CHAPTER SEVEN
Introduction to Alternating-Current Electricity

In direct-current electricity, you became familiar with electron flow in one direction. For example, in a battery, which is a common source of d-c electricity, electron flow is from the negative terminal through the circuit to the positive terminal.

In alternating current, the subject of this chapter, the flow of electrons is not continuous in one direction. The electrons are made to move first in one direction and then in the other. The direction of current flow reverses many times a second.

When you have finished this chapter you will be able to:

- explain how an alternator generates an a-c voltage;
- explain frequency and state the factors that affect it;
- analyze the sine waveform of a-c voltage or current;
- make the mathematical conversions between maximum and effective values of voltage or current; and,
- use vectors to add values of a-c voltage or current.

The Basic Alternating-Current Generator

1. The only practical way to produce alternating current is by means of a generator, which is a machine that converts mechanical energy into electrical energy. The electrical energy might be in the form of either direct current or alternating current, so the alternating-current generator is usually called an alternator, the term we shall normally use in this book. The basic components of an alternator are an armature, about which many turns of conductor are wound, which rotates in a magnetic field, and some means of delivering the resulting alternating current to an external circuit. We will go into the construction in more detail later, but first, let's look at the theory of operation.

   During your study of magnetism in Chapter Six, you learned that a current-carrying conductor produces a magnetic field around itself. A magnetic field may also, under certain conditions, induce an electromotive force (emf) in a conductor. One such condition exists when there is relative motion between the magnetic field and the conductor. (If either the conductor or the field moves, there is relative motion between the two.) It is not very practical to move a magnetic field while the conductor remains stationary. How else might we achieve relative motion between the magnetic field and the conductor? ____________

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2. When a conductor is moved within a magnetic field, it cuts lines of force as it moves. When the conductor cuts lines of force, current flows, provided there is a complete path for current flow in the conductor. This process, called electromagnetic induction, is one way to cause current flow in a conductor. What is electromagnetic induction? ____________

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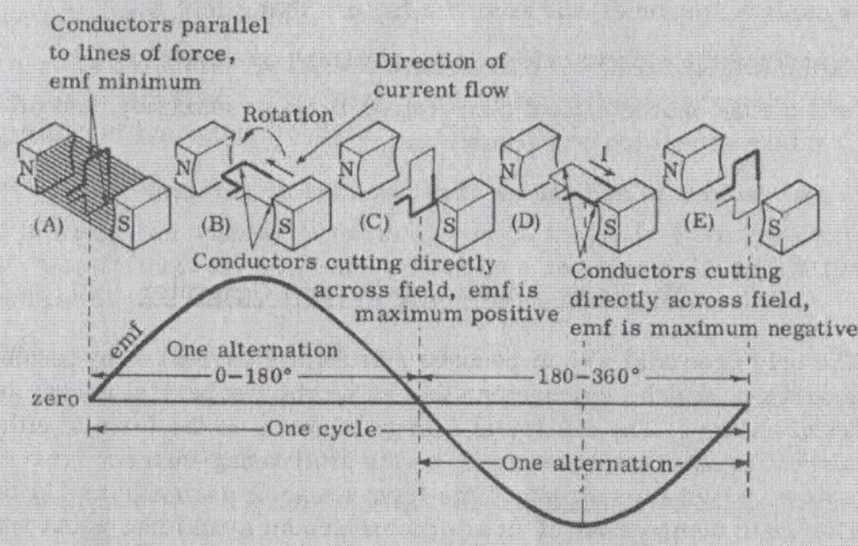

Figure 7-1. Basic alternator.

Refer to Figure 7-1 for Frames 3 through 20.

3. In Figure 7-1, a suspended loop of wire (conductor) is shown as it is rotated in a counterclockwise direction through the magnetic field that exists between the poles of a permanent magnet. For ease of explanation, the

loop has been divided into a dark and a light half. In this discussion, consider only the dark half. At position A, the conductor is parallel to the lines of force. It will not begin to cut the lines of force until it moves away from that position. The S-shaped line in the bottom half of Figure 7-1 represents varying values of voltage (emf) induced in the conductor as it rotates through the magnetic field. (This line is called a sine wave, which we will discuss later.) If the conductor is cutting no lines of force, as in position A, what is the value of emf induced in the conductor? ____

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4. Let's assume that the conductor is rotating at a constant speed. It cuts more and more lines of force as it moves away from position A because it is cutting more directly across the field. (That is, the angle of "cut" is approaching the perpendicular.) As it moves toward position B, what happens to the emf existing in the conductor at each instant of time—does it increase or decrease? ________________

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5. As the loop continues its rotation toward position C, it cuts fewer and fewer lines of force during each increment of time. Therefore, what happens to the induced voltage? ________________________

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6. As the armature of an alternator moves through one complete rotation, what must occur for maximum voltage to be generated? ____________

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7. That portion of the <u>sine wave</u> above the zero line represents positive voltages, while the portion below the zero line represents negative voltages. Therefore, at some point between position A and position E the current flowing in the conductor changes direction. Periodic changes of direction are a characteristic of alternating current. Can you identify at least one point at which current flow changes direction? ______________

What kind of current characteristically has periodic changes of direction?

