ECET 4520 – Fall 2016
Exam II – Part A   **Print Name (Last Name First):** KEY

Instructions: This exam is closed book except for the reference booklet provided by the instructor and one 8.5"x11" sheet of handwritten notes that may not contain any numerically-solved problems.

No credit will be given for illegible/illogical work or for numerical answers that are not justified by the work shown.

Maintain at least three significant digits of accuracy during all of your calculations, and then round all final calculated currents to their nearest ampere value.

Assume an *ambient temperature of 30°C* if needed for all problems unless stated otherwise.

Problem #1) A 480V, three-phase feeder is serving a set of continuous and a non-continuous loads that have the following combined ratings:

Load Ratings: 460V, 3Φ **15kVA, pf = 0.85** lagging, (continuous operation)
30kVA, pf = 0.85 lagging, (non-continuous operation)

a) Determine the **smallest, standard-sized circuit breaker** that can be used to protect this circuit.

CB ≥ 1.25% cont + 100% NC

= 1.25(19) + 38

= 61.75 A ≈ 62A

Next Larger → 70A

$\frac{15000}{\sqrt{3}(460)} = 18.8 \approx 19A$ cont.

$\frac{30000}{\sqrt{3}(460)} = 37.65 \approx 38A$ non-cont

CB rating = 70 A

b) Specify the **temperature rating** that should be applied to the conductors of this feeder based upon the rating of the load that it is serving. Justify your answer.

Circuit Rating ≤ 100A ∴ use 60°C

Temp rating = 60 °C

Justify your answer in the space below:

c) Specify the **smallest-size, THHN, copper conductors** that can be utilized for this feeder assuming that the circuit is composed of three, individual conductors that are run through a separate steel conduit, and that the ambient temperature is 30°C.

Need Ampacity ≥ 62A

#4 AWG Cu, 60°C ampacity = 70A ✓

Conductor Size = 4 AWG

Problem #2) Given the 3Φ, 480V feeder from problem #1, if the circuit conductors are **200' long,**

a) Determine the **drop** that will occur in the line-voltage of the feeder while supplying rated load.

#4 Cu, steel conduit, 60°C pf = 0.85

$R_{75°} = 0.31\ \Omega/1000'$ → $R_{60} = 0.31[1 + 0.00323(60 - 75)] = 0.295\ \Omega/1000'$

$X = 0.060\ \Omega/1000'$

$\cos\theta = 0.85 \rightarrow \theta = 31.8°$

$\rightarrow \sin\theta = 0.527$

$Z_e = R\cos\theta + X\sin\theta$

$= 0.295(0.85) + (0.06)(0.527) = 0.28236\ \Omega/1000'$

$I_{actual} = 18.8 + 37.7 = 56.5A$ ← Do Not adjust continuous load

$V_{drop\,(line)} = \sqrt{3} \cdot I \cdot Z_e \cdot \left(\frac{L}{1000}\right) = \sqrt{3}(56.5)(0.28236)\left(\frac{200}{1000}\right) = 5.53$ volts

$V_{drop(Line)}$ = 5.53 V

b) Does the voltage-drop calculated in part **(a)** fall under **acceptable standards** as recommended in the NEC? Justify/explain your answer:

Circle your answer → (Yes) / No
(Explain in the space below)

$\frac{5.53}{480} \times 100\% = 1.15\%$ ← less than the recommended 3% max

c) If the 3Φ, L-L-L short-circuit current available at the "service-end" of the feeder is **21,000A**, determine the **short circuit current** that will be available at "load-end" of the feeder using the point-to-point method of calculation.

#4 Cu, steel conduit → C = 3806

$f = \frac{\sqrt{3} \cdot L \cdot I_{LLL}}{C \cdot n \cdot V_{line}} = \frac{\sqrt{3}(200)(21000)}{(3806)(1)(480)} = 3.982$

$m = \frac{1}{1+f} = \frac{1}{4.982} = 0.2007$

$I_{SCA} = (21{,}000)(0.2007) = 4215\ A$

$I_{SCA(Load-End)}$ = 4215 **amps**

Problem #3) Given a 480V, 3Φ, 60Hz branch circuit that consists of three individual, **#6 AWG**, THHN, **aluminum conductors** that are fed through an **aluminum conduit**,

a) Determine the **AC resistance** and **reactance** of the conductors in **Ω** per 1000' (assuming an operational temperature rating of 60°C).

