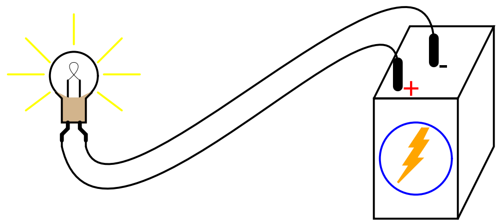
Question 1

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

Answer 1

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



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?

Question 2

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

file 03336

Answer 2

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

Notes 2

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

Question 3

Calculate the voltage dropped across a 1.8 kΩ resistor and the power dissipated by that resistor if it is conducting 20 mA of current.

$E =$ $\qquad\qquad$ $P =$

file 03344

Answer 3

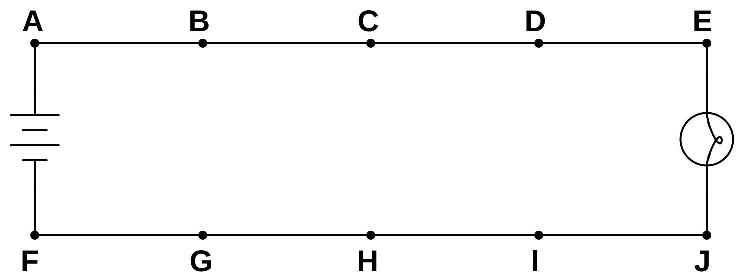
$E = 36$ volts $\qquad\qquad$ $P = 0.72$ watts

Notes 3

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

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

Answer 4

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

Notes 4

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

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

Answer 5

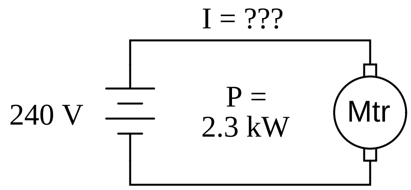
Green Blue Red Gold

Notes 5

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

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

Answer 6

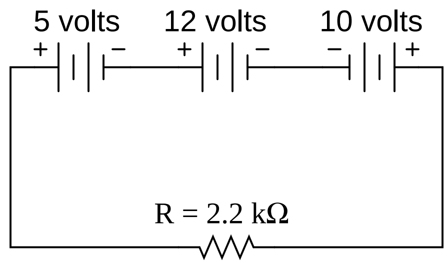
$I = 9.5833$ amps

Notes 6

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

Question 7

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



$V_R =$ $I_R =$

file 03370

Answer 7

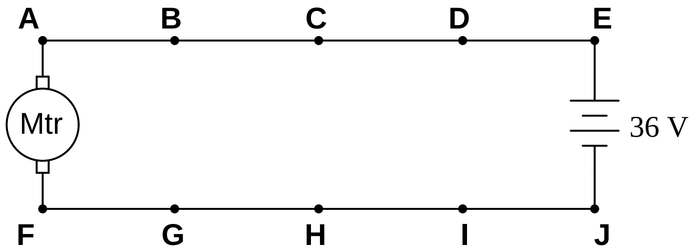
$V_R = 7$ volts $I_R = 3.182$ mA

Notes 7

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

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

Answer 8

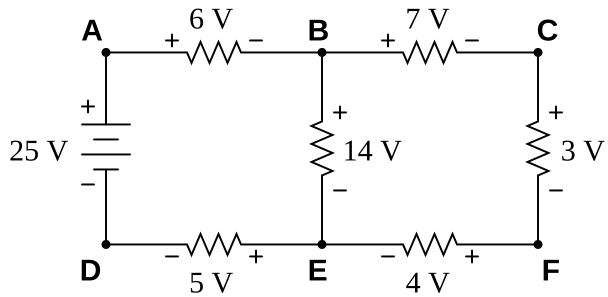
The fault must be somewhere to the *left* of points **B** and **G**.

Notes 8

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

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

Answer 9

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

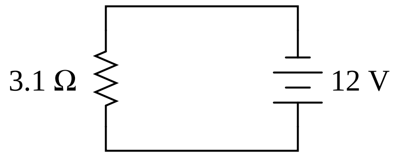
Between points **E** (red lead) and **C** (black lead): *-7 volts*

Notes 9

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

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

Answer 10

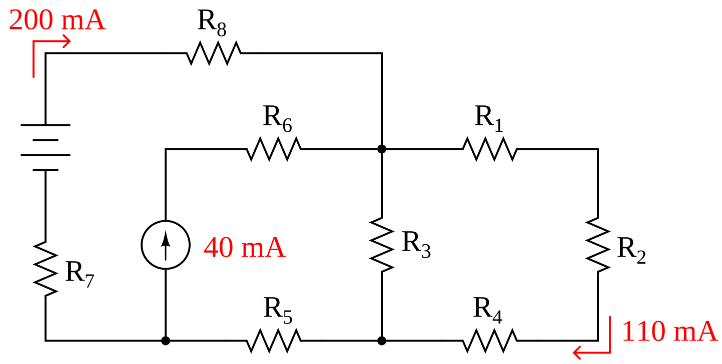
$I = 3.871$ A $t = 9.3$ hours

Notes 10

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

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} = ______________ ; Direction = *to the left* or *to the right*?
- I_{R5} = ______________ ; Direction = *to the left* or *to the right*?
- I_{R6} = ______________ ; Direction = *to the left* or *to the right*?
- I_{R3} = ______________ ; Direction = *up* or *down*?

file 03419

Answer 11

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

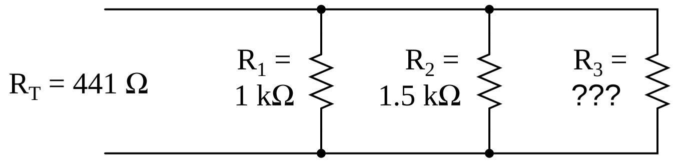
Notes 11

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

Question 12

Calculate the value of R_3 necessary to create a total resistance of 441 Ω:

$R_3 =$



Also, write an equation solving for the value of R_3 in terms of R_T, R_1, and R_2.
file 03411

Answer 12

$R_3 = 1.664$ kΩ

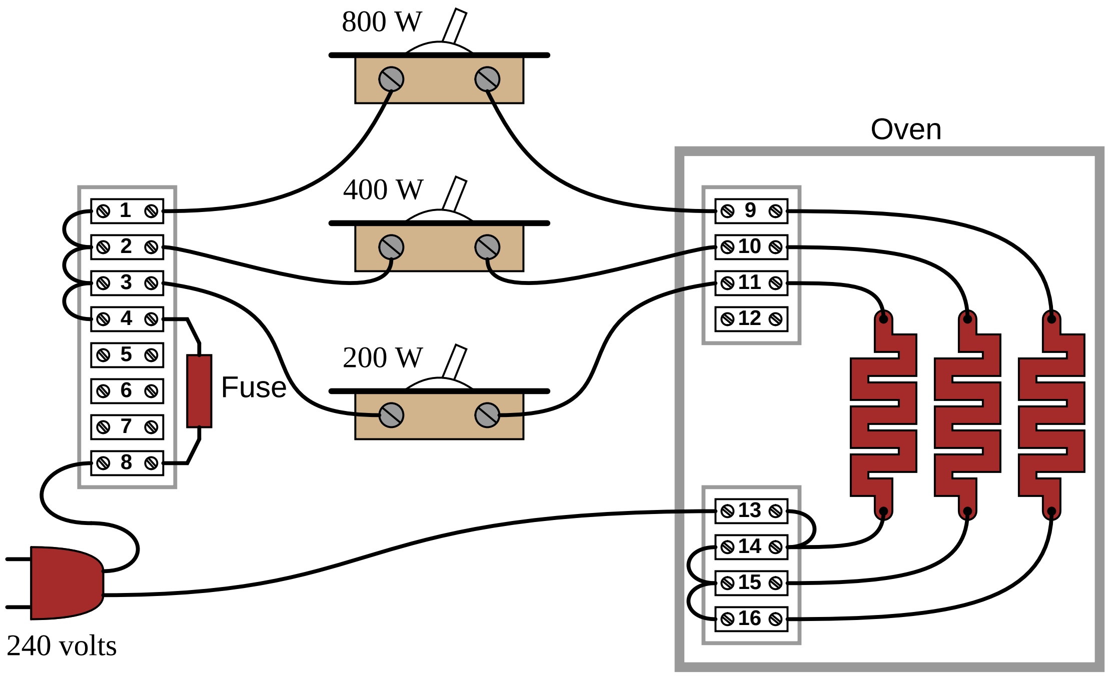
$$R_3 = \frac{1}{\frac{1}{R_T} - \left(\frac{1}{R_1} + \frac{1}{R_2}\right)}$$

Notes 12

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

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

Answer 13

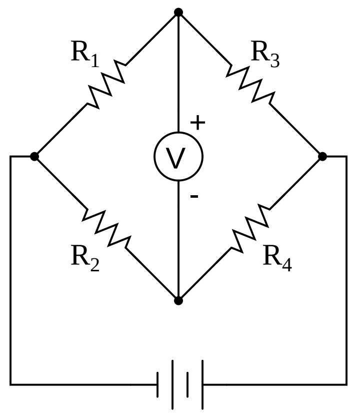
The data suggests something failed open in the 400 watt heater circuit. All wires and components conducting current to the 200 watt and 800 watt heaters must be good.

Notes 13

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

Question 14

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



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

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

file 03429

Answer 14

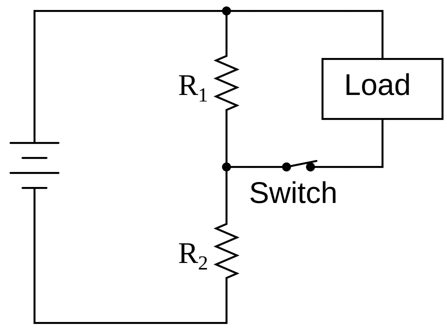
$R_3 = 760\ \Omega$ $\frac{R_1}{R_2} = \frac{R_3}{R_4}$

Notes 14

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

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

Answer 15

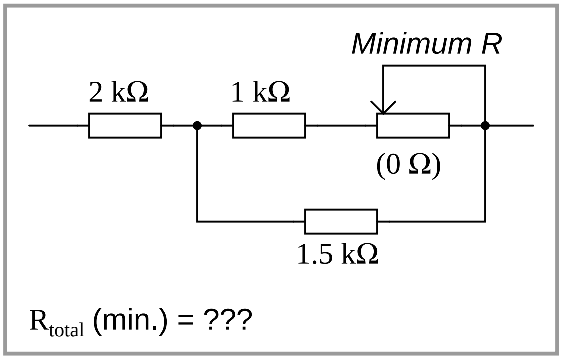
- I_{R1} will *increase*
- I_{R2} will *decrease*

