Agricultural and Biosystems Engineering Dept. 10/19/06
Iowa State University SKW

Name Key

TSM 363 - Exam 2

Part 1 – Formula sheet (8 ½" x 11", one-side, anything)
Multiple Choice and Short Answer: 2 points each (40%)

1) Materials which are good insulators
   a) have many free electrons.
   b) have few free electrons.
   c) have no electrons
   d) must have no resistance.
   e) have atoms which are positively charged

2) Duplex convenience outlets in the dining room would be served by this circuit:
   a) 15 A general purpose (also accepted)
   b) circuit supplying dining room lights
   c) 30 A appliance circuit
   d) 20 A appliance circuit

3) This is an advantage of 3-phase power, compared to single-phase power:
   a) larger wire size required
   b) greater safety because of no current-carrying neutral
   c) simple and low-cost motors
   d) will operate with one wire disconnected (also accepted)

4) A voltage of 208 Volts is measured between two wires on a 3-phase wye load, connected to a 3-phase wye service. This is a
   a) line voltage
   b) phase voltage
   c) both phase and line
   d) neither phase or line
   e) can't tell from info given

5) This type conductor is suitable for direct burial
   a) USE
   b) SE
   c) AC
   d) TW
   e) NM
   f) NMC
   g) DB

6) Phase current and line current on a 3-phase load
   a) are always equal
   b) are never equal
   c) are equal on a wye load
   d) are equal on a delta load

7) A farm shop has a 35-A, 230-V welder, 12 lighting and convenience outlets and a 3kW electric heater. The building demand at 230 V would be calculated to be about
   a) 60 amps
   b) 57 amps
   c) 66 amps
   d) 63 amps
   e) none of the above

$12 \times 1.5 = 18/2 = 9A$

$\frac{3000\,W}{230\,V} = 13.04 = 13A$

$+ 35A$

$57A$

8) A wild phase is present on this type of service:
   a) wye
   b) delta
   c) both wye and delta
   d) neither wye nor delta

9) Voltage drop determines wire size for:
   a) very short distances
   b) very long distances
   c) heavy loads
   d) branch circuits
   e) aluminum conductors

10) A cable designated as 3 wire with ground contains these conductors:
   a) black, red, white, green, or bare
   b) black, white, green, bare
   c) black, red, green, bare
   d) red, white, green, bare
   e) black, red, white

11) The area of a 0.25-inch-diameter rod in circular mils is:
   a) 0.0625
   b) 62,500
   c) 0.1965
   d) 625
   e) none of the above

$\left(\frac{0.25\,in \mid 1\,mil}{\mid 0.001\,in}\right)^2 = 62{,}500\ cmils$

12) In RLC circuits, inductance generally causes current to:
   a) be in phase
   b) lead by 90 degrees
   c) lag by 90 degrees
   d) none of the above

13) In order to have the same ampacity as a copper conductor of a certain size, an aluminum conductor
a) must be smaller diameter
b) must be the same size
c) must be larger diameter
d) must be stranded
e) must be shorter

14) The ampacity of a conductor is NOT dependent on
a) size of conductor
b) material of conductor
c) proximity to other conductors
d) conductor length
e) material of insulation

15) The useable phase-to-neutral voltage on a 3-phase system is commonly
a) 120 volts
b) 208 volts
c) 230 volts
d) 0 volts
e) depends on whether wye or delta system

16) What is one fuel utilized the City of Ames Power Plant? coal or RDF

17) For wiring connections, wire should be wrapped __________ and __________ around the screw before tightening.
a) clockwise and 3/4
b) clockwise and 2/3
c) counterclockwise and 3/4
d) counterclockwise and 2/3

18) Convert from Rectangular to Polar notation. $\vec{E} = 4.35 - j7.85$

$$M = \sqrt{(4.35)^2 + (-7.85)^2} = 8.97 \qquad \theta = \tan^{-1}\left(\frac{-7.85}{4.35}\right)$$