From table 9

#6 Al. / Al.

$R = 0.81\ \Omega/1000'$

$X = 0.051\ \Omega/1000'$

$R_{60} = 0.81[1 + 0.00330(60-75)]$

$= 0.81(0.9505)$

$= 0.77\ \Omega$

$R_{AC} =$ 0.770 **Ω/1000'**

$X_L =$ 0.051 **Ω/1000'**

b) If the branch circuit is supplying a load that operates with a power factor of 0.72 lagging, determine the **effective impedance** of the conductors in **Ω** per 1000'.

$\cos\theta = 0.72 \quad \theta = \cos^{-1}(0.72) = 43.95° \quad \sin\theta = 0.694$

$Z_e = R\cos\theta + X\sin\theta = 0.590$

$Z_e =$ 0.590 **Ω/1000'**

Problem #4) Determine the **general lighting load** for a **three-story, 160ft x 420ft** (per floor) motel after any appropriate demand factors are applied.

Table 220.12

motel → 2 VA/ft²

$\therefore\ 3 \times (160 \times 420\ ft^2) \times (2\ VA/ft^2) = 403{,}200\ VA$

20,000 × 0.50

+ 80,000 × 0.40

+ 303,200 × 0.30

132,960 VA

General Lighting Load = 132,960 **VA**

Problem #5) Given a **3Φ, 150kVA, 7200V– 208V**, Δ-Y, "step-down" transformer that provides service to an industrial building;

a) Determine the **rated phase-voltage** for the low-voltage side of the transformer.

$$\frac{208}{\sqrt{3}} = 120.1V$$

$V_{Phase(rated)LV}$ = 120 V

b) Determine the **rated line-current** for both the high-voltage and low-voltage sides of the transformer.

$$\frac{150{,}000}{\sqrt{3}(7200)} = 12.03\ A$$

$$\frac{150{,}000}{\sqrt{3}(208)} = 416.4\ A$$

$I_{Line(rated)HV}$ = 12 A

$I_{Line(rated)LV}$ = 416 A

c) Assuming that an "infinite bus" supplies the transformer's primary windings, determine the 3Φ, L-L-L **short-circuit current** available at the secondary terminals of the transformer.

150 kVA → %Z = 1.2

$$m = \frac{100\%}{1.2\%} = 83\tfrac{1}{3}$$

$$I_{SCA_s} = m \cdot I_{FLA_s} = 34{,}697\ A$$

$I_{SCA(Sec)}$ = 34,697 A

Problem #6) A raceway contains **four** different 3Φ branch circuits that are all supplying balanced loads. If all four circuits are composed of **#8 AWG**, THHN, copper conductors and the ambient temperature is **42°C**, determine the effective **ampacity** for each of the circuit conductors.