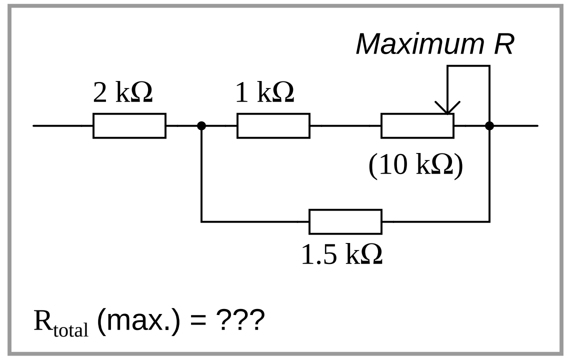
Notes 15

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

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

Answer 16

R_{total} (min.) $= 2.6$ kΩ

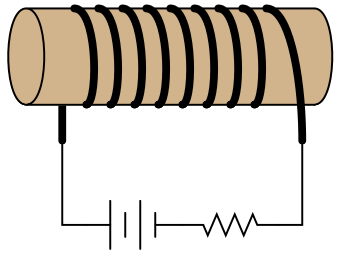
R_{total} (max.) $= 3.32$ kΩ

Notes 16

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

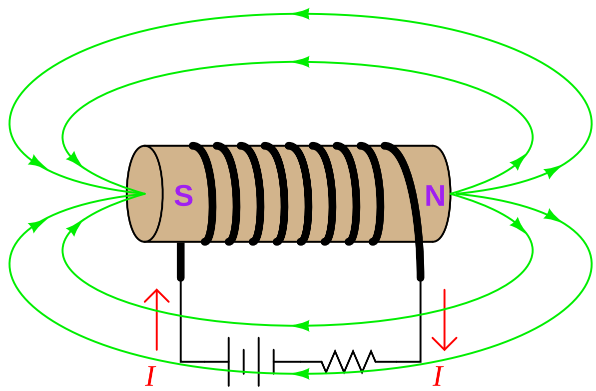
Question 17

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



file 03479

Answer 17

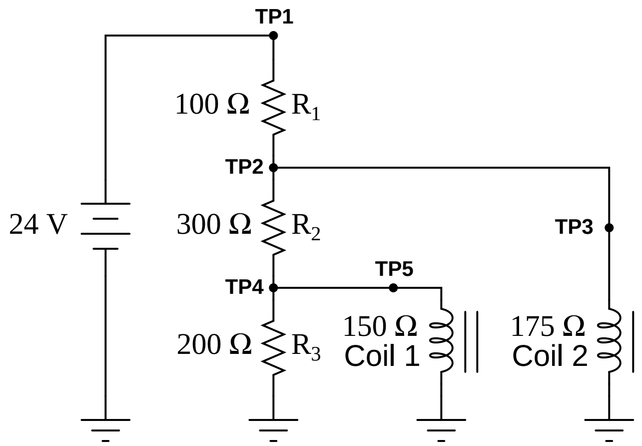


Notes 17

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

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

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:

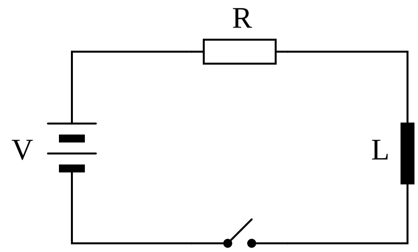
- Wire from TP4 to TP5 broken (open)
- Coil #1 failed open

Notes 18

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

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

Answer 19

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

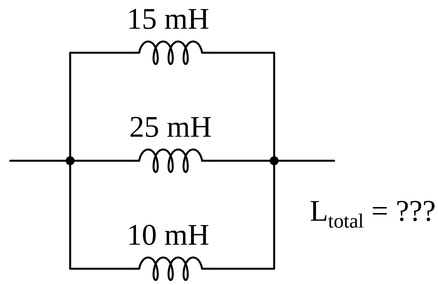
I recommend assigning two points to each properly identified component, and two points for each proper direction of change.

Notes 19

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

Question 20

Calculate the total inductance in this network:



file 03528

Answer 20

$L_{total} = 4.839$ mH

Notes 20

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

Question 21

Calculate the voltage across a 47 μF capacitor after charging from a 12 volt source through a total circuit resistance of 22 kΩ for 2 seconds.

V_C =

file 03540

Answer 21

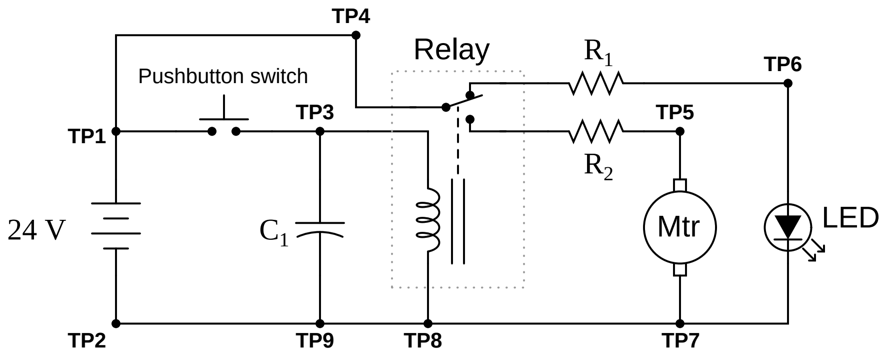
$V_C = 10.27$ V

Notes 21

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

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

Answer 22

Components known to be in good working condition:

- Pushbutton switch
- Capacitor
- Relay coil

Components which could possibly be faulted:

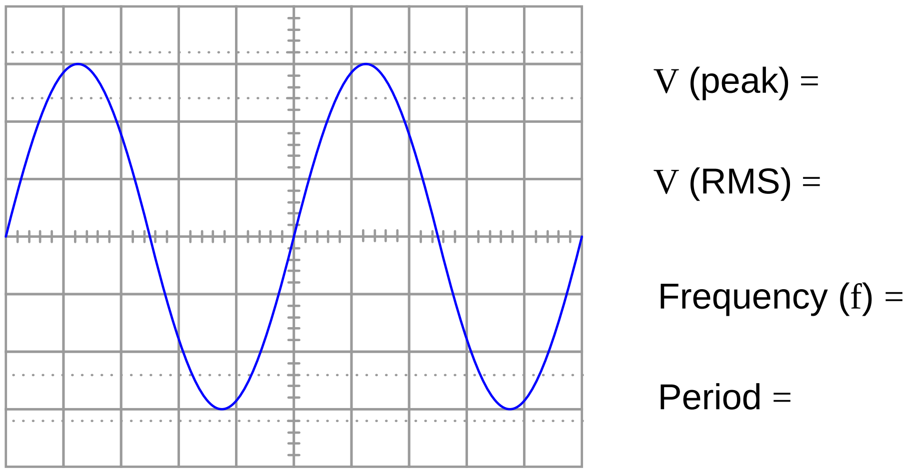
- Wire from TP1 to TP4 broken (open)
- Wire from TP4 to relay broken (open)
- Wire from TP7 to TP8 broken (open)
- Relay reed burnt so it cannot contact either "throw."

Notes 22

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

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:



file 03562

Answer 23

V_{peak} = 1.5 volts V_{RMS} = 1.061 volts

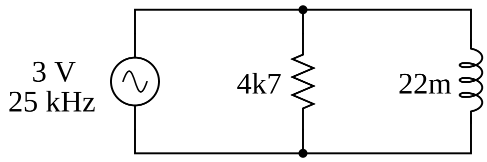
f = 200 Hz Period = 5 milliseconds

Notes 23

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

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

Answer 24

$Z_{total} = 2.784$ kΩ

$I_{total} = 1.078$ mA

$I_L = 868.1\ \mu$A

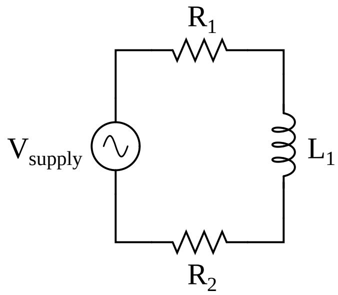
$I_R = 638.3\ \mu$A

Notes 24

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

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

Answer 25

I_{total} = *decrease*

V_{R1} = *decrease*

V_{L1} = *increase*

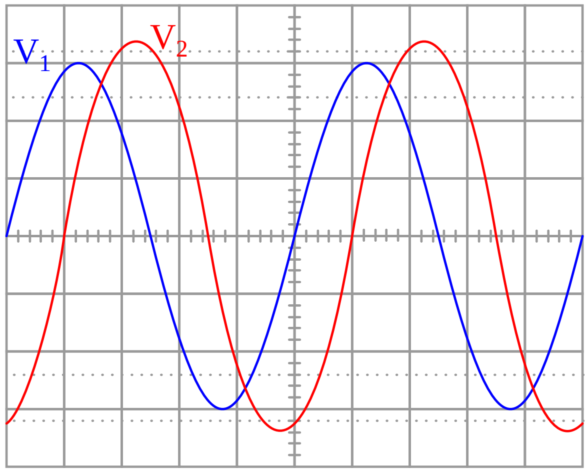
V_{R2} = *decrease*

Notes 25

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

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 (θ) =

file 03598

Answer 26

V_1 (peak) = 3 volts V_2 (peak) = 3.4 volts

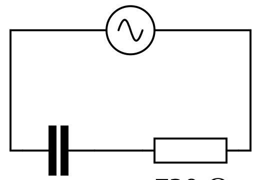
f = 100 Hz $\Theta = 72^o$

Notes 26

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

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 kΩ, and also its capacitance value (C) in Farads if the source frequency is 2 kHz:



$X_C =$ $C =$

file 03609

Answer 27

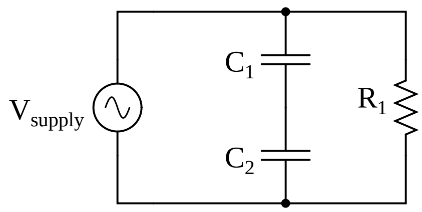
$X_C = 1540\ \Omega$ $C = 51.67$ nF

Notes 27

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

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 (Θ) between V_{total} and I_{total} = *increase* (approach -90^o), *decrease* (approach 0^o), or *stay the same*?

file 03606

Answer 28

I_{total} = *decrease*

V_{R1} = *stay the same*

I_{C1} = *decrease*

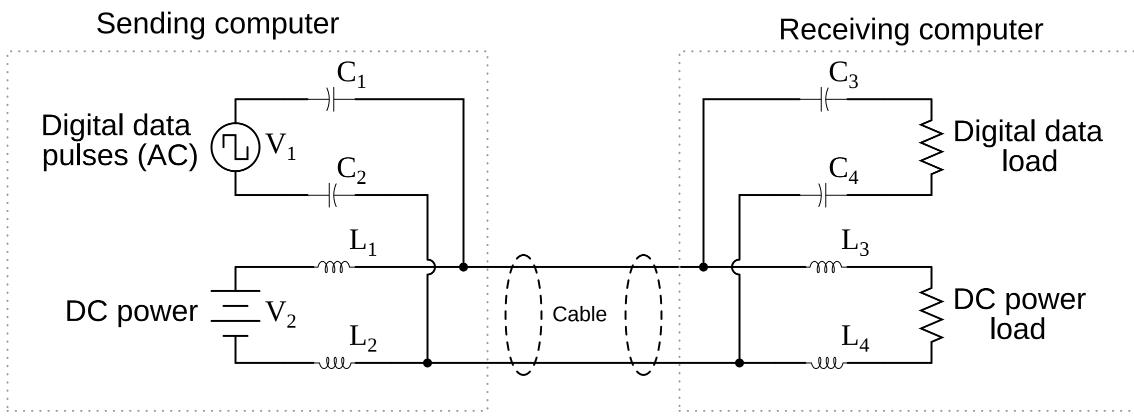
Phase shift (Θ) between V_{total} and I_{total} = *decrease* (approach 0^o)

Notes 28

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

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

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.