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8. Remember that the sine wave represents constantly changing values of voltage. The height above the zero line of any point on the sine wave represents the relative value of voltage at that point in the rotation of the conductor, compared with voltages generated at other points. As the conductor cuts more lines of force, the induced voltage increases. Of the positions pictured in Figure 7-1, the conductor cuts the greatest number of lines of force at what positions? ______________

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9. Position C is a point of (maximum/zero) ______________ voltage.

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10. A and E are also points of zero voltage. At what position has the conductor returned to its original starting point? ________

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11. A sine wave of voltage represents all the <u>instantaneous</u> values of voltage induced in a conductor as it moves through one complete rotation. A rotation of the conductor through 360 degrees is one <u>cycle</u>. A sine wave of voltage, then, might also be called a cycle of voltage. The positive part of the cycle is between what two positions? ______________

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12. In Figure 7-1, the induced voltage is zero when the conductor is parallel to the lines of force, as in position A. The instantaneous voltages vary as the conductor rotates, but they are all positive between positions A and C. The current flow changes direction when the conductor reaches position C, so all the instantaneous voltages between positions C and E are (positive/negative) ______________.

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13. In your own words, describe a sine wave as it relates to the armature of an alternator. ____

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14. The conductor moves through a complete circle of 360 degrees during one rotation. The portion of the sine wave representing rotation of the conductor between 0 and 180 degrees is designated one <u>alternation</u>. The portion of the sine wave between 180 and 360 degrees also represents one alternation. An alternation can be thought of as the portion of the cycle during which current flow is in one direction. The current flow changes direction how many times during one complete cycle? ____________

15. The wave of induced voltage goes through one complete cycle between positions A and E. If the loop is rotated at a steady rate, and if the strength of the magnetic field is uniform, the number of cycles per second and the effective voltage will remain at fixed values. Continuous rotation will produce a series of sine-wave voltage cycles; in other words, an alternating-current (a-c) voltage. In this way mechanical energy is converted into what other kind of energy? ______________________

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Frequency

16. The rotating loop in Figure 7-1 is actually wound on an armature. For simplicity, a single loop is shown, but the armature may have any number of loops or coils wound on it. The armature is moved at a constant speed, because we want the same number of sine waves, or cycles, of voltage to

be generated each second. The number of cycles per second is the <u>frequency</u> of the alternator.

If the armature is made to rotate faster, will the frequency increase or decrease? ____________________

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17. You have probably heard of the term "60-cycle voltage" in reference to the ordinary alternating-current electricity used in homes and industry in the United States. This term refers to the <u>frequency</u> of the current or voltage; that is, <u>the number of sine waves that are generated each second</u>. Several years ago, by international agreement, the old term "cycles per second," abbreviated "cps," was discontinued in favor of "hertz," abbreviated "Hz," in honor of Gustav Hertz, a German physicist. We will use the old term, "cycles per second," only when it seems necessary to make a point clear.

In the United States, the standard frequency is 60 cycles per second, or 60 Hz, while in many other parts of the world, it is 50 Hz. (A home tape cassette recorded in Europe and played in the U.S. might sound a bit odd for that reason, but that is another story.) Frequency (f) is related to time.

If a single-loop armature makes 60 complete rotations in one second, what is its frequency? __________

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18. If the conductor is rotated faster in the magnetic field of an alternator, what will happen to the frequency of the voltage? ____________________

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19. The frequency (number of complete cycles per second) is the same as the number of rotations per second <u>if the magnetic field is produced by only two poles</u>.

On the next page, however, Figure 7-2 illustrates a four-pole alternator; and in this alternator, one revolution of the armature produces <u>two</u> complete cycles of voltage.

22. The period of an a-c voltage is the time for one complete cycle, or 1/f. The period of ordinary 60-Hz voltage, for example, is 1/60 of a second, since 60 sine waves are generated each second. It is not necessary to calculate the periods of a-c voltages in this book, but the frequency is essential in calculating other values, such as inductive and capacitive reactance, which will be discussed in later chapters. The output voltage of an alternator depends on the strength of its magnetic field. The output frequency of an operating alternator depends on what two factors?