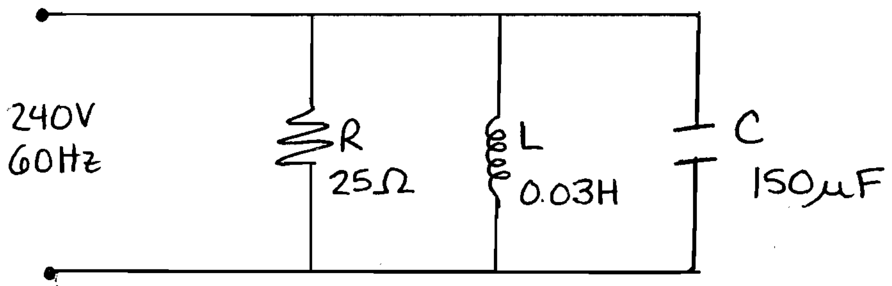
$$\boxed{\vec{E} = 8.97 \angle 299^\circ} \qquad \theta = -61.0^\circ$$

19) What is one advantage of an Aluminum conductor? less \$, less weight

20) What is one way to lessen voltage drop? conductor w/ lower R
placing load closer to pole
decreasing load (Amps)
using larger conductors
using higher voltages

Part 2 – Formula sheet (8 ½" x 11", one-side, anything)
Long Answer: 60 point total (60%)
SHOW YOUR WORK (no work = no credit)

21. (20 points) Use the following RLC parallel circuit to answer parts a-e.



4pts a) Calculate X_C and X_L.

$$X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi(60Hz)(150\times10^{-6})} = 17.68\Omega$$

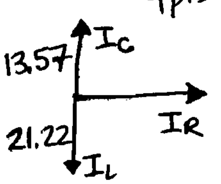
$$X_L = 2\pi f L = 2\pi(60Hz)(0.03H) = 11.31\Omega$$

4pts b) Calculate I_R, I_L, and I_C.

$$I_R = \frac{E}{R} = \frac{240V}{25\Omega} = 9.6A \qquad I_L = \frac{E}{X_L} = \frac{240V}{11.31\Omega} = 21.22A$$

$$I_C = \frac{E}{X_C} = \frac{240V}{17.68\Omega} = 13.57A$$

4pts c) Calculate I_T in rectangular and polar notation.



$$\vec{I}_T = I_R + j(I_L - I_C)$$

$$\vec{I}_T = 9.6A + j(21.22 - 13.57)$$

$$\boxed{\vec{I}_T = 9.6A - j\,7.65}$$

$$c = \sqrt{(9.6)^2 + (7.65)^2}$$

$$c = 12.28$$

$$\theta = \tan^{-1}\left(\frac{-7.65}{9.6}\right)$$

$$\theta = -38.55°$$

$$\boxed{\vec{I}_T = 12.28\angle-38.55°}$$

4pts d) Calculate Z in polar notation.

Parallel Reference E

$$Z = \frac{E}{I} = \frac{240\angle0°}{12.28\angle-38.55°}$$

$$\boxed{\vec{Z} = 19.54\angle+38.55°}$$

4pts e) Compute the value of a capacitor in microfarads which will correct this circuit's power factor to unity. (PF = 1)

$$I_L = I_C = 21.22A$$

$$X_C = \frac{E}{I_C} = \frac{240V}{21.22A} = 11.31\Omega$$

$$C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi(60Hz)(11.31\Omega)}$$

$$C = 0.0002345$$

$$\boxed{C = 234.5\mu F}$$

22. (20 points) Design a branch circuit using the ...

Copper (Cu)
120 volts, 7.2 kW Heater
Damp locations
One-way length (l) = 85 fe...

1 - formula
2 - (0.01)(120)
3 - A = # Right
4 - reasonably choice Right

1 - formula
2 - Area length
3+(4) - Correct

HWN
F
ed

3pts a) Environment – specify the conductor and insul...

Cu - given

Table 5.4 THHN - damp + heat

3pts b) What conductor size is needed for Ampacity? (...

$$\frac{7200W}{120V} = 60A$$

A...

4pts c) What conductor size is needed to meet a 1% design Voltage Drop criterion? (Hint: use formula)

$$A = \frac{22 I_e l}{E_{drop}} = \frac{(22)(60A)(85+8.5)}{(0.01)(120V)} = 102,850 \text{ cmils}$$

next one above: AWG-1/0 or AWG-0

Table 5.3 A = 105,600 cmils

4pts d) Write the overall specifications for <u>a conductor</u> order (4 pieces).

Cu, THHN, 93.5 ft, AWG-0

4pts e) Calculate the Actual Voltage Drop of the conductor used in part (d).

$$E_{drop} = \frac{22 I_e l}{A} = \frac{(22)(60A)(93.5ft)}{105,600 \text{ cmils}} = 1.17V$$

$$\frac{1.17}{120}(100) = 0.97\%$$

$$E_{drop} = \left(\frac{0.122\Omega}{1000ft} \middle| 93.5ft\right)(60A)(2)$$

$$E_{drop} = 1.37V$$

2pts f) Is this voltage drop acceptable? Why?