Notes 29

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

Question 30

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

file 03616

Answer 30

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

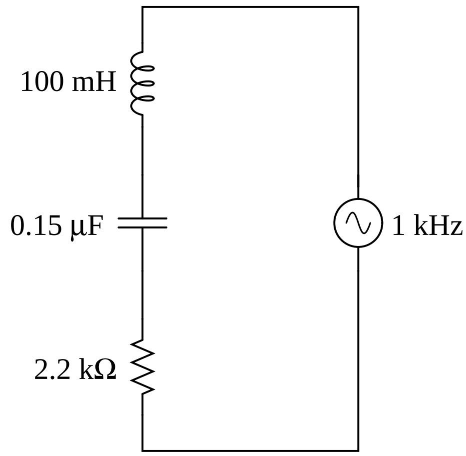
$$X_L = X_C$$

Notes 30

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

Question 31

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



$\mathbf{Z_{total}}$ =

file 03626

Answer 31

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

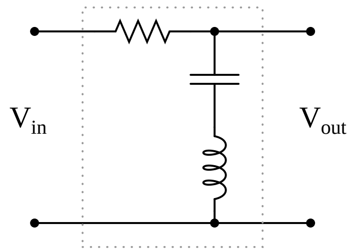
I recommend assigning 4 points to the correct magnitude and 4 points to the correct angle.

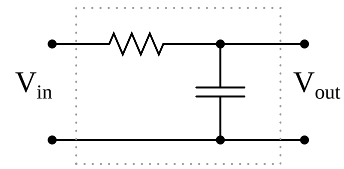
Notes 31

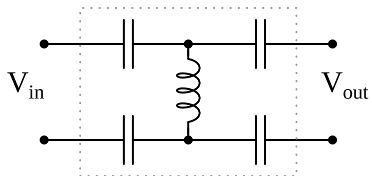
This question is intended for exams only and not worksheets!.

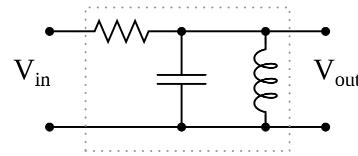
Question 32

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





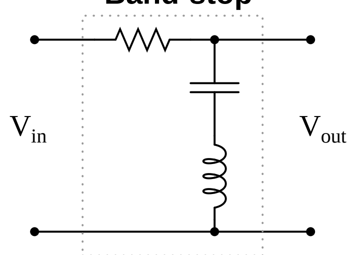




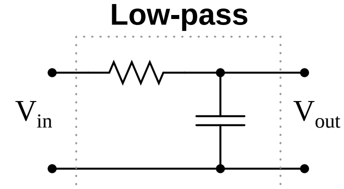
file 03631

Answer 32

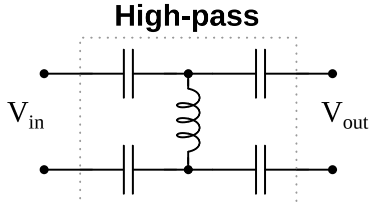
Band-stop



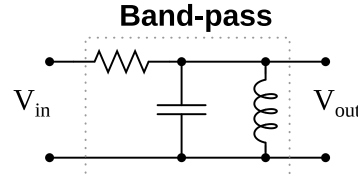
Low-pass



High-pass



Band-pass

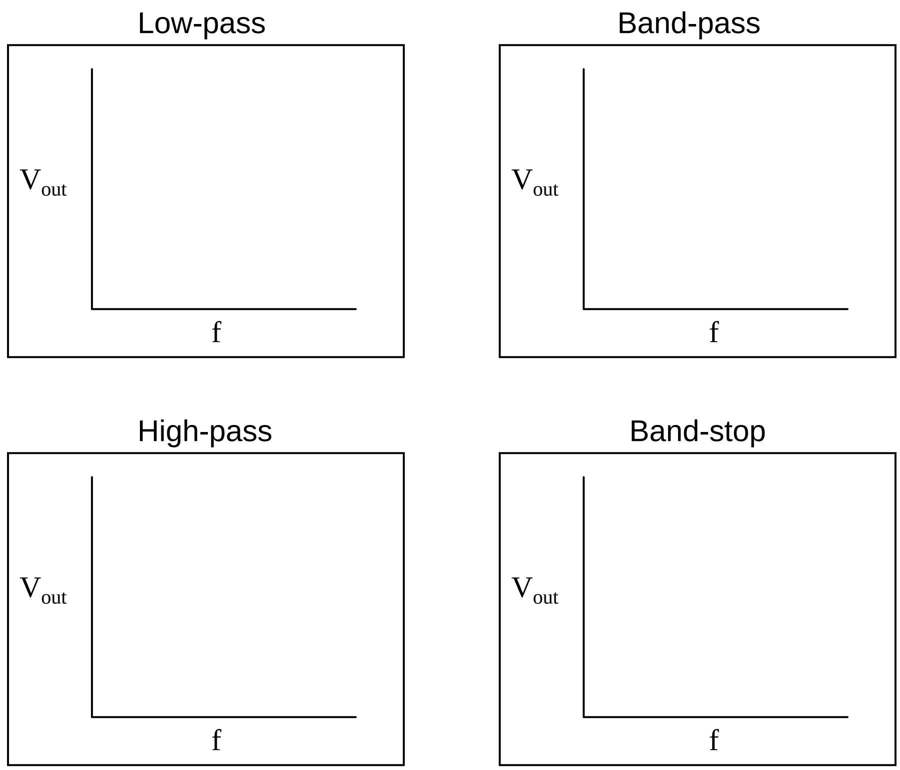


Notes 32

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

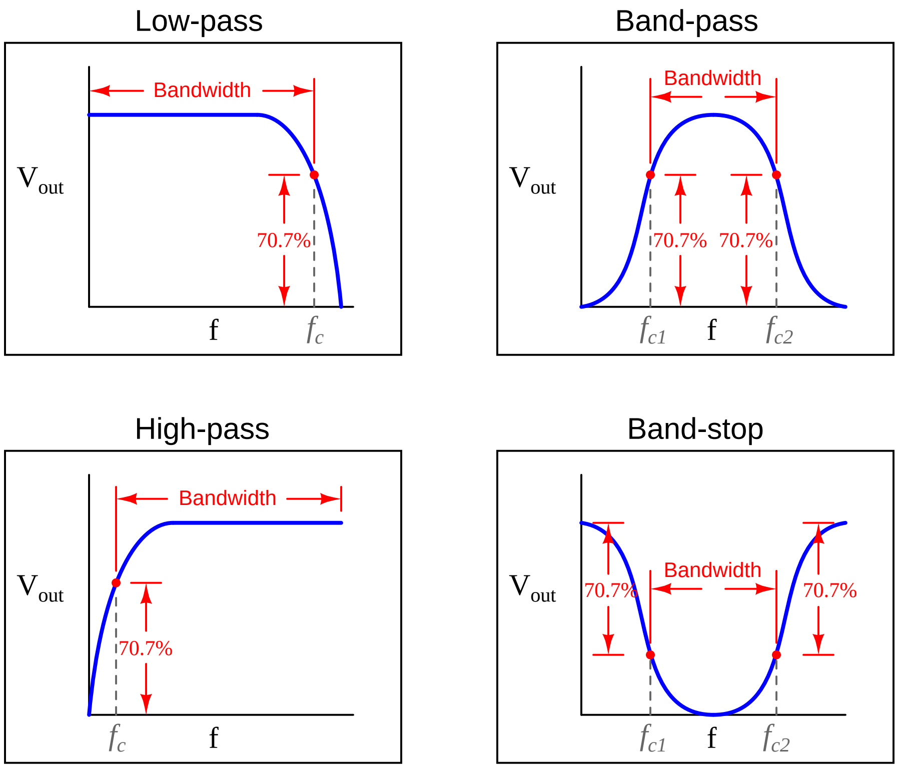
Question 33

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

Answer 33

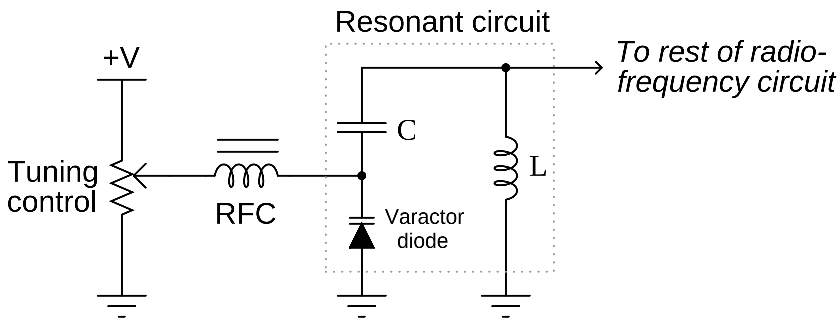


Notes 33

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

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

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.

Notes 34

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

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

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.

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?

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

Answer 36

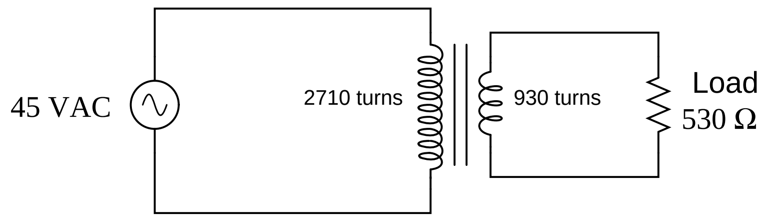
$V_{secondary} = 443.7$ volts

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!

Question 37

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



$I_{load} =$ $V_{load} =$

file 03656

Answer 37

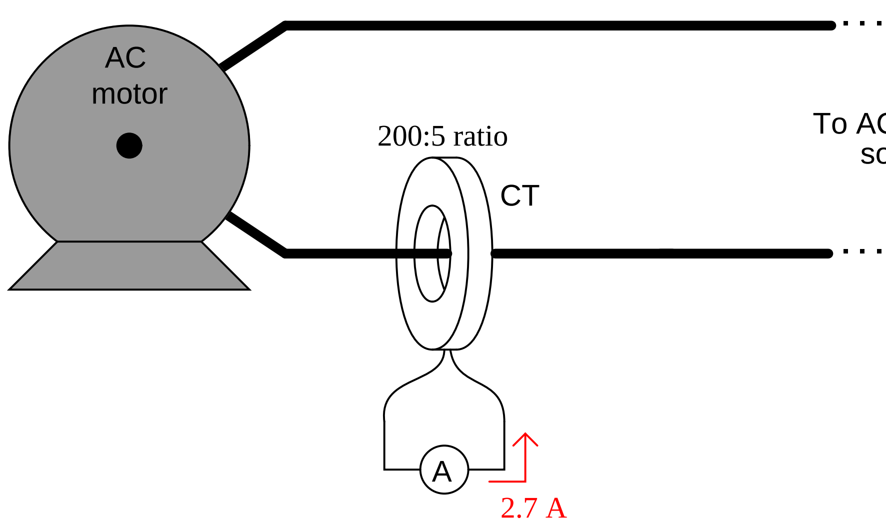
$I_{load} = 29.14$ mA $V_{load} = 15.44$ V

Notes 37

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

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

Answer 38

$I_{motor} = 108$ amps

Notes 38

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

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

Answer 39

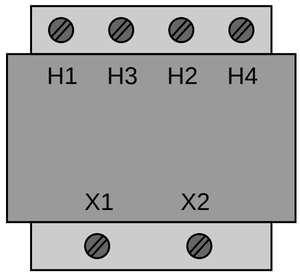
$N_{secondary} = 637$ turns

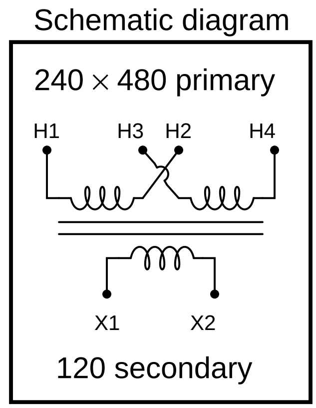
Notes 39

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

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.