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Analysis of a Sine Wave of Voltage

23. In earlier chapters, it was a simple matter to add various quantities of resistance, voltage, current, and power, because in direct current, all currents and voltages are in phase. That is, current and voltage are either present or not present, depending on whether a circuit is open or closed. In alternating current, on the other hand, current and voltage are often out of phase. Other circuit values (capacitance and inductance, which will be discussed later) might cause current to reach its peak ahead of or behind voltage. Phase will be discussed in detail later; for now, it is enough to know that a-c voltages and currents sometimes cannot be added by simple arithmetic. To solve problems involving sine-wave voltages and currents, you must understand vectors.

A vector is a line representing both magnitude and direction. If we say the wind is blowing at a speed of 10 mph, we are making a statement about magnitude only. A wind out of the northwest at 10 mph, however, is described in terms of both magnitude and direction. If we drew a line representing only wind speed, it would not be a vector, because it would not represent direction. (Similarly, a line representing direction only is not a vector.) If we drew a line representing wind speed and direction, the line would be a vector. A vector of any value represents what two characteristics?

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24. In the next drawing, the north-south and east-west axes show direction, while each mark crossing an axis indicates an increment of 5 mph. The arrow is a vector representing wind velocity.

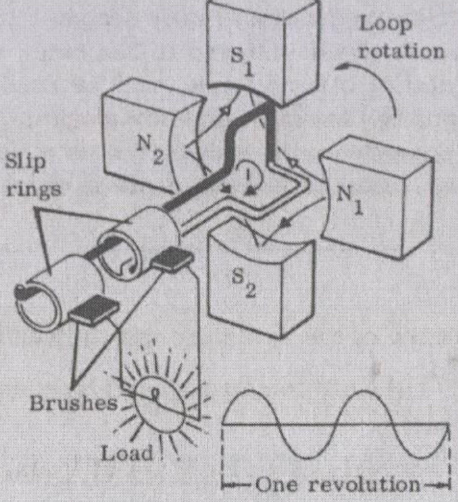

Figure 7-2. A four-pole basic alternator

If a four-pole alternator has an armature rotation of 30 revolutions per second, what is the frequency of the resulting output voltage? ________

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20. An alternator produces how many cycles of voltage for each pair of poles producing its magnetic field? ________

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21. Figure 7-2 shows some other components of an alternator: brushes and slip rings. It would be pretty awkward to have a lot of wiring twisting around itself as the armature rotates, so a system of slip rings and brushes provides the means of transferring the electric current from the generator to the outside circuitry. The slip rings are attached to the armature, while the brushes (usually made of carbon) are connected to the outside circuits and held against the slip rings by spring tension. There is contact, but not mechanical connection. If a spring were to break, allowing a brush to move away from the slip ring, the result would be a(n) (open/closed) ____________ circuit.

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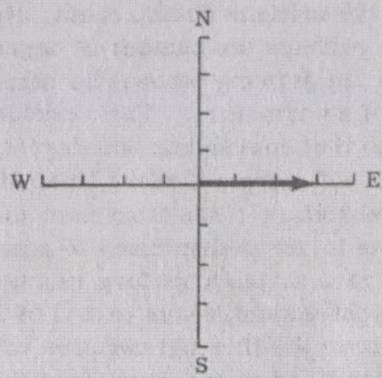
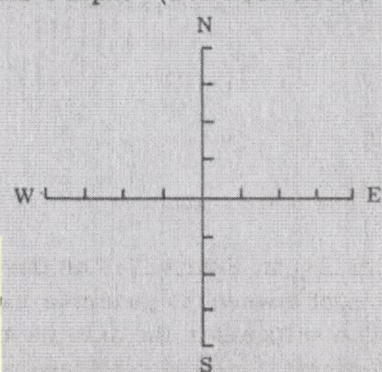
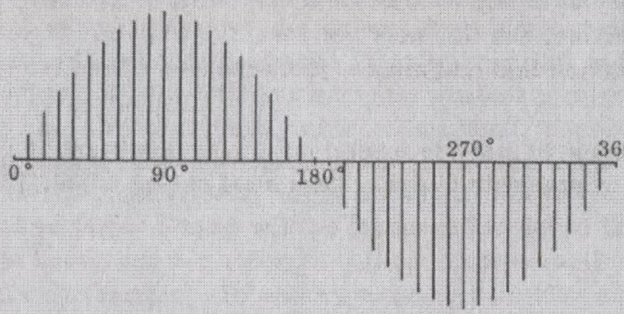


What are the magnitude and direction of the wind in this drawing?

25. Draw an arrow to indicate a wind out of the northeast at 10 mph. Each increment represents 5 mph. (You need not be exact; just approximate.)



