possibly at fault and more circuit elements known to be functioning properly!

- Circuit elements that are possibly faulted
  1. Overload contact tripped (open)
  2. "Stop" switch contacts open
  3. Contactor coil M1 failed open
- Circuit elements that must be functioning properly
  1. Control power transformer (480/120 volt unit supplying L1 and L2)
  2. Both fuses
  3. "Start" switch contacts

---

Answer 46



---

Answer 47

If the load current decreases,  $I_{zener}$  will increase and  $I_{R_{series}}$  will remain unchanged.

Challenge question: what do you think will happen with a *real* zener diode, where its voltage drop does change slightly with changes in current?

---

Answer 48

$$V_{out} \approx 21.4 \text{ volts}$$

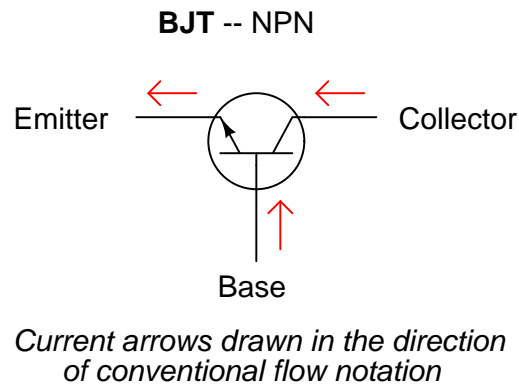
---

Answer 49

I'll let you and your classmates figure out some possibilities here!

---

Answer 50



---

Answer 51

The load will be *energized* as a result of this *enhancement-type* transistor being in the "on" state.

---

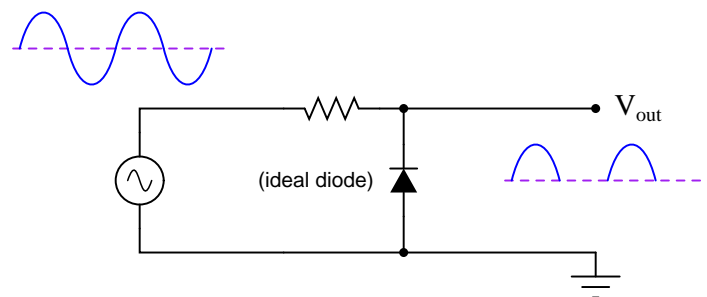
Answer 52

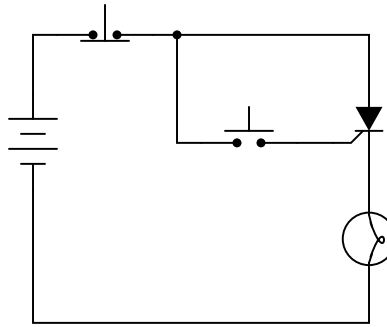
Note: the following answers are not exhaustive. There may be more circuit elements possibly at fault and more circuit elements known to be functioning properly!

- Circuit elements that are possibly faulted
  1. Transistor failed shorted between collector and emitter
  2. Capacitor failed shorted
- Circuit elements that must be functioning properly
  1. Battery
  2. Ignition switch

---

Answer 53





Duty cycle  $\approx 58.3\%$

$P_{average} \approx 80 \text{ W}$

Follow-up question: which oscilloscope setup parameters (vertical sensitivity, probe ratio, coupling, and timebase) are necessary for performing these calculations? Which parameters are unnecessary, and why?

Note: other failures and "good" elements may exist!

- Circuit elements that are possibly faulted
  1. open TRIAC
  2. open switch
- Circuit elements that must be functioning properly
  1. 9 volt battery
  2. AC power source

$$V_{load} = 4.9 \text{ V}$$

$$I_B = 1.134 \text{ mA}$$

Note: the following answers are not exhaustive. There may be more circuit elements possibly at fault and more circuit elements known to be functioning properly!

- Circuit elements that are possibly faulted
  1. Resistor  $R_4$  failed open
  2. Resistor  $R_5$  failed open
  3. Resistor  $R_6$  failed open
  4. Connection between TP6 and collector of  $Q_4$  broken open
- Circuit elements that must be functioning properly (besides power supply and signal source)
  1. Rheostat  $R_1$
  2. Resistor  $R_2$
  3. Capacitor  $C_1$
  4. Transistor  $Q_1$

---

Answer 59

This is a *low* speed alarm, and the wiper would have to be moved *up* to raise the wind speed threshold value.

---

Answer 60

Note: the following answers are not exhaustive. There may be more circuit elements possibly at fault and more circuit elements known to be functioning properly!