Yes 0.97% < 1% ← assumed

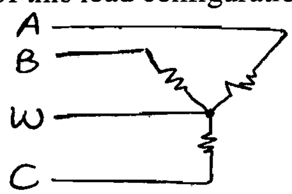
1.17V < 1.2V

No → 1.37V > 1.2V

23. (10 points) Use the following information on a 3-phase balanced Wye load configuration to answer parts a-c.

$E_P = 120$ volts
$I_L = 5$ amps
PF = 1

3pts a) Draw a circuit of this load configuration and label the wires (A, B, C, W).



$E_L = \sqrt{3}\, E_P$

$I_L = I_P$

3pts b) What power is the load using?

$E_L = \sqrt{3}(120) = 207.85\text{V} \sim 208\text{V}$

$P_{3\phi} = \sqrt{3}\, I_L E_L \cos\theta = \sqrt{3}(5\text{A})(208\text{V})(1) = \boxed{1801.33\,\text{W}}$

$= 3(120\text{V})(5\text{A})(1) = 1800\,\text{W}$

4pts c) Compute the resistance of each load resistor.

$\dfrac{1801.33\,\text{W}}{3} = 600.44\,\text{W} = P_I$

$\dfrac{P_I}{E_P} = I_P = \dfrac{600.44\,\text{W}}{120\text{V}} = 5.00\,\text{A}$ $\quad R = \dfrac{E_P}{I_P} = \dfrac{120\text{V}}{5\text{A}} = \boxed{24\,\Omega}$

$I_L = I_P = 5\text{A}$

24. (10 points) Use the following information on an electric motor to answer parts a-b.

230 volts load at 25 amps $\quad 0.75 = \cos\theta$
PF = .75 $\quad \theta = 41.41°$

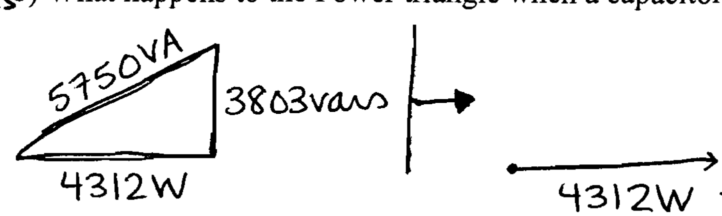
6pts a) Calculate Total, Actual, and Reactive Power.

Total $= (230\text{V})(25\text{A}) = \boxed{5750\,\text{VA}}$

$P_A = IE\cos\theta = (230)(25)(0.75) = \boxed{4312.5\,\text{W}}$

$P_R = IE\sin\theta = (230)(25)\sin(41.41°) = \boxed{3803.28\,\text{vars}}$

4pts b) What happens to the Power triangle when a capacitor is added ^making PF = 1?



4312W = Actual = Total

collapses to a line

5.4 Insulated conductor and cable types commonly used in agriculture

THHN	Heat-resistant thermoplastic	90°C	Flame-retardant, heat-resistant thermoplastic insulated individual conductors. For use in conduit, dry, and damp locations. Available in several colors.
THWN	Moisture and heat-resistant thermoplastic	75°C	Flame-retardant, moisture- and heat-resistant, thermoplastic insulated individual conductors. For use in conduit, dry, and wet locations. Available in several colors.
NM*	Non-metallic sheathed cable	60°C	Two or three conductors (plus bare grounding conductor) in a moisture-resistant, flame-retardant non-metallic sheath. For use in normally dry locations. Cannot be imbedded in poured concrete or used as service entrance cable. Use in family dwellings not exceeding 3 floors above grade and other structures. Can be used exposed or concealed.
SE	Service entrance cable	75°C	Commonly 3 conductors in a flame-retardant, moisture-resistant covering. The neutral is braided around the two energized conductors. Type SE is used primarily between an above-ground point of attachment and the service entrance panel.
USE	Underground service entrance cable	75°C	Single conductors cabled into an uncovered assembly for direct burial as a feeder or branch circuit or service lateral. Covering is moisture resistant but not necessarily flame retardant, or protective against mechanical abuse.
UF*	Underground feeder cable	60°C	Two or three conductors (plus bare grounding conductor) with a flame-retardant moisture-, fungus-, corrosion-resistant covering for direct burial as a feeder or branch circuit. Also used for interior wiring in wet, dry, or corrosive locations. Use in livestock buildings. Cannot be exposed to direct sunlight unless label specifies "Sunlight Resistant." Cannot be used as service entrance cable. Cannot be embedded in poured concrete.
Multiplex (triplex, quadruplex)	Overhead feeder	90°C	Two or three insulated aluminum conductors wound around a bare stranded messenger which serves as a neutral, and supports the assembly. The messenger contains one steel strand for strength. For use as overhead feeders. Conductors are usually XHHW (Surbrook and Mullin 1985).