26. Direction does not have to mean north, south, etc. It can also mean negative or positive, or perhaps the number of degrees away from a given point in a circle. In the drawing below, the horizontal line represents degrees of rotation of an armature. The armature of an alternator rotates in a circle, which of course has 360 degrees. As the armature rotates, the conductors cut more and more lines of force at each instant of time, and the induced voltage rises from zero to some maximum positive value, then decreases to zero, then rises to a negative peak value, and finally decreases to zero as the armature reaches its starting point. The vertical lines represent instantaneous values of induced voltage, with positive values shown above the line and negative values shown below the line. Maximum voltage is induced at one-quarter of the full circuit of rotation (90 degrees) and three-quarters of the full circle (270 degrees). Zero voltage is induced at the starting point (0 or 360 degrees) and halfway through the circle (180 degrees). If you connect the ends of all the vertical lines with a single line (smoothed into a curve, since not all values are shown), what is the result? ____________________



27. Some vectors, such as E_M in Figure 7-3 on the following page, may be rotated like the spokes of a wheel to generate angles. (The vectors representing instantaneous voltages in the sine wave are not rotating vectors.) Positive rotation is counterclockwise and generates positive angles. Negative rotation is clockwise and generates negative angles. The vertical projection of a rotating vector may be used to represent the voltage induced in an armature at any given instant. In Figure 7-3, the line E_M is a rotating vector, and the dashed line e is the vertical projection representing the instantaneous voltage when the angle θ (theta) reaches 60 degrees. The cross-section of the armature (conductor) is shown, with its positions numbered 0/12 (the starting and ending points are the same) through 11. Angle θ is 60 degrees when the armature is at position 2.

What is angle θ at position 3? ____________

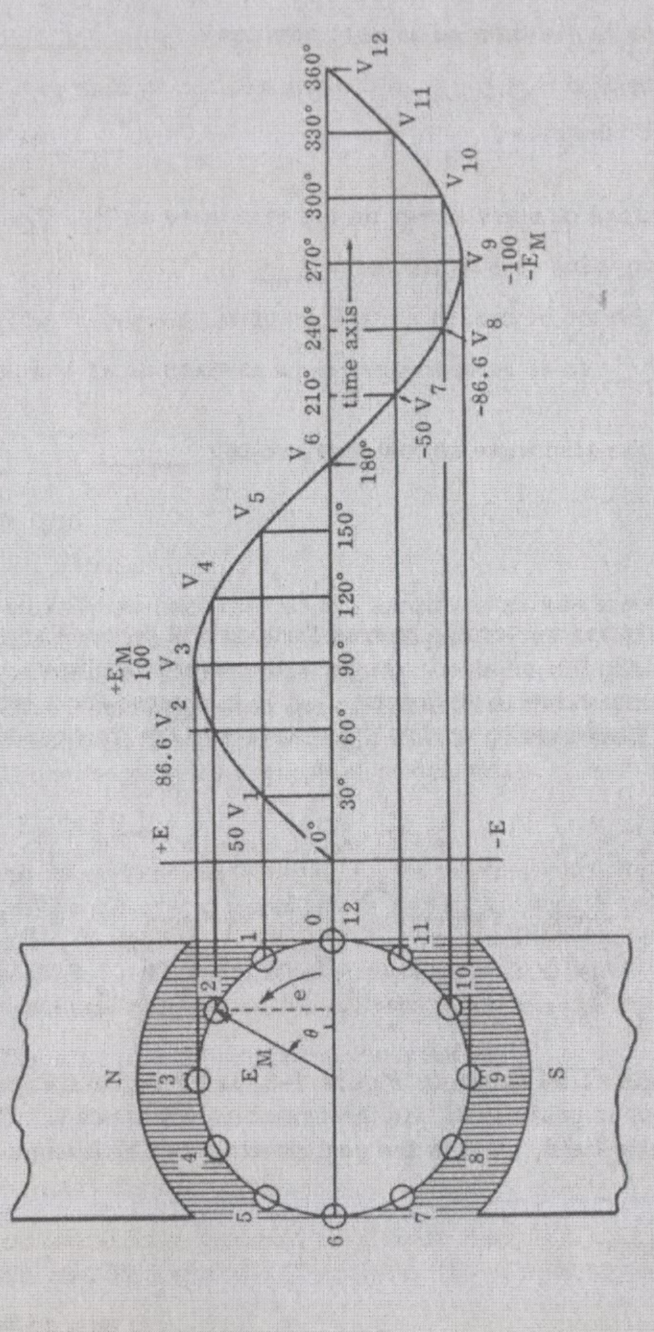


Figure 7-3. Generation of sine-wave voltage.

Refer to Figure 7-3 for Frames 27 through 41.