- Circuit elements that are possibly faulted
  1. Transistor  $Q_1$  failed open (base-to-emitter, collector-to-emitter, or both)
  2. Broken wire/trace between +V opamp terminal and  $Q_1$  collector terminal.
  3. Broken wire/trace between -V opamp terminal and "-" output terminal.
- Circuit elements that must be functioning properly (besides 120 volt AC source, switch, and fuse)
  1. Transformer
  2. Rectifying diodes

---

Answer 61

Inverting.

---

Answer 62

$$A_V = 2.75$$

It is okay if students express this answer as a negative quantity, since some texts teach the gain formula  $A_V = -\frac{R_f}{R_i}$ .

---

Answer 63

$$A_V = 2.833$$

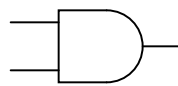
---

Answer 64

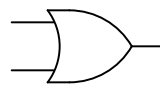
$$A_{V(min)} = 1.09 \qquad A_{V(max)} = 12$$

---

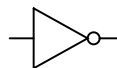
Answer 65



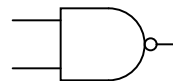
**AND**



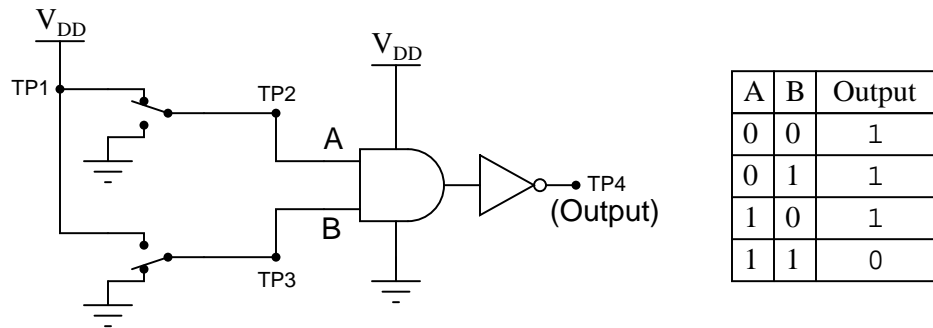
**OR**



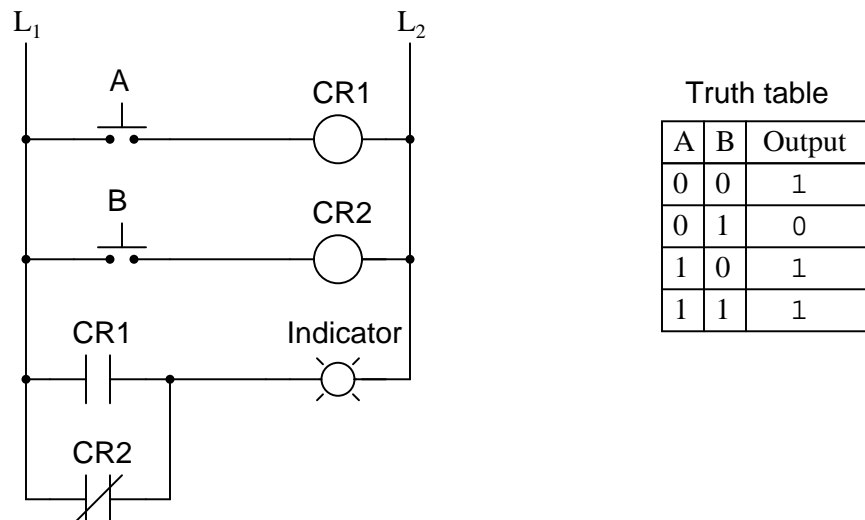
**INVERTER**  
(or **NOT**)



**NAND**



- TP1 = High
- TP2 = High
- TP3 = Low
- TP4 = High



Note: the following answers are not exhaustive. There may be more circuit elements possibly at fault!