*NM and UF may be marked as NM-B and UF-B. This marking means the conductors within the cable are rated at 90°C. For the purpose of ampacity, the temperature rating of the cable remains 60°C.

TABLE 5.5 Minimum copper conductor sizes (AWG or mcmil) for 115–120 V bran

5	14	14	14	14	14	10	8	14	14	14
7	14	14	14	14	14	10	8	14	14	12
10	14	14	14	14	14	10	8	14	12	12
15	14	14	14	14	14	10	8	14	12	10
20	12	12	12	12	12	10	8	12	10	8
25	10	10	10	10	10	10	8	12	8	8
30	10	10	10	10	10	10	8	12	8	6
35	8	8	8	8	8	8	8	10	8	6
40	8	8	8	8	8	8	8	10	6	6
45	6	8	8	6	8	8	8	10	6	4
50	6	8	8	6	8	8	8	8	6	4
60	4	6	6	4	6	8	6	8	6	4
70	4	4	6	4	4	8	6	8	4	3
80	3	4	4	3	4	6	4	6	4	3
90	2	3	4	2	3	6	4	6	4	2
100	1	3	3	1	3	4	4	6	4	2
115	1/0	2	2	1/0	2	4	3	6	3	1
130	2/0	1	2	2/0	1	3	2	4	2	1
150	3/0	1/0	1	3/0	1/0	1	1	4	2	1/0
175	4/0	2/0	2/0	4/0	2/0	2	1/0	4	1	2/0
200		3/0	3/0		3/0	1/0	2/0	4	1	2/0

Source: Hiatt (2000); reprinted with permission.

*Single conductors in overhead branch circuits must be at least AWG-12 copper or AWG-8 aluminum for : copper or AWG 6 aluminum (NEC articles 225-6 (a) and 230-23).

**UF not permitted in sizes larger than AWG-4/0.

NM not permitted in sizes larger than AWG-2.

NM cannot be used in agricultural environments defined by NEC article 547.

In most applications, equipment will be rated at 60°C. Therefore, conductor ampacity must be that listed

TABLE 5.3 Properties of conductors

AWG**							
14	4110	1	0.064	12.5	3.07	3.78	5.06
12	6530	1	0.081	19.8	1.93	6.01	3.18
10	10380	1	0.102	31.43	1.21	9.556	2.00
8	16510	1	0.128	49.98	0.764	15.20	1.26
6	26240	7	0.061	79.44	0.491	24.15	0.808
4	41740	7	0.077	126.3	0.308	38.41	0.508
3	52620	7	0.087	159.3	0.245	48.43	0.403
2	66360	7	0.097	205	0.194	62.3	0.319
1	83690	19	0.066	259	0.154	78.6	0.253
0	105600	19	0.074	326	0.122	99.1	0.201
00	133100	19	0.084	411	0.0967	125	0.159
000	167800	19	0.094	518	0.0766	157	0.126
0000	211600	19	0.106	653	0.0608	199	0.100
kcmil***							
250	250000	37	0.082	772	0.0515	235	0.0847
300	300000	37	0.090	925	0.0429	282	0.0707
350	350000	37	0.097	1080	0.0367	328	0.0605
400	400000	37	0.104	1236	0.0321	375	0.0529
500	500000	37	0.116	1542	0.0258	469	0.0424
600	600000	61	0.099	1850	0.0214	563	0.0353
700	700000	61	0.107	2160	0.0184	657	0.0303
750	750000	61	0.111	2316	0.0171	704	0.0282
800	800000	61	0.114	2469	0.0161	751	0.0265
900	900000	61	0.122	2780	0.0143	845	0.0235
1000	1000000	61	0.128	3086	0.0129	938	0.0212

* DC resistance at 75°C.

** American Wire Gage numerical designation.

*** kcmil = thousands of circular mils.