28. The vector E_M represents the maximum voltage that can be induced in the armature for a given magnetic field strength. E_M represents e, the instantaneous voltage, only when the conductor is cutting the maximum number of lines of force in a given time. The only positive value of e that is equal to E_M is induced at what position? ____________________

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29. The values of e are shown on the sine wave as V_1, V_2, etc. The maximum positive value of e is labeled V_____.

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30. V_3 on the sine wave is how many volts? _____

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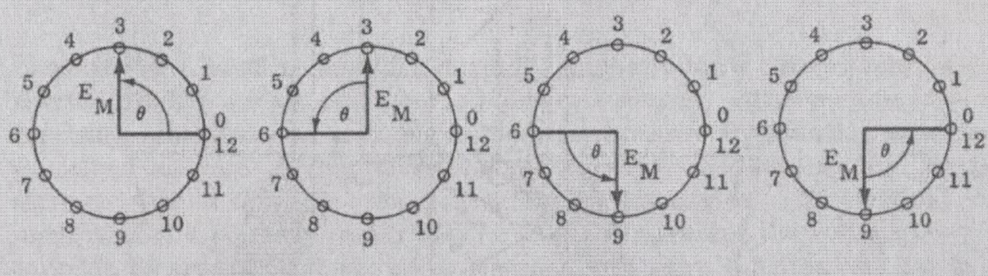
31. The rotating vector E_M moves through 360 degrees as the armature completes one full rotation. Angle θ, however, is always an acute angle—its maximum value is 90 degrees. It is measured from the zero (base) line of the sine wave to vector E_M. Here are the four quadrants of the circle.



Angle θ, as shown in Figure 7-3, is 60 degrees at position 2 and 90 degrees at position 3. As the armature continues to rotate through the magnetic field, what is the next position at which angle θ is 60 degrees?

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32. Write in the values of angle for the following positions of the armature.

6 ___°	8 ___°	10 ___°
7 ___°	9 ___°	12 ___°

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33. The value of e is maximum when angle θ is ____° and minimum (zero) when angle θ is ____°.

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34. Angle θ must be 90 degrees or less, but the armature rotates through 360 degrees. Angle θ is 30 degrees when the armature is at _____, _____, _____, and _____.

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35. The voltage wave form produced as the armature moves through 360 degrees of rotation is called a sine wave because the instantaneous voltage e is related to the sine (abbreviated <u>sin</u>) of the angle θ. (Sine is a trigonometric function that expresses the ratio between the length of the side <u>opposite</u> a given angle in a right triangle to the hypotenuse of that right triangle.) The sine curve is a graph of the equation

$$e = E_M \sin \theta,$$

where e is the instantaneous voltage, E_M is the maximum voltage, and θ is the angle of the generator armature. You have already learned that $e = E_M$ when $\theta = 90$ degrees. Therefore, you don't need trigonometric tables to discover the sine of a 90-degree angle. You merely have to ask, "What value must be substituted for sin θ to preserve the equation $e = E_M$?" The sine of a 90-degree angle must be _____.

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36. The instantaneous voltage e cannot be greater than E_M, and angle θ is never greater than 90 degrees. Therefore, the sine of any other value of angle θ must be less than _____.

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37. Any value e may be found by multiplying E_M by $\sin \theta$. (The sines of angles between 0 and 90 degrees may be found in a table of trigonometric functions.) The sine of 60 degrees is 0.8660. If $E_M = 100$ v., what is the induced voltage when the armature of a generator is at 120 degrees (angle $\theta = 60$)? ____________

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38. When the armature in Figure 7-3 is at any point between 0 and 180 degrees, e is positive. The value of e is negative when the armature is at any point between ______ and ______ degrees.

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39. When the armature is at 60 or 120 degrees and $E_M = 100$ v., the value of e is (+86.6/−86.6) __________ v.

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40. When the armature is at 240 or 300 degrees and $E_M = 100$ v., the value of e is __________ v. (Include the polarity.)

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41. Sin 30 = 0.5000 and $E_M = 100$ v. What is the value of e when the armature is at 150 degrees? __________ When the armature is at 330 degrees? __________

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We have seen that the magnitude of the voltage generated by an alternator changes from instant to instant as the armature rotates in the magnetic field. By connecting all the instantaneous vectors, we can see that a symmetrical sine wave results from one complete rotation, or cycle. The information gained so far is helpful in understanding the nature of alternating current, but we need some method of translating the instantaneous voltages into a constant value that is useful in solving problems. We will discuss such a method in the next section.

This is a convenient place to take a break.