- Circuit elements that are possibly faulted
1.  $SW_1$  contacts not closing (dirty or worn)
  2.  $SW_2$  contacts not closing (dirty or worn)
  3. Broken wire between  $SW_1$  and TP1
  4. Broken wire between  $SW_2$  and TP2
  5. Broken wire between  $SW_1$  and ground
  6. Broken wire between  $SW_2$  and ground
  7.  $U_3$  output stuck high
  8.  $U_1$  output stuck high

---

Answer 69

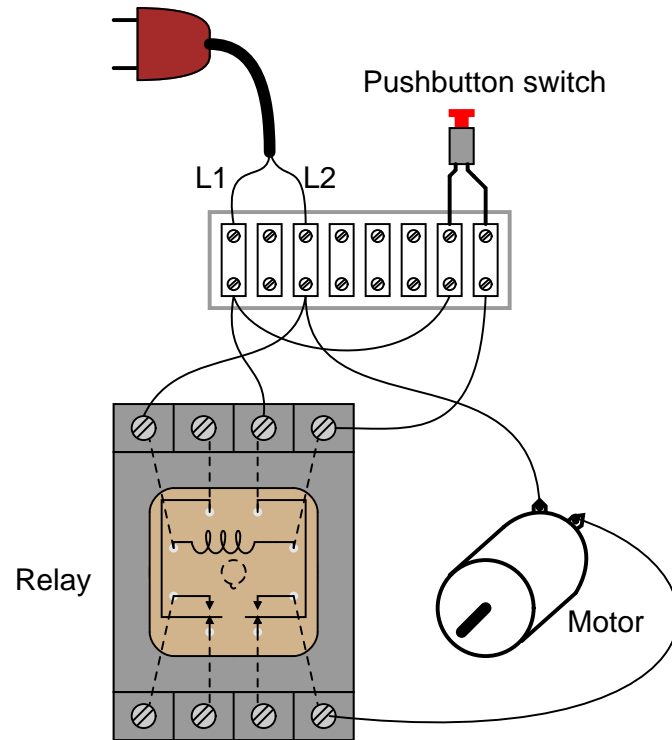
Note: the following answers are not exhaustive.

- Possible causes
  1. Cooling water source "B" actually ceased flowing
  2. Switch contacts for flow switch "B" failed open
  3. Broken wire between TP3 and TP4

---

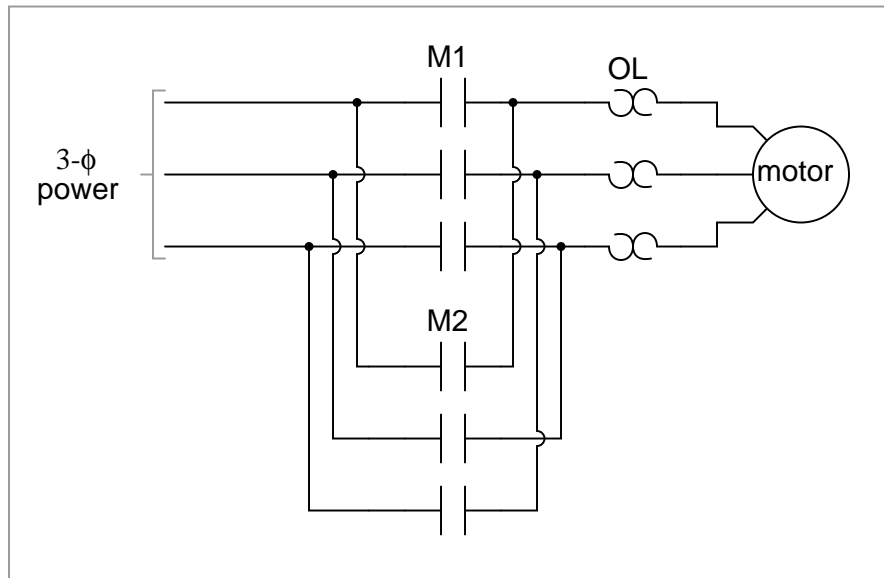
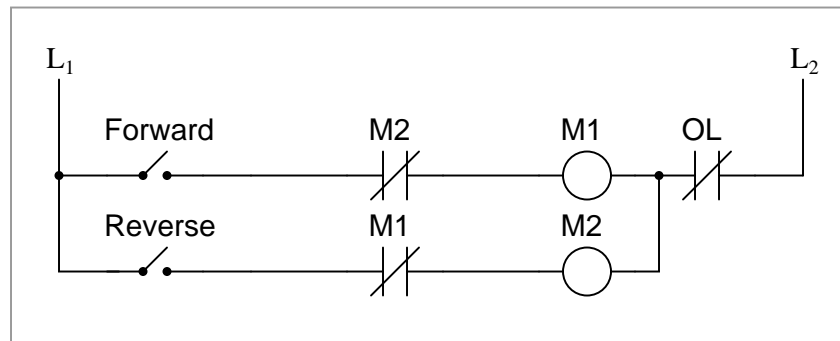
Answer 70

Note: this is not the only valid solution!