<u>First (left) primary winding failed open</u>

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

<u>Second (right) primary winding failed open</u>

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

<u>First (left) primary winding shorted to iron core</u>

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

<u>Secondary winding shorted to iron core</u>

- Meter connected between:
- Measurement expected for this type of fault:
  <u>file 03667</u>

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*

Notes 40

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

Question 41

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

$P =$ P.F. =

file 03680

Answer 41

$P = 7.482$ kW P.F. $= 0.866$, or 86.6%

Notes 41

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

Question 42

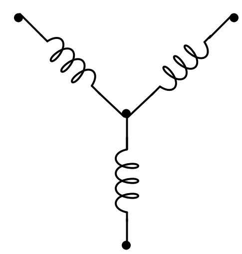
Draw a schematic diagram showing how the windings (coils) of a *Wye* three-phase AC generator are connected together:

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

Answer 42



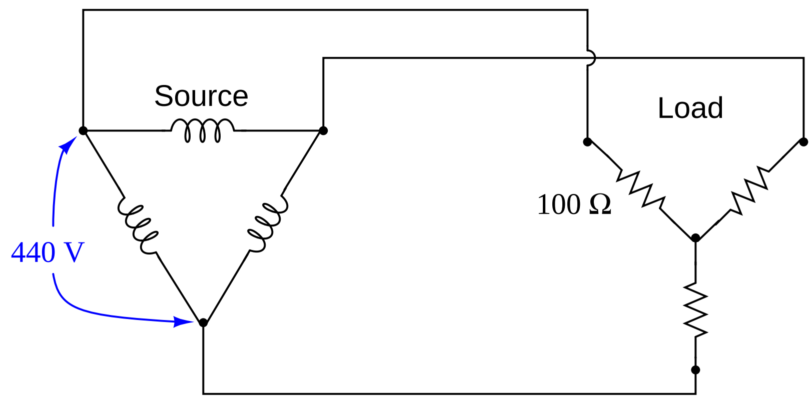
$V_{line} = 12.3$ kV

Notes 42

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

Question 43

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



V_{line} =

I_{line} =

$V_{phase(load)}$ =

P_{total} =

file 03689

Answer 43

V_{line} = 440 volts

I_{line} = 2.54 amps

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

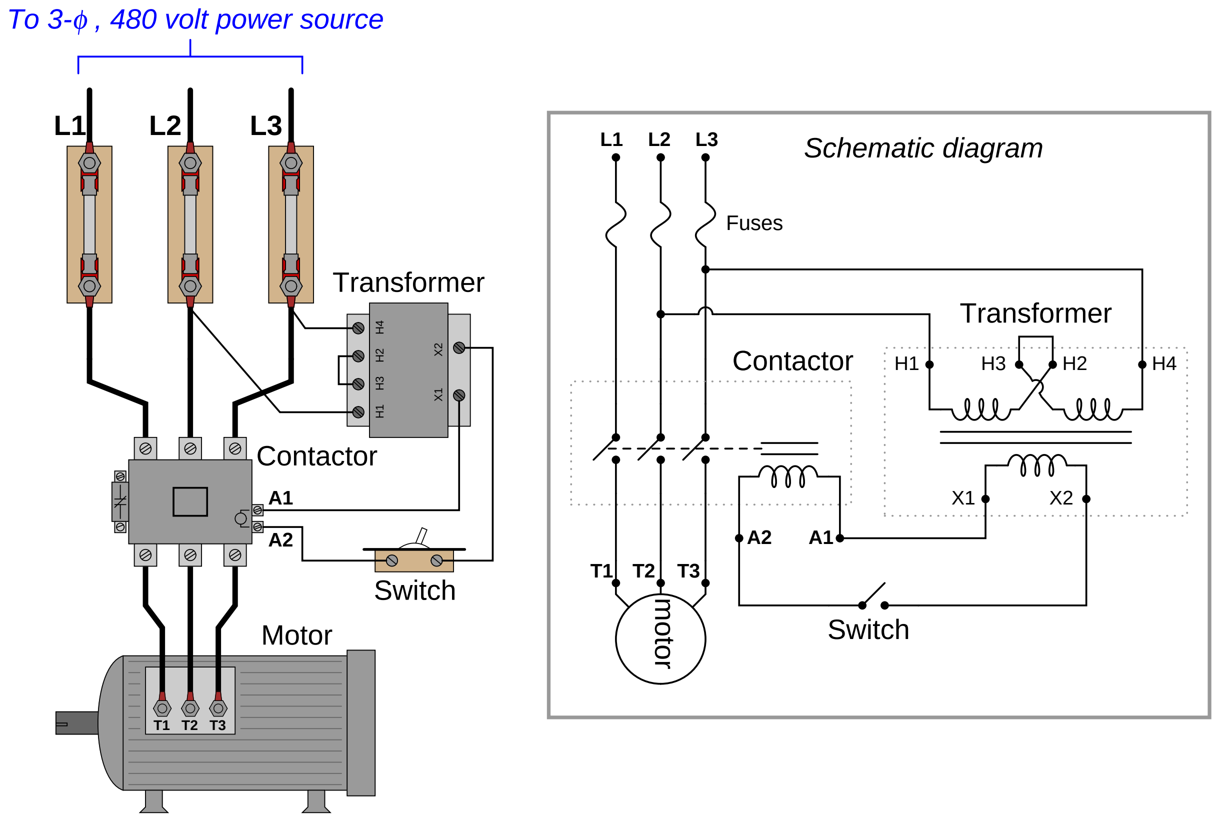
P_{total} = 1.936 kW

Notes 43

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

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.



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

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:

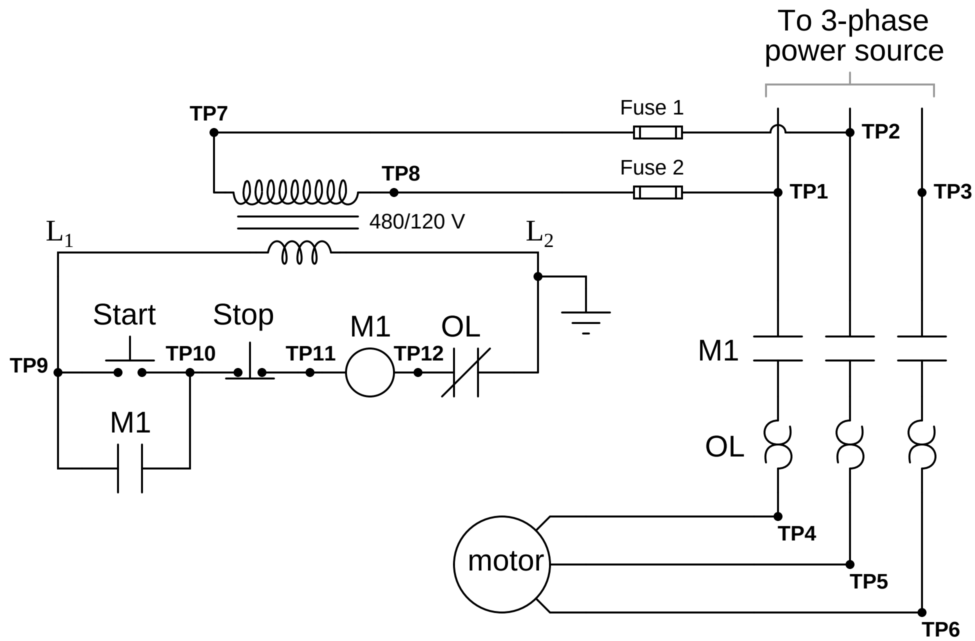
- Transformer primary winding(s) failed open
- Transformer secondary winding failed open or failed shorted
- Jumper wire from H2 to H3 failed open
- Contactor coil failed shorted

Notes 44

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

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

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

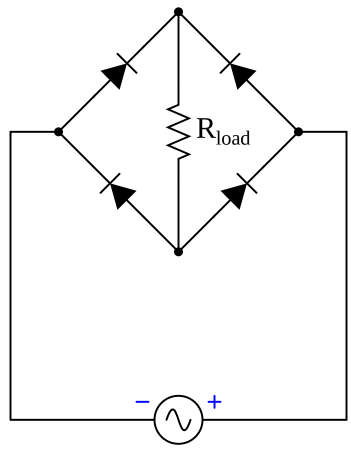
1. Control power transformer (480/120 volt unit supplying L1 and L2)
2. Both fuses
3. "Start" switch contacts

Notes 45

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

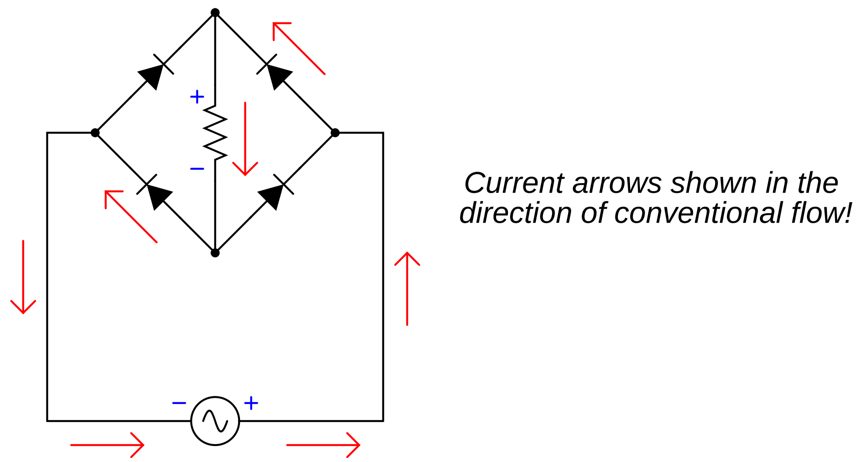
Question 46

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

Answer 46

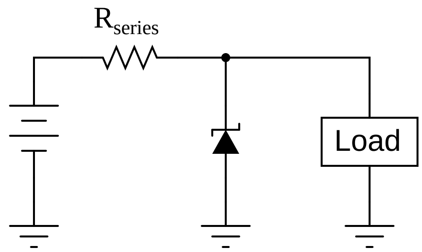


Notes 46

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.

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

Answer 47

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

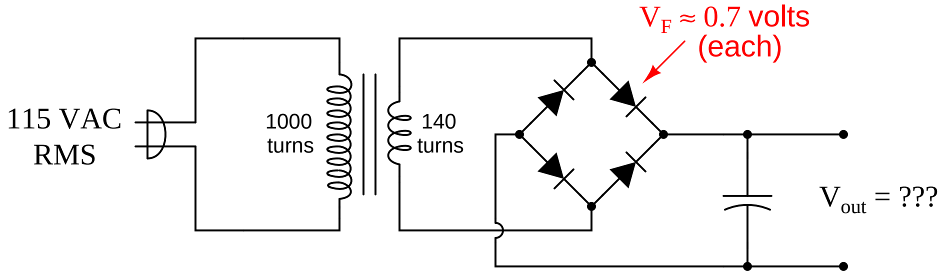
Challenge question: what do you think will happen with a *real* zener diode, where its voltage drop does change slightly with changes in current?