Effective Value of Alternating Current or Voltage

42. The instantaneous value of voltage constantly changes as the armature of an alternator moves through a complete rotation. Since current varies directly with voltage, according to Ohm's Law, the instantaneous changes in current also result in a sine wave whose positive and negative peaks and intermediate values can be plotted exactly as we plotted the voltage sine wave. However, instantaneous values are not useful in solving most a-c problems, so an effective value is used. The effective value of an a-c voltage or current of sine waveform is defined in terms of an equivalent heating effect of a direct current. Heating effect is independent of the direction of current flow. Since all instantaneous values of induced voltage are somewhere between zero and E_M (maximum, or peak voltage), the effective value of a sine wave voltage or current must be greater than zero and less than what? ________

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43. An alternating current of sine waveform having a maximum value of 14.14 amperes produces the same amount of heat in a circuit having a resistance of one ohm as a direct current of 10 amperes. Since this is true, we can work out a constant value for converting any peak value to a corresponding effective value. This constant is represented by X in the simple equation below. Solve for X to three decimal places.

$$14.14X = 10$$

$X =$ ____

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44. The insulation of a conductor must be designed to withstand the peak voltage, not merely the effective voltage. A voltmeter, however, reads the effective value. Let us assume that a certain type of insulation is intended to withstand 1,000 v. How can we find the highest effective voltage (which is the value we can read on a voltmeter) that should occur in the circuit?

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45. The effective value is also called the root-mean-square (rms) value because it is the square root of the average of the squared values between zero and maximum. (You may be relieved to know that you don't have to remember the math.) The effective value of an a-c current is stated in terms of an equivalent d-c circuit. What phenomenon is used as the standard of comparison? ______________________________

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46. A-c voltmeters and ammeters (which read voltage and current, respectively) are designed to read the effective value. If the peak a-c voltage across a resistor is 100 v., what is the rms voltage? __________

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47. The peak current in an a-c circuit is 84.8 ma. An ammeter would indicate (to the nearest milliampere) ________ ma.

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48. As we mentioned earlier, the insulation for conductors must be designed for the maximum voltage. A little arithmetic will show you that the peak voltage is about 1.41 times the effective voltage. When a circuit is designed, if the effective voltage between two conductors in a cable is 440 v., what maximum voltage must the insulation be able to withstand? ______

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49. Effective voltage (or current) in an a-c circuit is __________ times the peak value.

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50. Peak voltage (or current) in an a-c circuit is __________ times the effective value.

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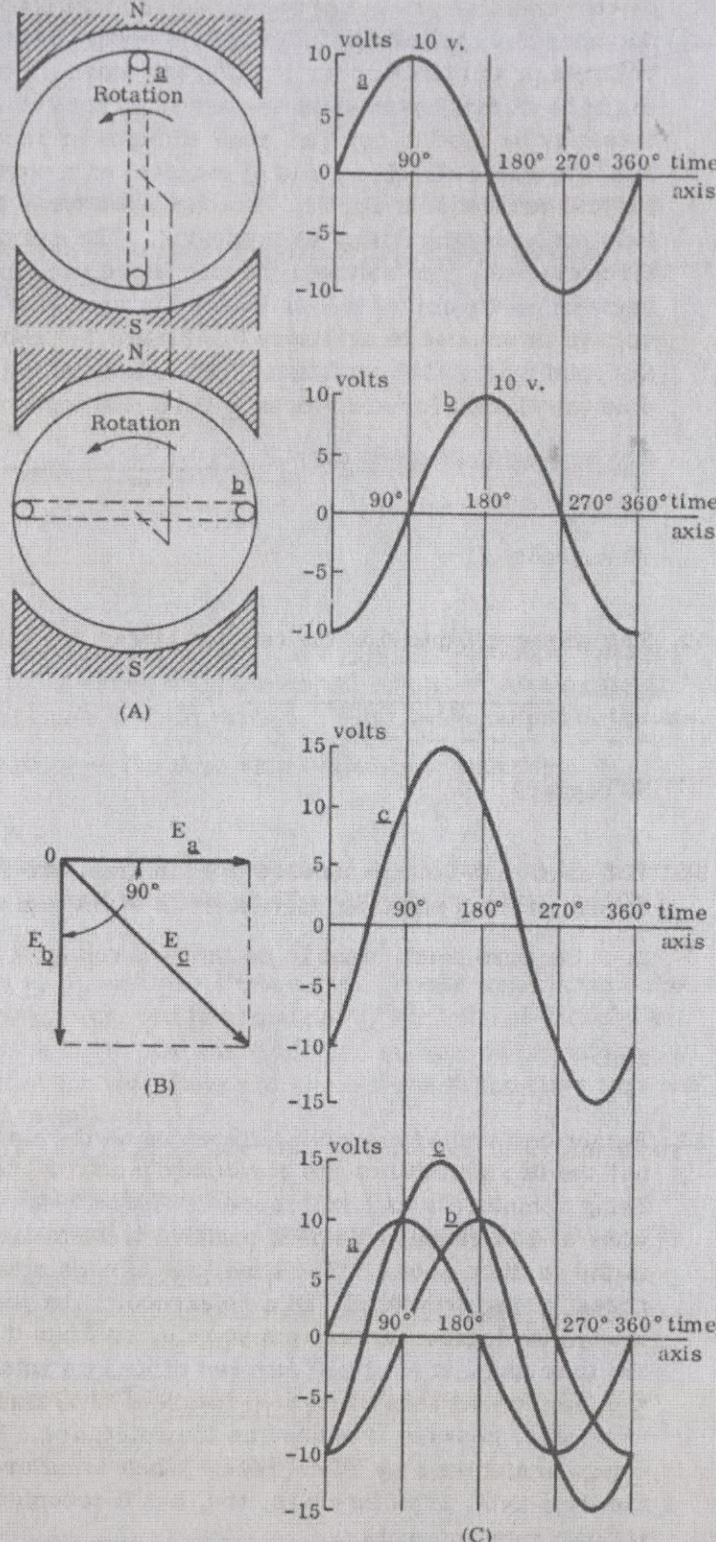
Combining A-C Voltages