#8 Cu 60°C ⇒ 40A base ampacity

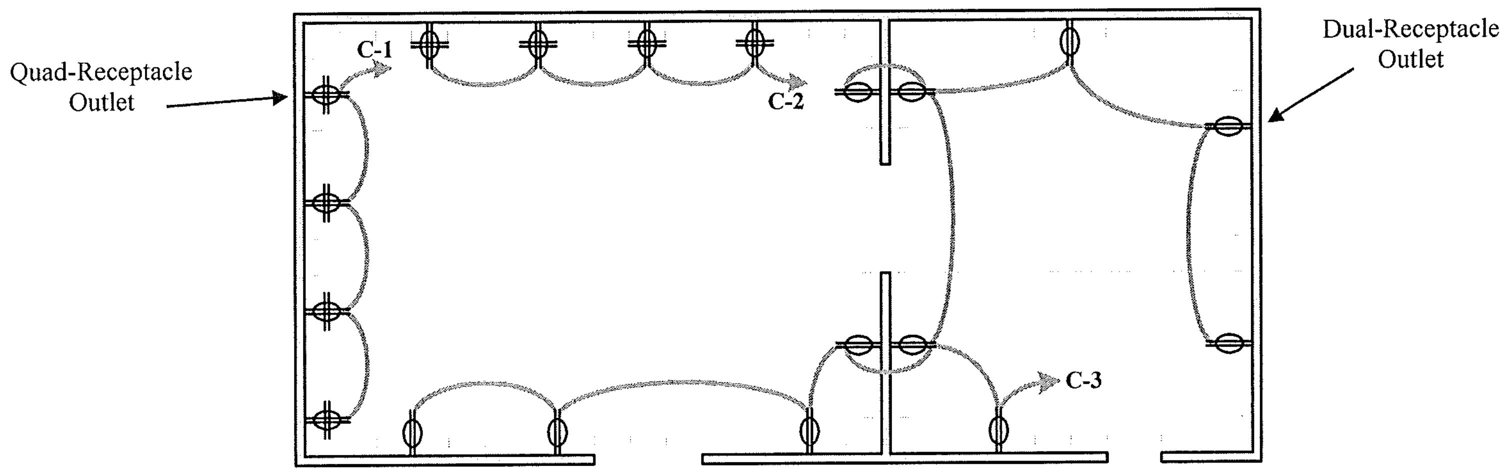
4 × 3 = 12 cond. in raceway ⇒ × 0.50

42°C ambient Temp ⇒ × 0.71

40 × 0.5 × 0.71 = 14.2 A

Ampacity = 14 A

Problem #7) The following figure shows three (120V, 1Φ) general-purpose receptacle circuits located within a building. A separate coduit is utilized for each set of circuit conductors.



Assuming an ambient temperature of 30°C and based on NEC guidelines,

a) Determine the **minimum load rating** that can be applied to circuit **C-1**, the **smallest-size copper conductors** that can be utilized for the circuit, and the **smallest, standard-sized circuit breaker** that can be used to protect the circuit.

b) Determine the **minimum load rating** that can be applied to circuit **C-3**, the **smallest-size copper conductors** that can be utilized for the circuit, and the **smallest, standard-sized circuit breaker** that can be used to protect the circuit.

C-1 4 quad × (90×4 VA/quad) = 1440 VA / 120V = 12 A

↳ 15 A CB

↳ #14 AWG Cu

C-3 11 duplex × 180 VA/duplex = 1980 VA / 120V = 16.5 A

↳ 20 A CB

↳ #12 AWG Cu.

a) C−1 Load Rating = 1440 **VA**

C−1 CB Rating = 15 A

C−1 Conductor Size = 14 AWG

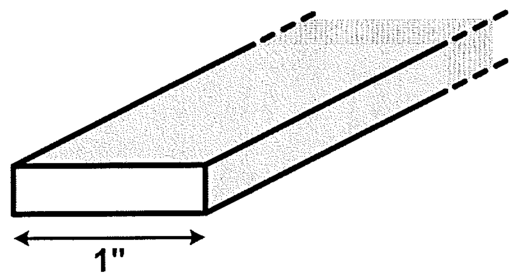
b) C−3 Load Rating = 1980 **VA**

C−3 CB Rating = 20 A

C−3 Conductor Size = 12 AWG

Problem #8) Given the rectangular-shaped conductor shown below, determine the **cross-sectional area** of the conductor in **circular mils**.

$1 \text{ cmil} = \pi \cdot \left(\frac{\frac{1}{1000}}{2}\right)^2 = 7.854 \times 10^{-7} \text{ in}^2$



$A_{rec} = \frac{(1 \times \frac{1}{4}) \text{ in}^2}{7.854 \times 10^{-7} \text{ in}^2/\text{cmil}} = 318{,}310 \text{ cmil}$

Area = 318,310 cmils

Problem #9) Specify if the statements are **TRUE** or **FALSE** based on the NEC and/or standard design practice:

TRUE Given a standard **100A circuit breaker** that is protecting a circuit, the circuit breaker may eventually trip if 85A flows continuously in the circuit.

any load over 80% may trip

false **Ampacity** may be defined as the maximum continuous current that a conductor may carry without causing the conductor's temperature to exceed its limiting temperature rating designated for the type of insulated conductor involved.