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.

Question 48

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



file 02301

Answer 48

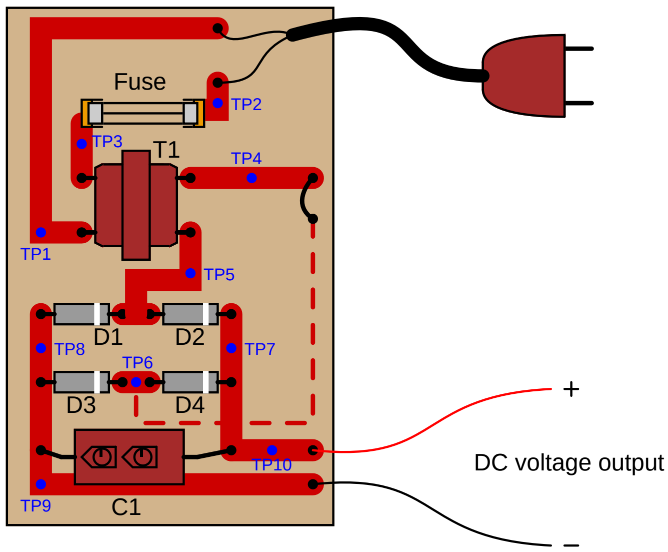
$V_{out} \approx 21.4$ volts

Notes 48

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

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

Answer 49

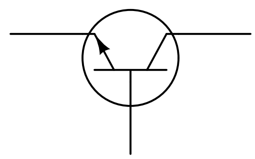
I'll let you and your classmates figure out some possibilities here!

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.

Question 50

Examine the following transistor symbol:

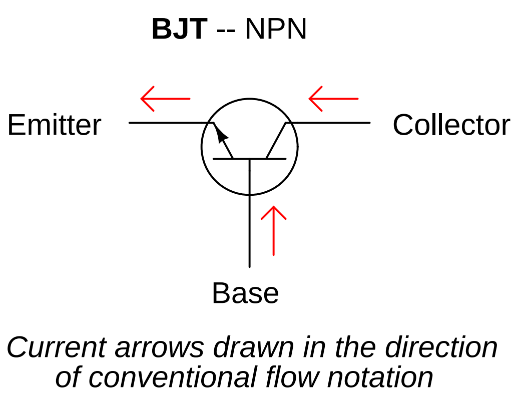


Identify the following:

- 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

Answer 50

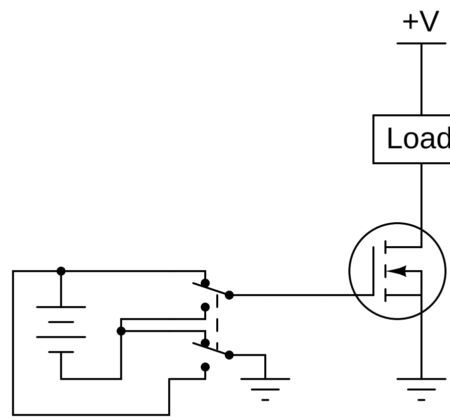


Notes 50

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!

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

Answer 51

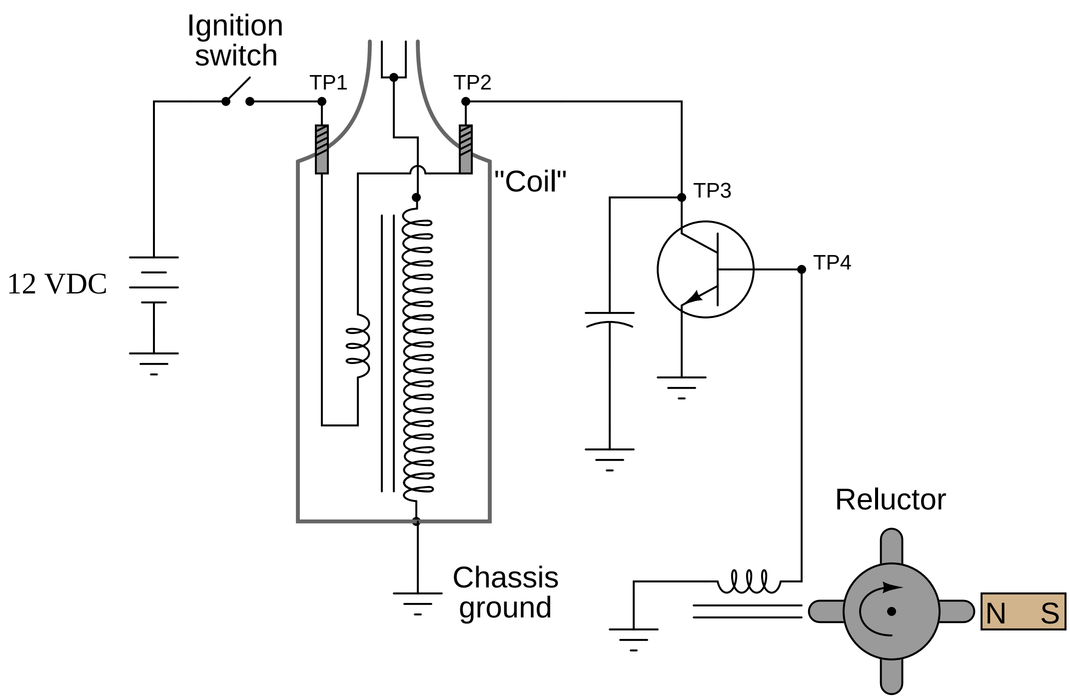
The load will be *energized* as a result of this *enhancement-type* transistor being in the "on" state.

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!

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

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

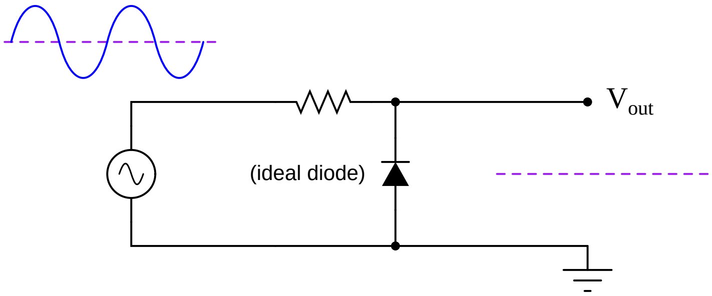
Notes 52

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.

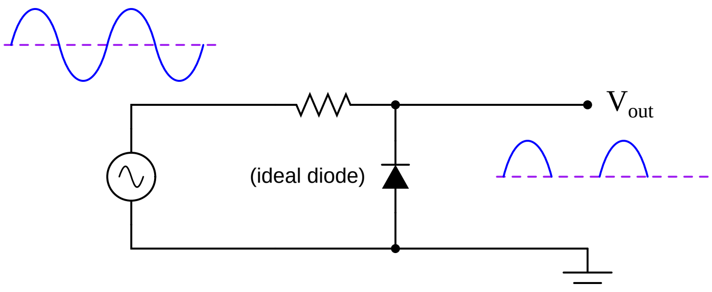
Question 53

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



file 02352

Answer 53

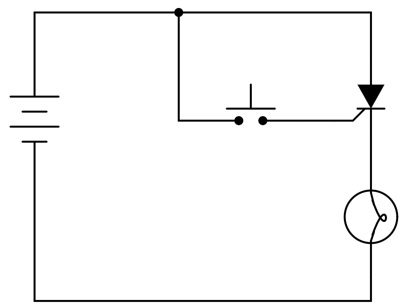


Notes 53

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.

Question 54

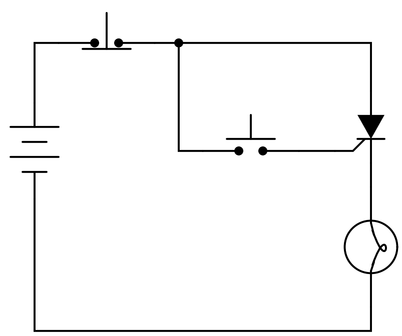
When the pushbutton switch is actuated, the lamp energizes and remains energized even when the switch is released:



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

Answer 54

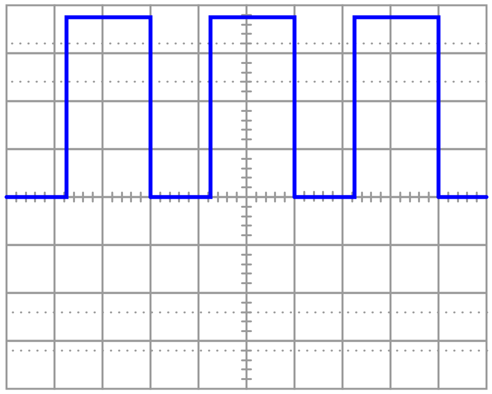


Notes 54

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

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 µs/div

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

file 02348

Answer 55

Duty cycle ≈ 58.3%
$P_{average} \approx 80$ 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?

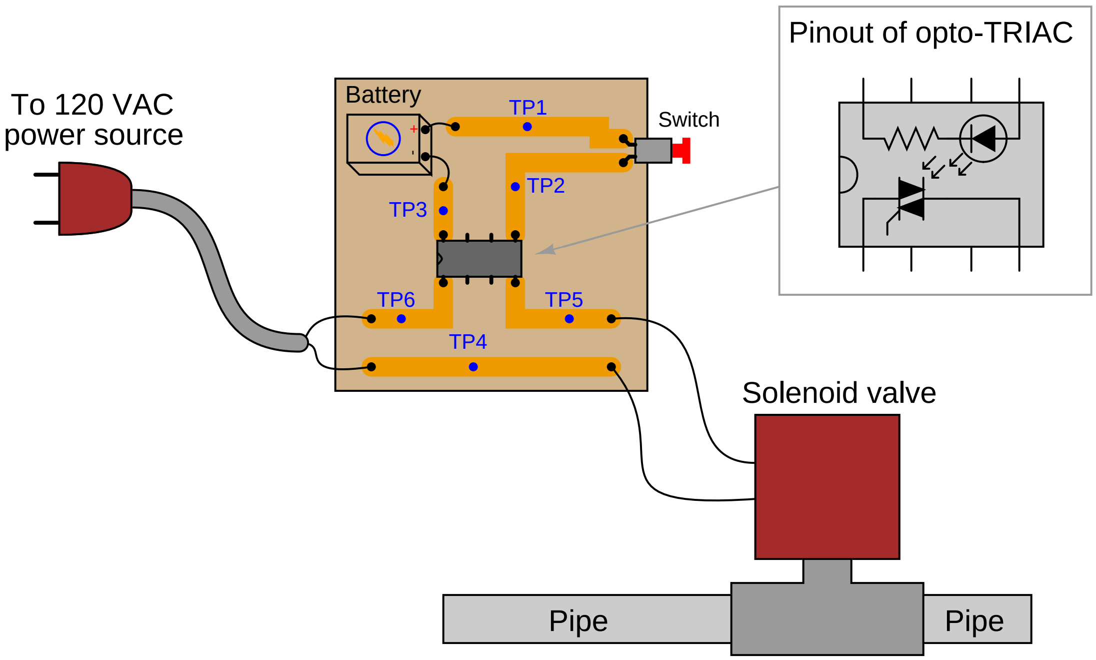
Notes 55

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.

