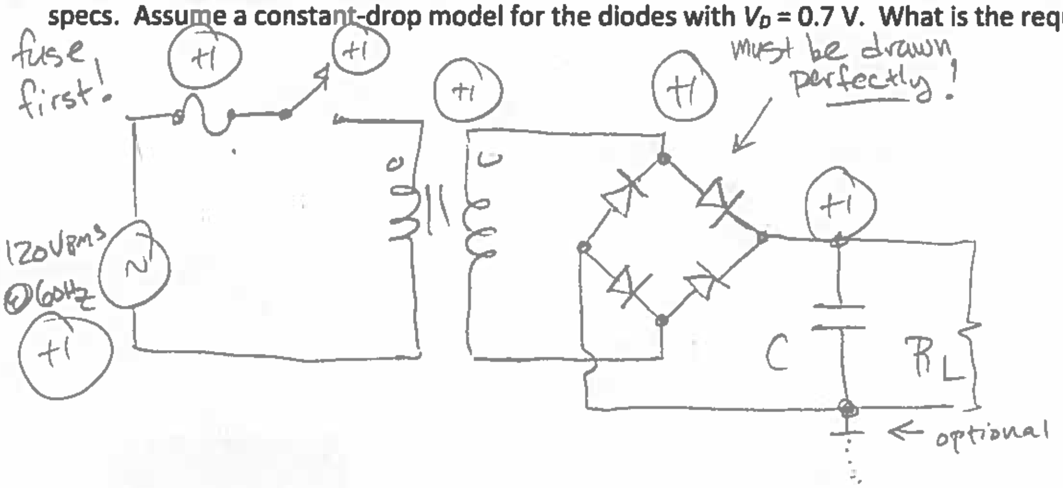
BME-ISE 3511 • Exam IV • November Fools' Day 2019 NAME SOLUTION

1) A linear power supply is to be designed with the following specifications:

- 120-V_{RMS}, 60-Hz sinsusoidal voltage source
- Ideal transformer, fused and switched on the primary winding
- Full-wave bridge rectifier with capacitor-input filter
- V_L = 15 V @ I_L = 0.12 A
- Ripple less than 1% of V_L

Sketch the circuit. Determine the required transformer secondary voltage in V_{RMS} and E6 capacitor value to meet these specs. Assume a constant-drop model for the diodes with V_D = 0.7 V. What is the required capacitor voltage rating?



ripple < 1% ; ∴ $V_L \approx V_{peak}$

$$V_{ripple} = \frac{I_L}{2fC} < .01\,V_L \quad +1$$

$$\longrightarrow C = \frac{I_L}{2 \cdot f \cdot V_{ripple}} \quad +1$$

$$= \frac{0.12}{2 \cdot 60 \cdot .01 \cdot 15}$$

$$C = 0.0067\text{ F} \quad +1$$

use $C = 6.8$ mF ($6800\ \mu F$) +1

$$V_{peak} = V_{S(RMS)}\sqrt{2} - 2V_D$$

$$\longrightarrow V_{S(RMS)} = \frac{V_{peak} + 2V_D}{\sqrt{2}} \quad +1$$

$$= \frac{15 + 2 \cdot 0.7}{\sqrt{2}}$$

$$V_S = 11.6\ V_{RMS} \quad +1$$

(probably use 12V secondary)

-- cap voltage should be at least 15V (more like 25V) +1

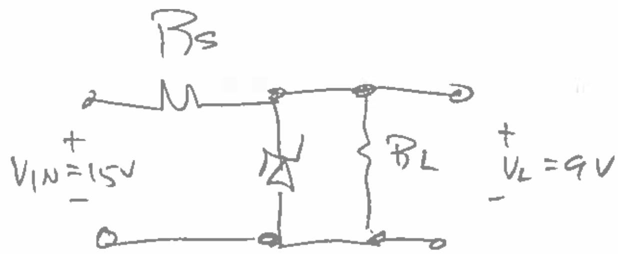
What is the PIV rating for the diodes in the bridge rectifier? Choose a 1N400X-series diode [redacted]

$$PIV > V_{S(RMS)}\sqrt{2}$$

$$= 11.6\sqrt{2} = 16.4\text{ V} \quad +1$$

Use 1N4001 (50V PIV; fine) +1

2) A Zener diode-based shunt voltage regulator is to be added to the circuit in problem #1. What E24 value of R_S should be used if the final output voltage is 9 V with a load current that varies between zero and .12 A? Assume the Zener should have a minimum current of 2 mA. Determine the required power ratings of the resistor and Zener diode.



$$I_{S\,max} = I_{L\,max} + I_{Z\,min}$$

$$= 0.12 + .002 = \underline{0.122\ A} \quad +1$$

$$\therefore\ R_S = \frac{V_{IN} - V_L}{I_{S\,MAX}} = \frac{15-9}{0.122} = 49.18\ \Omega \quad +1$$

use $\underline{47\ \Omega}$ +1

($51\ \Omega$ is closer; but wouldn't keep $I_Z > 2mA$)

$$I_{Z\,max} = I_{S\,max} = 0.122A \quad +1$$

$$P_{Z\,max} = V \cdot I = 9 \cdot 0.122 = 1.098W \quad +1$$

use 2W zener diode +1

$$P_{R_S} = I^2 R = 0.122^2 \cdot 47 = 0.7\ W \quad +1$$

use 1W resistor +1

3) Design a relay circuit that turns on a ½-hp air compressor powering a train horn whenever someone pushes your doorbell button, assuming specs for the following components:

