Math Lab 6 MS 3

Computing an Electric Bill by Using Information from Kilowatt-Hour Meter Readings

Solving Power Problems That Appear in Electrical Energy Systems

For best results, print this document front-to-back and place it in a three-ring binder.
Corresponding teacher and student pages will appear on each opening.

TEACHING PATH - MATH SKILLS LAB - CLASS M

RESOURCE MATERIALS

Student Text: Math Skills Lab

CLASS GOALS

1. Teach students to compute an electric bill when given kilowatt-hours of **energy** used.
2. Teach students to solve problems that involve power in an electrical energy system.
3. In problems with mixed units, teach students to convert all units to one system. Then teach them to solve the problems for answers in the desired units.

CLASS ACTIVITIES

1. Take five or ten minutes to go through the Student Exercises. Make sure that your students understand the correct answers.
2. Complete the activities. Students already should have read the discussion material and looked at the examples for each activity before coming to this class. You should summarize the main points in each activity, work an example or two, and have students complete the Practice Exercises for each activity on their own. Supervise student progress. Help students obtain the correct answers.
3. Before the class ends, tell students to read Lab 6E1, "Measuring Electrical Energy With a Watt-Hour Meter," as homework.

NOTE: One kilowatt-hour is the amount of **ENERGY** consumed by an electrical device that uses 1000 watts of power for one hour--or 2000 watts of power for one-half hour, and so on.

The unit, kilowatt-hour (kWh), had the form of power (kW) multiplied by time (hour). But "power × time" is equal to "work/time × time" or just work, since the time units cancel out.

Work and energy have the same units. Therefore, **kilowatt-hours** is just another way of writing an **energy** unit.

Math Skills Laboratory

Lab 6 MS 3

MATH ACTIVITIES

Activity 1: ***Computing an Electric Bill by Using Information from Kilowatt-hour Meter Readings***

Activity 2: ***Solving Power Problems that Appear in Electrical Energy Systems***

MATH SKILLS LAB OBJECTIVES

When you complete these activities, you should be able to do the following:

1. ***Compute an electric bill when given kWh of energy used.***
2. ***Solve problems that involve power in an electrical energy system.***
3. ***Given problems where mixed units are involved, convert all units to one system. Then solve the problems for answers that are expressed in the desired units.***

LEARNING PATH

1. ***Read the text. Give particular attention to the Math Skills Lab Objectives.***
2. ***Work the problems.***

In Subunit 2's Math Skills Lab (on fluid power), you learned that businesses that use large quantities of natural gas pay a lower rate for "interruptible" gas service. Many utilities have a variety of billing rate systems. Some examples include agricultural rates, industrial rates, commercial rates and church-building rates.

The rates electric utility companies charge are based on how much electricity is used during a given time. There are two types of meters that measure the electrical energy used by a customer. These are the kilowatt-hour meter and the peak-load meter.

Kilowatt-hour meters are the familiar glass-enclosed meters on electrical service entrances to homes, businesses and industrial plants. Large consumers of electrical energy have peak-load meters that are used to help set their yearly rates.

In Activity 1, you'll learn how to use a kilowatt-hour meter. You'll learn to use it to compute an electric bill. In Activity 2, you'll solve the types of electrical power problems that electrical and electronics technicians solve on the job.

NOTE: Review the billing rate schedule (located below Figure 2) with the class. Explain that the charges are in *cents per kWh*. Explain that the additional charges for "*fuel adjustment*" are passed on to the customers. These additional charges are due to the increased costs incurred by electric power companies, since the clean air act of 1970 required them to use high-grade fuels to cut down on air pollution.

NOTE: Students will learn how to read the meter dials in Lab 6E1 that follows. The reading shown on the dials in Figure 1 is 70,084 kWh. The same dial-face arrangement and reading occurs on several pictures in Lab 6E1.

ACTIVITY 1

Computing an Electric Bill by Using Information from Kilowatt-hour Meter Readings

Kilowatt-hour meters measure electrical ***energy*** used. That is, they measure the kilowatts of power consumed times the duration (hours) of consumption.

The most common meter has a dial register like the one shown in Figure 1. Each dial is driven by a gear that's meshed with a gear on the next dial. Each digit on the register has a value of 10 kilowatt-hours.

When the dial on the far right moves clockwise ***one complete revolution*** (10 kilowatt-hours), the dial just to its left will rotate counterclockwise ***one digit.*** The time it takes for the dials farther to the left to move depends on the power used over a period of time. Small power uses—hence small movements—can be calculated by a method you'll learn in a future lab exercise.

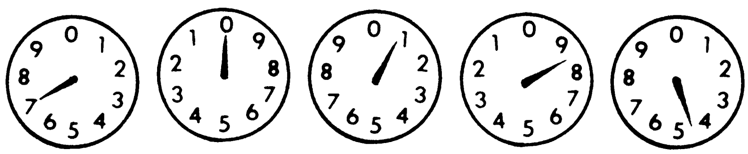
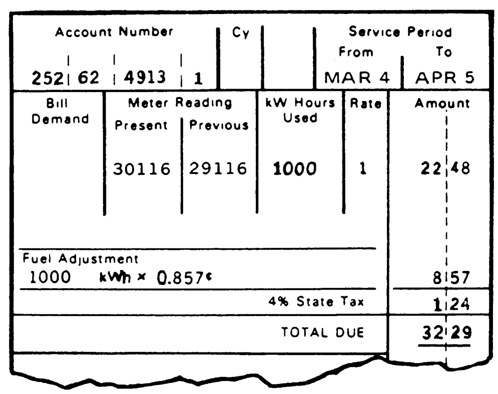


Fig. 1 Dials on a kilowatt-hour meter.