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

Answer 56

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

- Circuit elements that are possibly faulted
1. open TRIAC
2. open switch

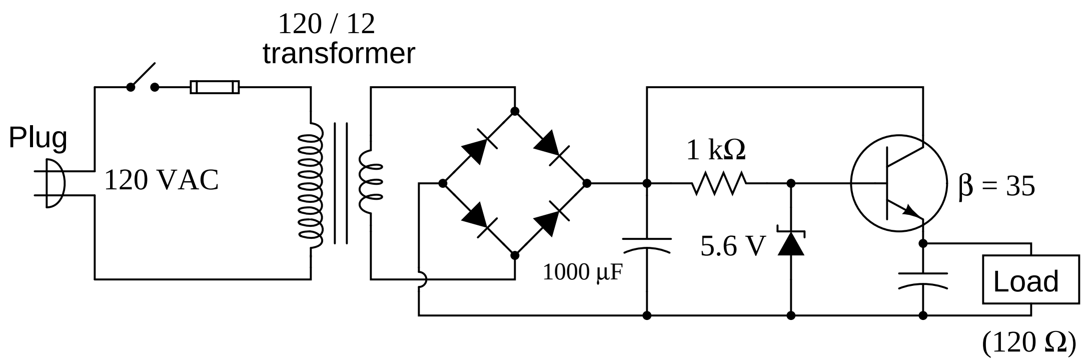
- Circuit elements that must be functioning properly
1. 9 volt battery
2. AC power source

Notes 56

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

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 Ω:



$V_{load} =$ $I_B =$

file 02496

Answer 57

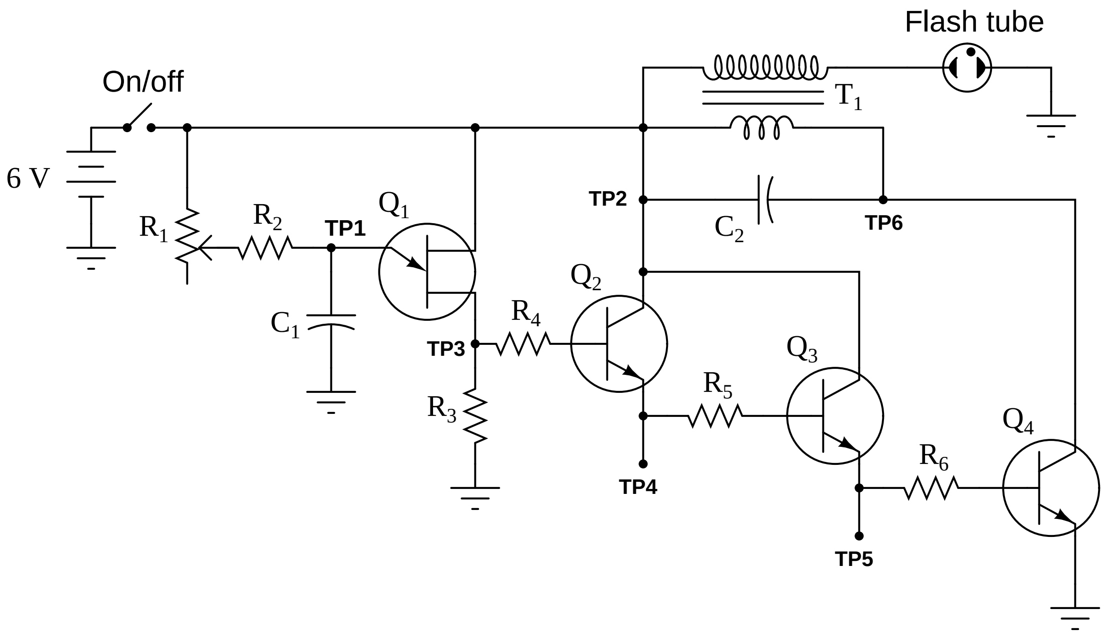
$V_{load} = 4.9$ V $I_B = 1.134$ mA

Notes 57

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

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

Answer 58

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)

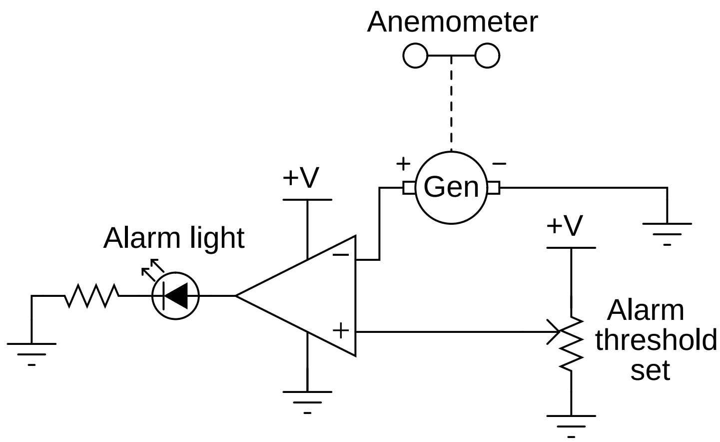
1. Rheostat R_1
2. Resistor R_2
3. Capacitor C_1
4. Transistor Q_1

Notes 58

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

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

Answer 59

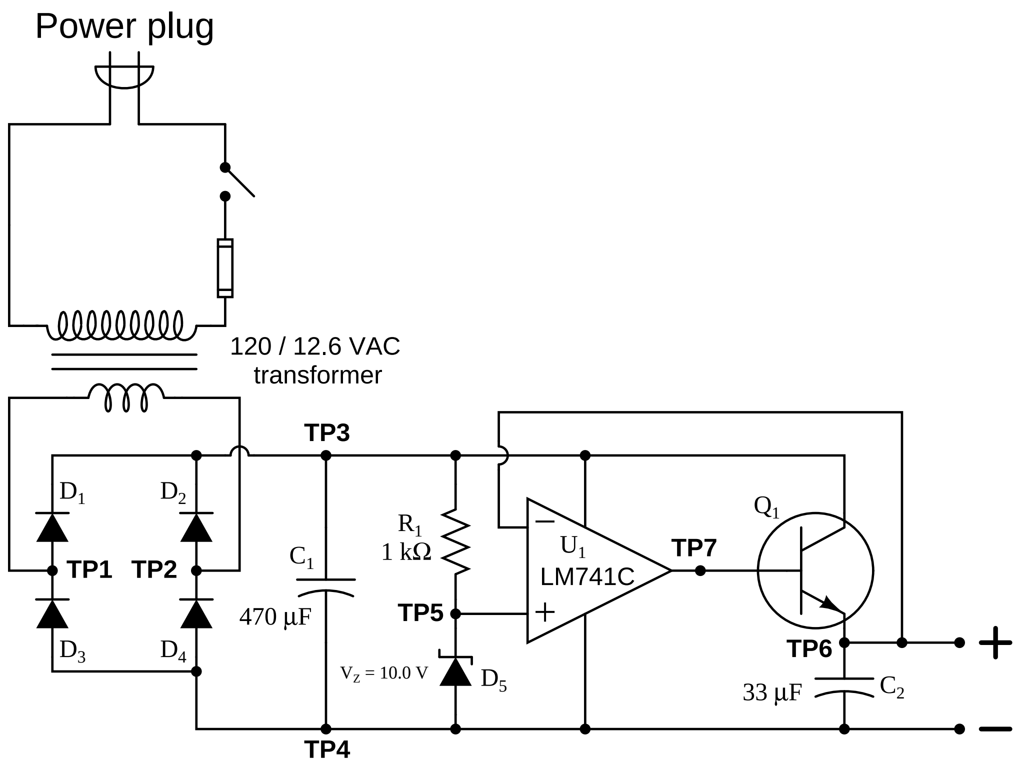
This is a *low* speed alarm, and the wiper would have to be moved *up* to raise the wind speed threshold value.

Notes 59

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

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

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

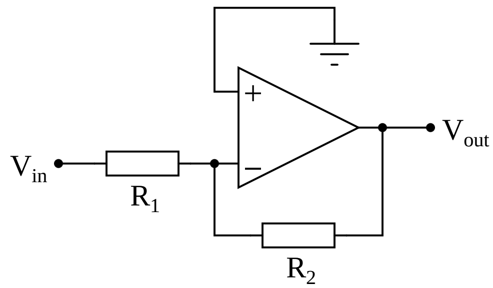
Notes 60

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.

Question 61

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



file 02710

Answer 61

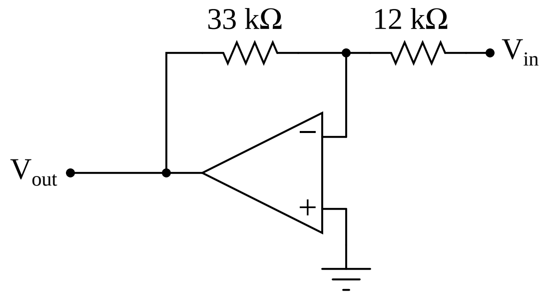
Inverting.

Notes 61

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

Question 62

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



file 02715

Answer 62

$A_V = 2.75$

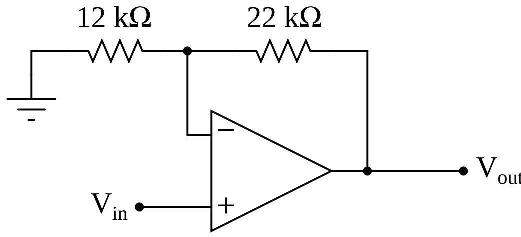
It is okay if students express this answer as a negative quantity, since some texts teach the gain formula $A_V = -\frac{R_f}{R_i}$.