Answer 71



Answer 72

$$344_8 = 228_{10}$$

Answer 73

$$35_{10} = 23_{16}$$

Answer 74

TP1 = 0 (low)

TP3 = 1 (high)

TP2 = 1 (high)

TP4 = 0 (low)

Note: the following answers are not exhaustive. There may be more circuit elements possibly at fault than what is listed here!

- Possible causes of the problem
  1. Phototransistor  $Q_1$  failed open
  2. LED failed open
  3. Resistor  $R_1$  failed open
  4. Wire or connection broken between TP1 and LED, or TP1 and  $Q_1$
  5. Resistor  $R_2$  failed shorted
- Next logical test point(s) to check, with reason why you would check there
  - TP14 to ground, to see if  $Q_1$  is being supplied power
  - TP13 to ground, to see if the LED is being supplied power

Notes 1

This question gives students a good opportunity to discuss the basic concept of a circuit. It is very easy to build, safe, and should be assembled by each student individually in class. Also, emphasize how simple circuits like this may be assembled at home as part of the "research" portion of the worksheet. To research answers for worksheet questions does not necessarily mean the information has to come from a book! Encourage experimentation when the conditions are known to be safe.

Have students brainstorm all the important concepts learned in making this simple circuit. What general principles may be derived from this particular exercise?

---

Notes 2

**This question is intended for exams only and not worksheets!.**

---

Notes 3

**This question is intended for exams only and not worksheets!.**

---

Notes 4

**This question is intended for exams only and not worksheets!.**

---

Notes 5

**This question is intended for exams only and not worksheets!.**

---

Notes 6

**This question is intended for exams only and not worksheets!.**

---

Notes 7

**This question is intended for exams only and not worksheets!.**

---

Notes 8

**This question is intended for exams only and not worksheets!.**

---

Notes 9

**This question is intended for exams only and not worksheets!.**

---

Notes 10

**This question is intended for exams only and not worksheets!.**

---

Notes 11

**This question is intended for exams only and not worksheets!.**

---

Notes 12

**This question is intended for exams only and not worksheets!.**

---

Notes 13

**This question is intended for exams only and not worksheets!.**

---

Notes 14

**This question is intended for exams only and not worksheets!.**

---

---

Notes 15

**This question is intended for exams only and not worksheets!.**

---

Notes 16

**This question is intended for exams only and not worksheets!.**

---

Notes 17

**This question is intended for exams only and not worksheets!.**

---

Notes 18

**This question is intended for exams only and not worksheets!.**

---

Notes 19

**This question is intended for exams only and not worksheets!.**

---

Notes 20

**This question is intended for exams only and not worksheets!.**

---

Notes 21

**This question is intended for exams only and not worksheets!.**

---

Notes 22

**This question is intended for exams only and not worksheets!.**

---

Notes 23

**This question is intended for exams only and not worksheets!.**

---

Notes 24

**This question is intended for exams only and not worksheets!.**

---

Notes 25

**This question is intended for exams only and not worksheets!.**

---

Notes 26

**This question is intended for exams only and not worksheets!.**

---

Notes 27

**This question is intended for exams only and not worksheets!.**

---

Notes 28

**This question is intended for exams only and not worksheets!.**

---

Notes 29

**This question is intended for exams only and not worksheets!.**

---

Notes 30

**This question is intended for exams only and not worksheets!.**

---

Notes 31

**This question is intended for exams only and not worksheets!.**

---

---

Notes 32

**This question is intended for exams only and not worksheets!.**

---

Notes 33

**This question is intended for exams only and not worksheets!.**

---

Notes 34

**This question is intended for exams only and not worksheets!.**

---

Notes 35

Ask your students to explain the answer in detail, rather than just repeating what the given answer states. Why is high-voltage power distribution more efficient than low-voltage distribution? Why would high voltage have to be stepped down for point-of-use applications?

---

Notes 36

Transformer winding calculations are simply an exercise in mathematical ratios. If your students are not strong in their ratio skills, this question provides an application to sharpen them!

---

Notes 37

**This question is intended for exams only and not worksheets!.**

---

Notes 38

**This question is intended for exams only and not worksheets!.**

---

Notes 39

**This question is intended for exams only and not worksheets!.**

---

Notes 40

**This question is intended for exams only and not worksheets!.**

---

Notes 41

**This question is intended for exams only and not worksheets!.**

---

Notes 42

**This question is intended for exams only and not worksheets!.**

---

Notes 43

**This question is intended for exams only and not worksheets!.**

---

Notes 44

**This question is intended for exams only and not worksheets!.**

---

Notes 45

**This question is intended for exams only and not worksheets!.**

---

Notes 46

Have your students explain their reasoning when tracing currents and determining voltage drop polarities in front of the class for all too see. The bridge rectifier circuit is one that many students find confusing to analyze, and so it is worth spending time on in class to fully understand.