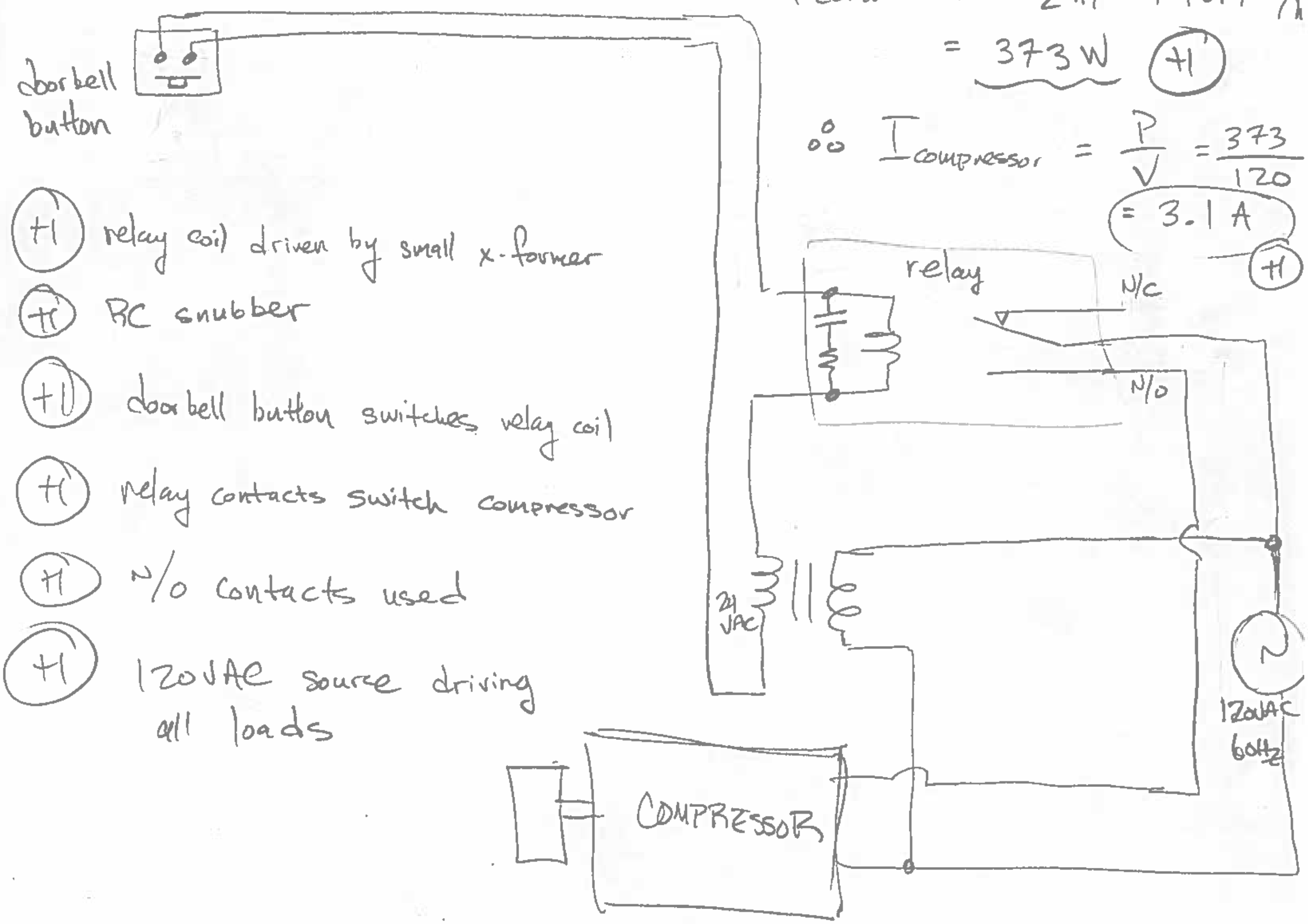
Air compressor:	Doorbell button:	Relay:
120 VAC, 60 Hz AC induction motor	momentary switch normally open	24VAC supplied from a small local transformer 35Ω coil w/ RC snubber SPDT, N/O and N/C contacts

Draw the circuit. Determine the current in the doorbell button wiring and the current supplying the compressor. What relay contact voltage and current ratings do we need?

$$I_{relay} = \frac{V}{R} = \frac{24}{35} = 0.6857\text{ A} \quad +1$$

$$P_{compressor} = \frac{1}{2}\text{ hp} \cdot 745.7\ \text{W/h} = 373\text{ W} \quad +1$$

$$\therefore I_{compressor} = \frac{P}{V} = \frac{373}{120} = 3.1\text{ A} \quad +1$$



+1 relay coil driven by small x-former

+1 RC snubber

+1 doorbell button switches relay coil

+1 relay contacts switch compressor

+1 N/O contacts used

+1 120VAC source driving all loads

need at least 120VAC contacts @ > 3.1 A +2

(Probably 10A or 20A contacts for turn-on surge)