Notes 62

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

Question 63

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



file 02718

Answer 63

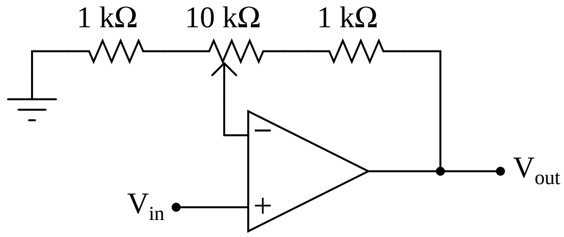
$A_V = 2.833$

Notes 63

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

Question 64

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



$A_{V(min)} =$ $A_{V(max)} =$

file 02734

Answer 64

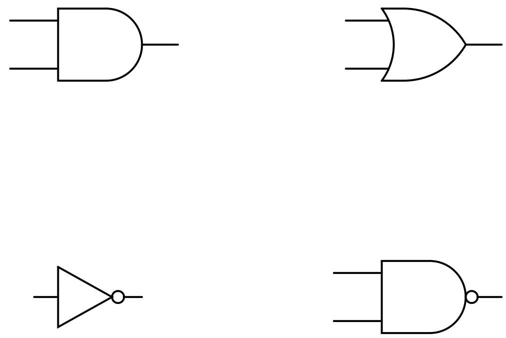
$A_{V(min)} = 1.09$ $A_{V(max)} = 12$

Notes 64

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

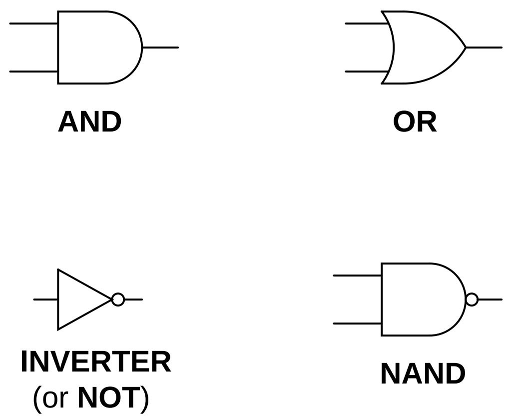
Question 65

Identify the names of the following logic gates:



file 02874

Answer 65

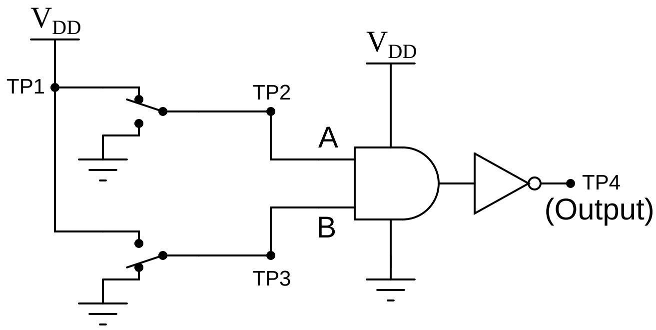


Notes 65

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

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:

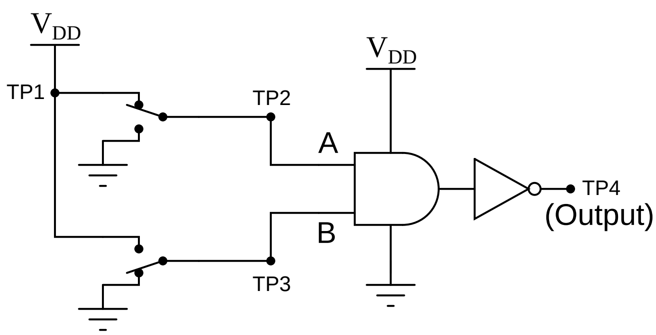


A	B	Output
0	0	
0	1	
1	0	
1	1	

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

file 03976

Answer 66



A	B	Output
0	0	1
0	1	1
1	0	1
1	1	0

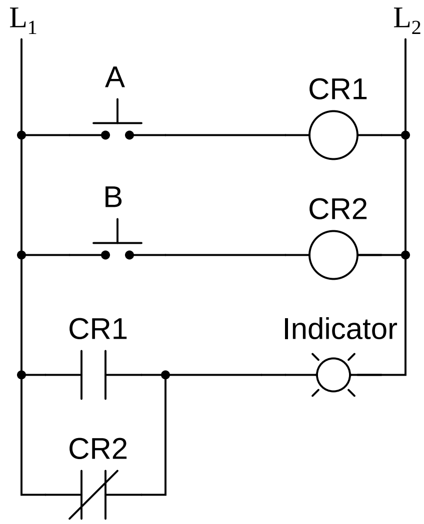
- TP1 = High
- TP2 = High
- TP3 = Low
- TP4 = High

Notes 66

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

Question 67

Complete the truth table for the following relay logic circuit:

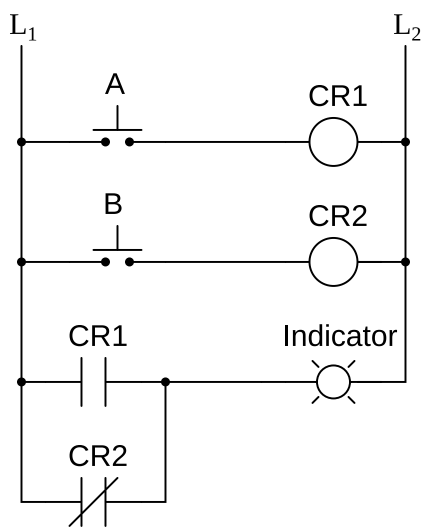


Truth table

A	B	Output
0	0	
0	1	
1	0	
1	1	

file 02878

Answer 67



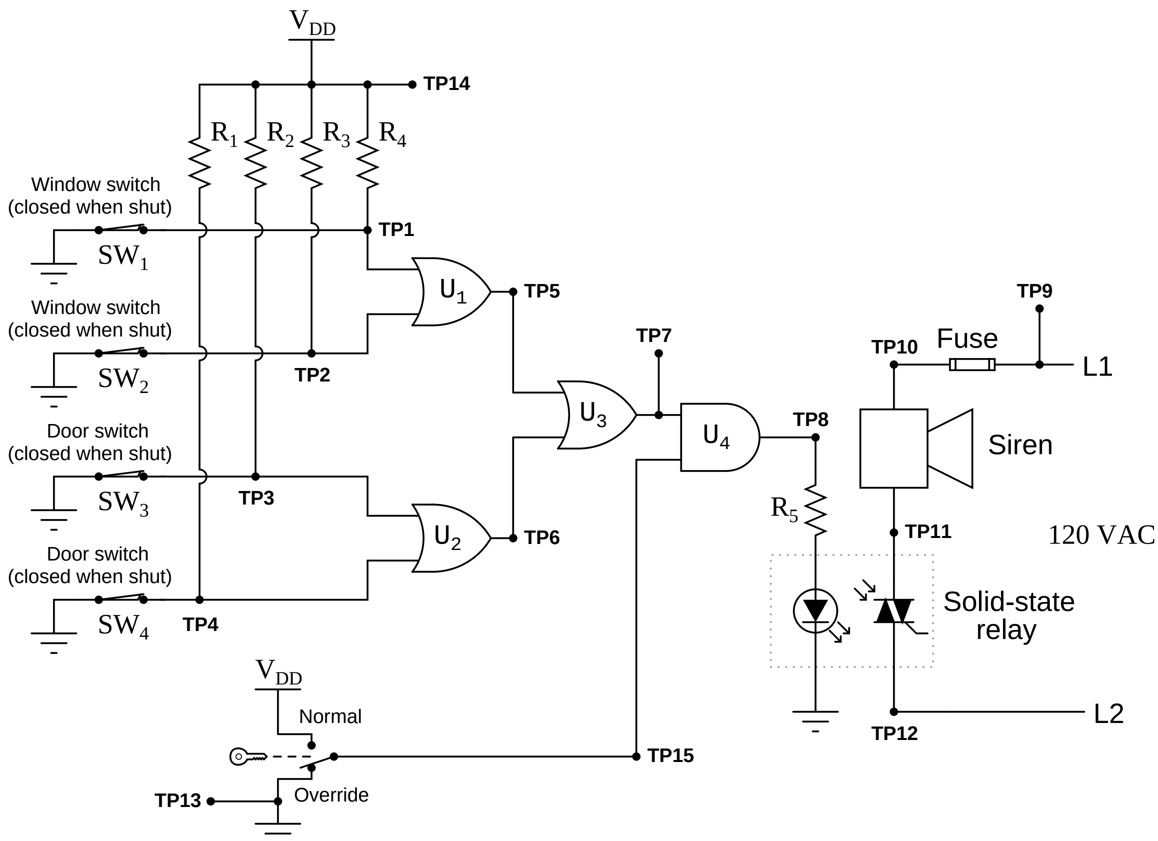
Truth table

A	B	Output
0	0	1
0	1	0
1	0	1
1	1	1

Notes 67

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

Answer 68

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

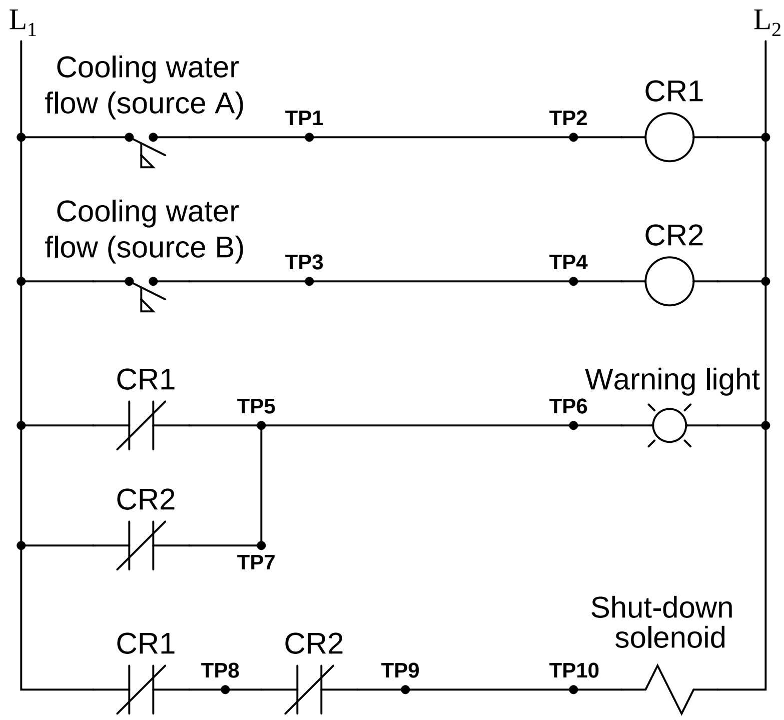
Notes 68

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.

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

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

Notes 69

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

Question 70

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

Ladder diagram:

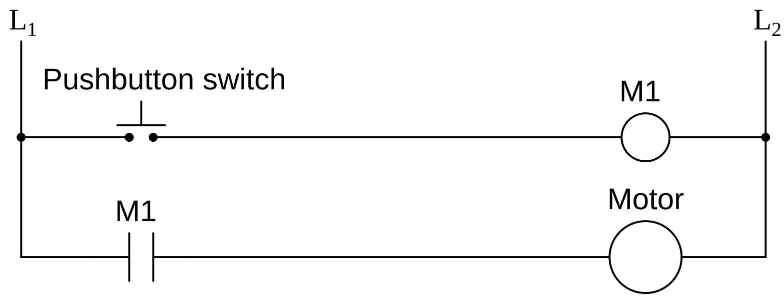
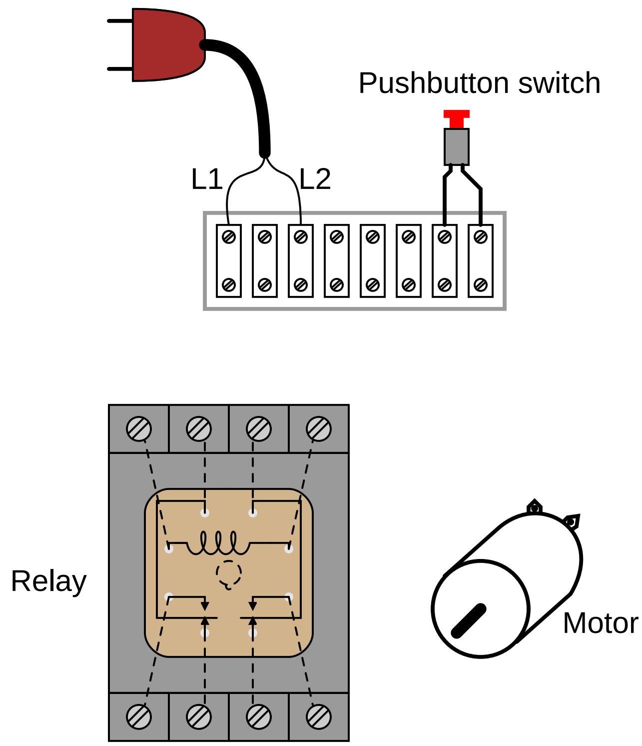