Figure 7-4. Combining a-c voltages. Refer to Figure 7-4 for Frames 51 through 67. Two armatures, several waveforms, and a vectorial diagram are presented in this illustration. You will not understand the entire illustration immediately, but it is necessary to show several relationships, which will become clear as you work through the frames.



51. It is sometimes necessary to calculate the combined effect of a-c voltage or currents that are out of phase, as you will discover when you study inductance and capacitance later in this book. That is, the peaks of various voltages or currents occur at different times. For example, one voltage might be at maximum while another is at zero or some other value. Vectors may be used to combine such voltages or currents. Figure 7-4 shows two armatures (labeled a and b) mounted on a common shaft in an alternator and connected in series. The two armatures are shown separately to help you understand what is happening. The armatures are rotating counterclockwise. The voltages induced in the two armatures are out of phase, because maximum voltage is induced in armature a at the point where zero voltage is induced in armature b. Figure 7-4 shows the two armatures at the point where that condition exists. Look at the positive peaks of the sine waveforms for armatures a and b (the top two waveforms). The peaks are how many degrees apart? ____________________

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52. The voltages induced in the two armatures are how many degrees out of phase? ____________________

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53. The maximum voltage induced in each armature is 10 v. The sine wave for armature a starts at zero degrees of its own rotation. If armature a is at the zero point, what is its induced voltage? __________ v.

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54. Remember that armature b is mounted on the same shaft as armature a, but the two armatures are physically placed 90 degrees apart. We are using armature a as a reference in Figure 7-4. The top waveform, sine wave a, has reached its peak positive value of 10 v. when armature a is in the position shown. The time axis of each waveform is laid out in degrees, using armature a as a reference. The position of armature b is always 90 degrees behind armature a, so when it is at zero degrees on the time axis, it is at 270 degrees of its own rotation. When armature a is at zero degrees of its own rotation, it is also at zero degrees on the time axis, because it is used as the reference. Remember that armature b lags armature a by 90 degrees. When armature a is at 180 degrees on the time axis, armature b is, too, but it occupies some other position in its own rotation cycle.

When armature a is at 180 degrees, armature b has rotated through how many degrees of its own cycle? ________

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55. When armature a is at zero degrees, its induced voltage is also zero. At that same point along the time axis, maximum (positive/negative) ______ voltage is induced in armature b.

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56. Armature a (leads/lags) ____________ armature b by 90 degrees.

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57. The third waveform in Figure 7-4 shows the combined induced voltages of armatures a and b. It represents the actual output of the alternator whose two armatures are shown in view A. What is the output of the alternator at the zero point of the time axis? (Indicate polarity.) _______

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(Note: This is easy to see, because armature a is at zero—no induced voltage—while armature b is at 270 degrees

58. Compare waveforms a, b, and c in Figure 7-4. These waveforms show, respectively, the voltage induced in armature a, the voltage induced in armature b at the same time, and the combined voltage output of armatures a and b. Look at the waveforms at 90 degrees on the time axis and answer the following questions.
   (a) When armature a is at 90 degrees, armature b is at how many degrees of its own rotation? ________
   (b) What is the voltage induced in armature a at 90 degrees on the time axis? (Indicate polarity.) ________
   (c) What is the voltage induced in armature b at 90 degrees on the time axis? ________
   (d) What is the output of the alternator at 90 degrees on the time axis? (Indicate polarity.) ________ .