No – "operational Temp. rating"

false **Convenience receptacles** should be placed no more than 6 feet apart along any continuous wall within any habitable room of a dwelling unit.

✗ 12'

TRUE An **increase in the lengths** of a circuit's conductors will result in an increase in the voltage-drop caused by the circuit, a decrease in the short-circuit current available at the load-end of the circuit, and no change in the ampacity of the circuit's conductors.

TRUE Given a branch circuit that utilizes aluminum conductors, the **ampacity** of the conductors can be increased by switching from aluminum to copper without changing conductor size.

false Branch circuits rated **greater than 50A** can be used to supply heavy-duty lighting outlet loads.

>50A → Non lighting loads

false The **overcurrent protection device** protecting a branch circuit should always be placed at the "load-end" of the circuit conductors.

✗ Source or service end

false According to the NEC, each 3-feet (or fraction thereof) of a **fixed multi-outlet assembly**, where appliances are unlikely to be used simultaneously, shall be considered as one outlet (with a rating) of not less than 180 volt-amperes.

✗ each 5' section

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1) ____/8 2) ____/10 3) ____/8 4) ____/6 5) ____/8 6) ____/5 7) ____/10 8) ____/3 9) ____/12

Total) ________/70

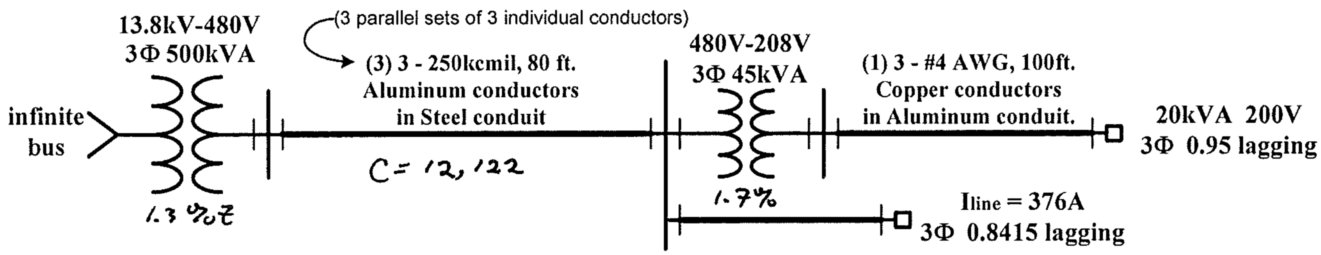
ECET 4520 – Fall 2016 Due by: 9:30am on Thursday November 17th

Indust. Dist. & NEC – Exam II pt. B Print Name (Last Name First): ____________

Instructions: Part "B" of this exam is composed of two "take-home" problems that must be completed individually, under "closed-book" conditions, with no assistance from any person/resource except for the PowerPoint slides, the reference booklet, and the Exam IIA "note-sheet".

Problem #10) Given the portion of a 3Φ distribution system shown in the following figure:

Note - Assume 30°C ambient temperature.



Using the point-to-point method of calculation:

a) Determine the 3Φ, L-L-L **short circuit current** available at the secondary terminals of the 500kVA transformer.

$$I_{FLA} = \frac{500{,}000}{\sqrt{3}\cdot 480} = 601.4A$$

$$m = \frac{100\%}{1.3\%} = 76.9$$

$$I_{SCA} = I_{FLA}\cdot m = 46{,}262\ A$$

$I_{SCA(SecT1)}$ = 46,262 amps

b) Determine the 3Φ, L-L-L **short circuit current** available at "load-end" of the 80' feeder circuit.

$$f = \frac{\sqrt{3}(80)(46{,}262)}{(12{,}122)(3)(480)} = 0.3672$$

$$m = \frac{1}{1+f} = 0.7314$$

$$I_{SCA} = 46{,}262\cdot(0.7314) = 33836\ A$$

$I_{SCA(Feeder)}$ = 33,836 amps

c) Determine the 3Φ, L-L-L **short circuit current** available at the secondary terminals of the 480-208V transformer.