Illustration showing components:

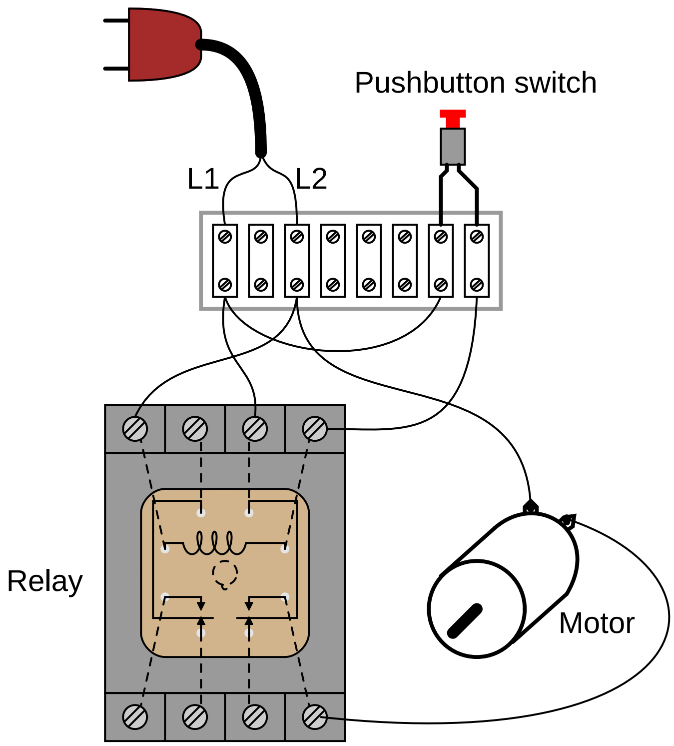


(Dashed lines represent connections between relay terminals and socket screw lugs, hidden from sight)

file 03209

Answer 70

Note: this is not the only valid solution!

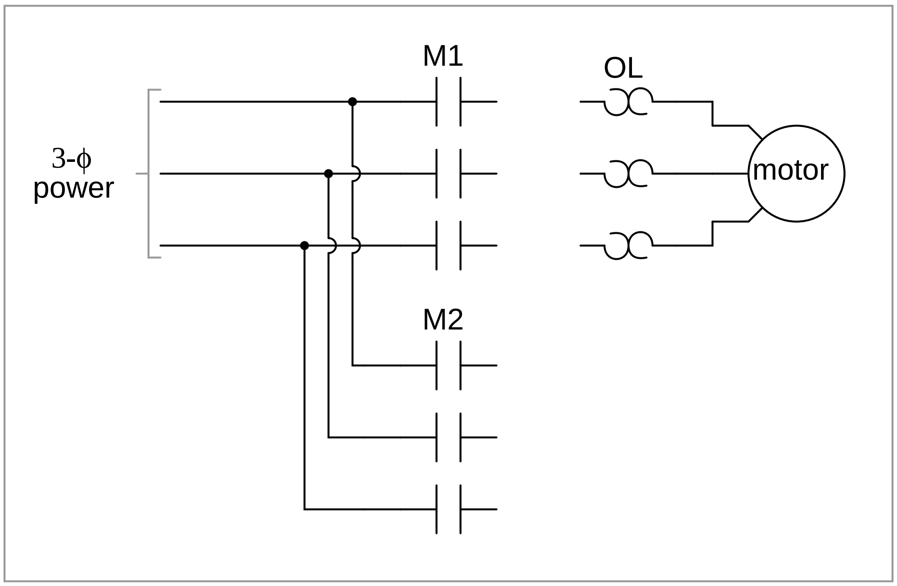


Notes 70

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

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:

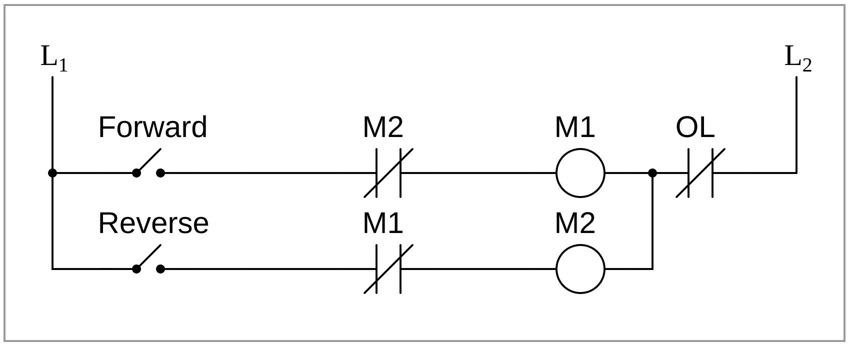


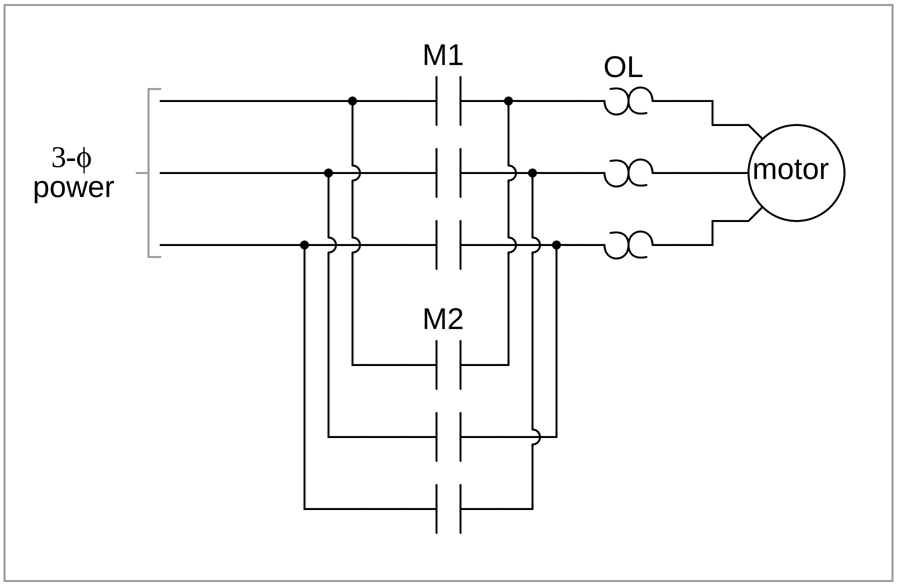
Be sure to include all these details:

- 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

Answer 71





Notes 71

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

Question 72

Convert the octal number 344 to decimal form.
file 02965

Answer 72

$344_8 = 228_{10}$

Notes 72

This question is intended for exams only and not worksheets!.
Nothing to comment on here!

Question 73

Convert the decimal number 35 to hexadecimal form.
file 02968

Answer 73

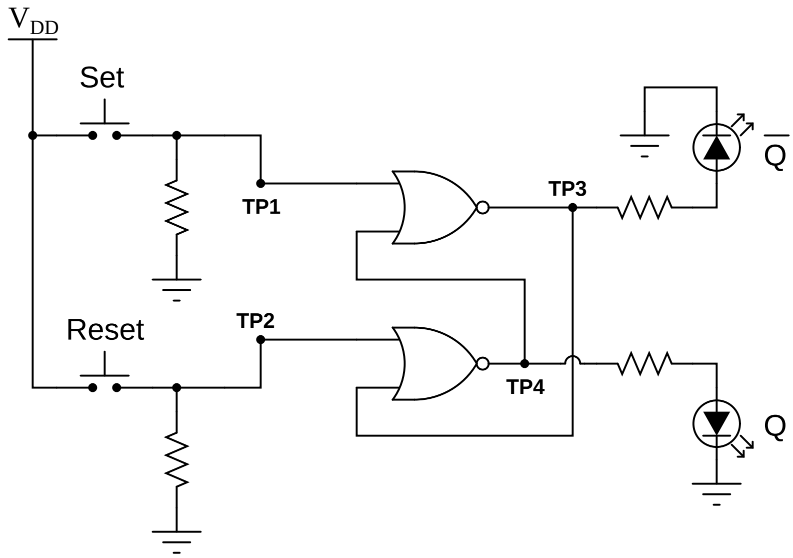
$35_{10} = 23_{16}$

Notes 73

This question is intended for exams only and not worksheets!.
Nothing to comment on here!

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

Answer 74

TP1 = 0 (low) TP3 = 1 (high)

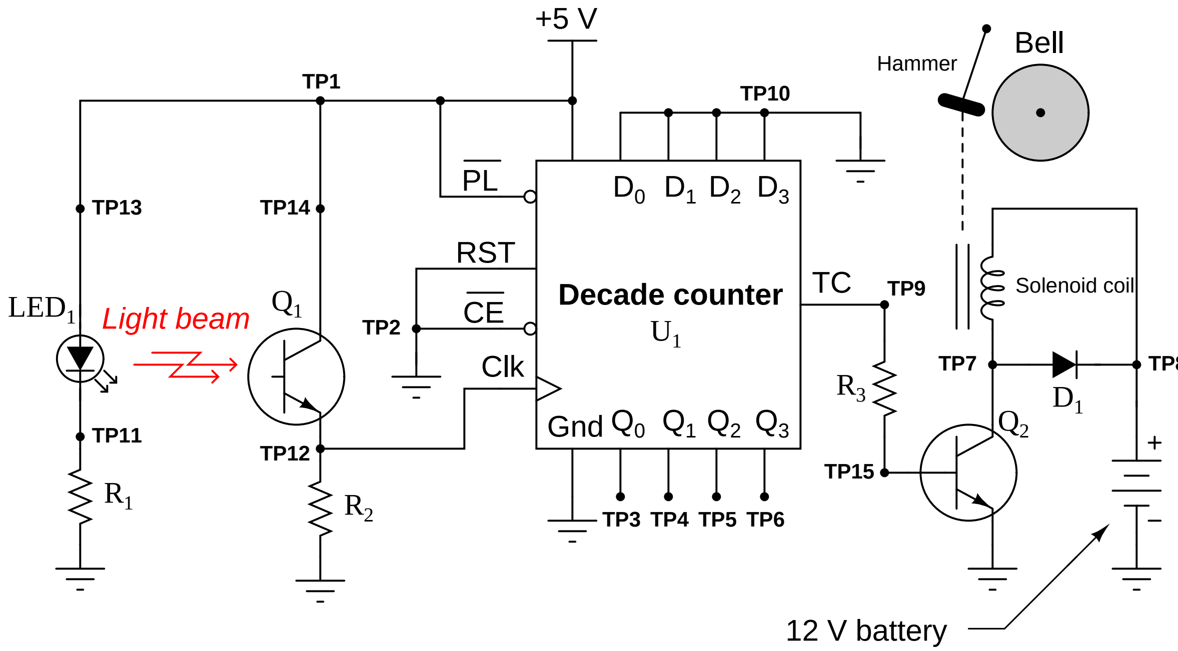
TP2 = 1 (high) TP4 = 0 (low)

Notes 74

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

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

Answer 75

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 75

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