---

#### Notes 47

A conceptual understanding of zener diode regulator circuits is important, perhaps even more important than a quantitative understanding. Your students will need to understand what happens to the different variables in such a circuit when another parameter changes, in order to understand how these circuits will dynamically react to changing load or source conditions.

---

#### Notes 48

Ask your students to explain how they solved for this output voltage, step by step.

---

#### Notes 49

Troubleshooting scenarios are always good for stimulating class discussion. Be sure to spend plenty of time in class with your students developing efficient and logical diagnostic procedures, as this will assist them greatly in their careers.

---

#### Notes 50

This question probes some basic yet important knowledge about transistor identify and operation. If students have difficulty identifying all the parameters asked for in this question, you need to spend more time on transistor fundamentals before proceeding with any other aspects of transistor circuitry!

---

#### Notes 51

Ask your students to explain how they figured out the state of the transistor in this circuit, and also what function the double-pole, double-throw (DPDT) switch performs. Incidentally, this DPDT switch wiring configuration is quite common in electrical and electronic circuits!

---

#### Notes 52

Ask your students to identify means by which they could confirm suspected circuit elements, by measuring something other than what has already been measured.

Troubleshooting scenarios are always good for stimulating class discussion. Be sure to spend plenty of time in class with your students developing efficient and logical diagnostic procedures, as this will assist them greatly in their careers.

---

#### Notes 53

This circuit is not difficult to analyze if you consider both half-cycles of the AC voltage source, one at a time. Ask your students to demonstrate this method of analysis, either individually or in groups, at the front of the classroom so everyone can see and understand.

---

#### Notes 54

**This question is intended for exams only and not worksheets!.**

---

#### Notes 55

Calculating the duty cycle should be easy. Calculating load power dissipation requires some thought. If your students do not know how to calculate average power, suggest this thought experiment: calculating power dissipation at 0% duty cycle, at 100% duty cycle, and at 50% duty cycle. The relationship between duty cycle and average power dissipation is rather intuitive if one considers these conditions.

If a more rigorous approach is required to satisfy student queries, you may wish to pose another thought experiment: calculate the *energy* (in units of Joules) delivered to the load for a 50% duty cycle, recalling that Watts equals Joules per second. Average power, then, is calculated by dividing Joules by seconds over a period of one or more whole waveform cycles. From this, the linear relationship between duty cycle and average power dissipation should be clear.

---

Notes 56

**This question is intended for exams only and not worksheets!.**

---

Notes 57

**This question is intended for exams only and not worksheets!.**

---

Notes 58

**This question is intended for exams only and not worksheets!.**

---

Notes 59

**This question is intended for exams only and not worksheets!.**

---

Notes 60

Ask your students to identify means by which they could confirm suspected circuit elements, by measuring something other than what has already been measured.

Troubleshooting scenarios are always good for stimulating class discussion. Be sure to spend plenty of time in class with your students developing efficient and logical diagnostic procedures, as this will assist them greatly in their careers.

---

Notes 61

**This question is intended for exams only and not worksheets!.**

---

Notes 62

**This question is intended for exams only and not worksheets!.**

---

Notes 63

**This question is intended for exams only and not worksheets!.**

---

Notes 64

**This question is intended for exams only and not worksheets!.**

---

Notes 65

**This question is intended for exams only and not worksheets!.**

---

Notes 66

**This question is intended for exams only and not worksheets!.**

---

Notes 67

Notes 68

Ask your students to identify means by which they could confirm suspected circuit elements, by measuring something other than what has already been measured.

Troubleshooting scenarios are always good for stimulating class discussion. Be sure to spend plenty of time in class with your students developing efficient and logical diagnostic procedures, as this will assist them greatly in their careers.

---

Notes 69

**This question is intended for exams only and not worksheets!.**

---

---

Notes 70

**This question is intended for exams only and not worksheets!.**

---

Notes 71

**This question is intended for exams only and not worksheets!.**

---

Notes 72

**This question is intended for exams only and not worksheets!.**

Nothing to comment on here!

---

Notes 73

**This question is intended for exams only and not worksheets!.**

Nothing to comment on here!

---

Notes 74

**This question is intended for exams only and not worksheets!.**

---

Notes 75

**This question is intended for exams only and not worksheets!.**