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59. Each of the two armatures has a peak voltage of 10 v. What is the effective voltage induced in each armature? __________

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60. The two effective voltages cannot be combined by arithmetic because they are 90 degrees out of phase. However, they can be added by the use of vectors. View B of Figure 7-4 shows a vectorial representation of the voltages induced in armatures a and b. E_a represents the effective voltage induced in armature b. The vectors represent the effective equivalents of the first two waveforms. Do not try to relate them to the third waveform. Remember that the vectors are generated counterclockwise.

E_a (leads/lags) _______________ E_b by ______ degrees.

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61. The combined effect of the two voltages represented by vectors E_a and E_b is shown by vector E_c. If the coordinates of the vectors (E_a and E_b) in View B were marked off in units to represent voltages, you could just measure E_c (using the same units) to obtain the effective output of the alternator, but this would be laborious. Such vectors are normally solved by the mathematics of right triangles. First you have to identify the right triangle that is the basis of your mathematics. In View B of Figure 7-4, vectors E_a and E_b are the coordinates that represent specific voltages: the outputs of armature a and armature b. Vector E_c is the resultant, or the vector that represents the combined output of the two armatures. Since vectors E_a and E_b are both generated from the same point, one of them (it doesn't matter which) must be moved to form a triangle with the other two vectors. The dashed lines represent the positions of vectors E_a and E_b after they are moved. The dashed line parallel to each vector is the "new" position of that vector.

The Pythagorean theorem states that the square of the hypotenuse of any right triangle is equal to the sum of the squares of the other two sides. This is stated mathematically as

$$a^2 + b^2 = c^2.$$

Take the square root of each side of the equation:

$$\sqrt{a^2 + b^2} = \sqrt{c^2}.$$

If two sides of a right triangle are 3 and 4 units, the length of the hypotenuse can be found by substituting:

$$\sqrt{9 + 16} = \sqrt{c^2}$$
$$5 = c$$

The length of vector E_c can be found by the use of the Pythagorean theorem, since it is known that E_a and E_b are each 7.07. Solve for E_c. (Note: The 7.07 is actually rounded off a little, so round off each number in your solution to the nearest whole number.) __________

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62. If the sides of a right triangle forming the right angle are equal, as E_a and E_b are equal, there is an easier solution. The length of <u>one</u> of the equal sides multiplied by 1.414 (the square root of 2) is equal to the hypotenuse. (We won't explore the reason in this book.) Using this solution, if E_a and E_b are each 12 v., E_c is ______ v. (Round off your answer.)

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63. View C in Figure 7-4 shows all three waveforms (a, b, and a + b) on the same time axis. The instantaneous output of the alternator is about +15 v. when both a and b are at about +7.5 v. This point is approximately how many degrees on the time axis? __________

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64. At what points on the time axis is the instantaneous output of the alternator zero? ____________________

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In this chapter you have become acquainted with the basic theory of alternating current. You have learned how the sine-wave voltage output of an alternator is generated and how output voltages are combined vectorially. You have examined the relationship between peak voltage and effective voltage and have had some practice in solving problems involving these values.

This chapter provided some of the basic information that you will need in later chapters, when you study some of the special characteristics of a-c circuits.

When you feel that you understand the material in this chapter, turn to the Self-Test.

Self-Test

The following questions will test your understanding of Chapter Seven. Write your answers on a separate sheet of paper and check them with the answers provided following the test.

1. What happens when a conductor (which provides a complete path for current flow) is moved in a magnetic field?
2. What is electromagnetic induction?
3. As the armature of an alternator moves through one complete rotation, what must occur for maximum voltage to be generated?
4. What characteristic of alternating current distinguishes it from direct current?
5. What is a sine wave?
6. An alternator converts __________ energy into __________ energy.
7. What is frequency?
8. What is the modern unit of frequency? What is its abbreviation?
9. What are the two factors that affect the frequency of the voltage generated by an alternator?
10. What two values are represented by a vector?
11. What directions are indicated by the vectors that describe a sine wave?
12. As an armature moves through one complete cycle of rotation, a maximum positive voltage of 50 v. is induced at 90 degrees of rotation away from zero. As rotation continues:
    (a) At how many degrees away from zero will the voltage induced in the armature next be zero?
    (b) At how many degrees away from zero will the induced voltage be −50 v.?
13. The maximum voltage generated by an alternator is 200 v. What is the effective voltage?
14. The rms voltage generated by an alternator is 500 v. What is the peak voltage?
15. Two armatures, x and y, are mounted on the same shaft of an a-c generator. When armature x is at 180 degrees, armature y is at 145 degrees. Armature x (leads/lags) __________ armature y by __________ degrees.
16. How can the combined value of out-of-phase voltages or currents be calculated?