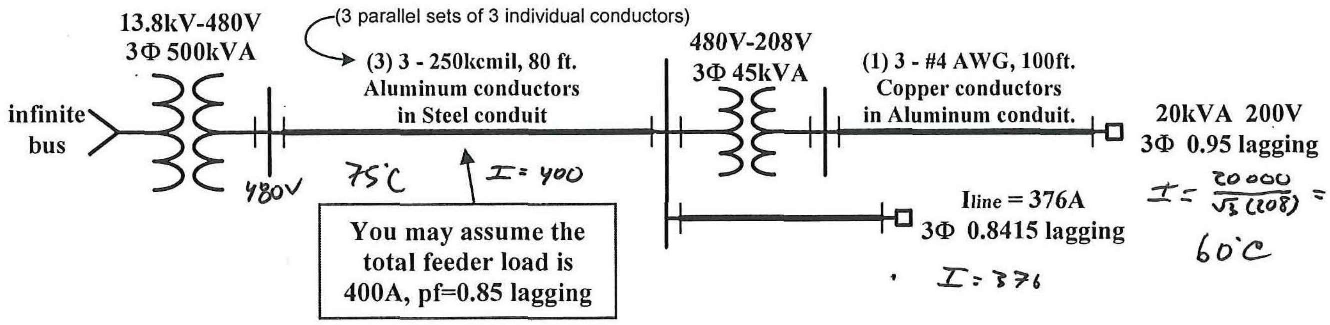
$$f = \frac{\sqrt{3}(33836)(480)(1.7)}{(100{,}000)(45)} = 10.627$$

$$m = \frac{1}{1+f} = 0.086$$

$$I_{SCA} = (33836)(0.086)\left(\frac{480}{208}\right) = 6{,}716\ A$$

$I_{SCA(SecT2)}$ = 6,716 amps

Problem #11) Given the same system as in problem #10:



Neglecting any transformer losses, determine the **operational line-voltage** seen at the 20kVA load outlet assuming that rated voltage is present at the secondary terminals of the 500kVA transformer, that the load supplied by the #4 AWG, 100' branch circuit is drawing rated power, and that the total current supplied by the 80' long feeder circuit is 400A at a pf = 0.85 lagging.

Feeder

$Z_e = 0.10\ \Omega/1000'$ (Table 9) ← 3 in parallel ∴ $Z_e\left(\frac{1}{3}\right)$

$V_{drop\ 3\phi} = \sqrt{3}(400)(0.10)\left(\frac{80}{1000}\right) = 5.54V\left(\frac{1}{3}\right) = 1.85V$

$480 - 1.85 = 478.15$ V @ primary step-down transformer

Transformer

$V_s = V_p \cdot \left(\frac{208}{480}\right) = (478.15)\left(\frac{208}{480}\right) = 207.2$ V

Branch Ckt

$X = 0.048\ \Omega$ $\quad R_{75} = 0.31\ \Omega$ $\qquad pf = \cos\theta = 0.95 \quad \theta = 18.2° \quad \sin\theta = 0.31225$

$R_{60} = 0.31(1 + 0.00323(60-75)) = (0.31)(0.95155) = 0.295$

$Z_e = R\cos\theta + X\sin\theta = (0.295)(0.95) + (0.048)(0.31225) = 0.29524\ \Omega/1000'$

$V_{drop} = \sqrt{3}(55.5)(0.29524)\left(\frac{100}{1000}\right) = 2.84\ V$

$V_{LOAD} = 207.2 - 2.84 = 204.4\ V$

$V_{Line(Load)} =$ 204.4 volts

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Part A) ______/70 **10)** ______/14 **11)** ______/16 **Total)** ______/100