Electric companies usually offer five classifications of billings rates: *residential, farm, commercial, industrial* and *special.* Kilowatt-hour meters are used to find the amount of energy that's used in a given time.

For example, if you record the meter readings on the first days of two consecutive months, the difference between them is the kWh of electrical energy used during that month. Figure 2 shows a typical residential-rate electric bill. Let's examine it.

The meter register reading on March 4 was 29116 kWh. On April 5, it was 30116 kWh. That means 1000 kWh of electrical energy were used during those 32 days. The billing rate schedule for the 1000 kWh was as follows:



Account Number	Cy		Service Period From	To
252 62 4913	1		MAR 4	APR 5

Bill Demand	Meter Reading Present	Previous	kW Hours Used	Rate	Amount
	30116	29116	1000	1	22 48
Fuel Adjustment 1000 kWh × 0.857¢					8 57
				4% State Tax	1 24
				TOTAL DUE	32 29

Fig. 2 Typical electric bill.

1st 650 kWh @ 2.3 cents/kWh, so	650 kWh	× 2.3 cents	=	$14.95
Next 500 kWh @ 2.15 cents/kWh, so	350 kWh	× 2.15 cents	=	7.53
Charge Subtotal	1000 kWh			$22.48
Base Charge ($4.00 if less than 100 kWh)				0.00
Fuel Adjustment: @ 0.857 cents/kWh	1000 kWh	× 0.857 cents	=	8.57
Tax @ 4%				1.24
Total Bill				$32.29

ANSWERS TO PROBLEMS

Problem 1:

a.

82 kWh @ 2.3 cents/kWh	$ 1.89
Base charge (less than 100 kWh)	4.00
Fuel adjustment @ 0.857 cents/kWh	.70
Charge subtotal	$ 6.59
State sales tax @ 4%	.26
Total	$ 6.85

b.

648 kWh at 2.3 cents/kWh	$ 14.90
Fuel adjustment @ 0.857 cents/kWh	5.55
Charge subtotal	$ 20.45
State sales tax @ 4%	.82
Total	$ 21.27

c.

650 kWh @ 2.3 cents/kWh	$ 14.95
500 kWh @ 2.15 cents/kWh	10.75
Fuel adjustment @ 0.857 cents/kWh	9.86
Charge subtotal	$ 35.56
State sales tax @ 4%	1.42
Total	$ 36.98

d. The rate schedule shown can be used for a maximum of 1150 kWh. Beyond 1150 kWh, a different rate schedule would be used. Therefore, the rate schedule shown <u>could not</u> be used to accurately determine the charge for 1200 kWh of energy.

(Answers to Problems 2, 3, 4 and 5 on Page T-77c.)

ANSWERS TO PROBLEMS, Continued

Problem 2:

$$P = \frac{\text{Work}}{\text{Time}}$$

$$P = \frac{500{,}000\ \text{J}}{5\ \cancel{\text{min}} \times \frac{60\ \text{sec}}{1\ \cancel{\text{min}}}}$$

$$P = \left(\frac{500{,}000}{5 \times 60}\right)\left(\frac{\text{J}}{\text{sec}}\right)\ ;\ \left(1\ \frac{\text{J}}{\text{sec}} = 1\ \text{watt}\right)$$

$$P = 1666.67\ \text{watts.}$$

Problem 3:

$P = \Delta V \times I$. Therefore, $I = \dfrac{P}{\Delta V}$.

$$I = \frac{P}{\Delta V}$$

$$I = \frac{1666.67\ \cancel{\text{V}}\bullet\text{A}}{120\ \cancel{\text{V}}} \qquad (\text{watt} = \text{V}\bullet\text{A})$$

$$I = 13.89\ \text{A.}$$

Problem 4:

$$P = \Delta V \times I$$

$$P = 120\ \text{V} \times 0.625\ \text{A} \qquad (625\ \text{mA} = 0.625\ \text{A})$$

$$P = 75\ \text{watts.} \qquad (1\ \text{V}\bullet\text{A} = 1\ \text{watt})$$

Problem 5:

a. $P = \Delta V \times I = I^2 \times R$

$$P = I^2R$$

$$P = (0.004\ \text{A})^2 \times 5000\ \Omega \qquad (4\ \text{mA} = 0.004\ \text{A};$$

$$P = 0.08\ \text{watt.} \qquad 5\ \text{k}\Omega = 5000\ \Omega)$$

b. $P = \Delta V \times I = \dfrac{(\Delta V)^2}{R}$

$$P = \frac{(\Delta V)^2}{R} \qquad \text{where: } \Delta V = 10\ \text{V};\ R = 300\ \Omega$$

$$P = \frac{(10\ \text{V})^2}{300\ \Omega} = 0.333\ \frac{\text{V}^2}{\Omega}\ ;\ \left(1\ \frac{\text{V}^2}{\Omega} = 1\ \text{watt}\right)$$

$$P = 0.333\ \text{watt.}$$

The base charge, as an equipment rental fee of \$4/month, is applied only if less than 100 kWh is used. Fuel adjustment fees are justified on the basis of the 1970 Clean Air Act that requires utility companies to use high-grade fuel.

Problem 1: Given: The same billing schedule as that in the discussion that follows Figure 2.

Find: The cost of electrical energy in *each* of the following cases.

a. 82 kWh residential
b. 648 kWh residential
c. 1150 kWh residential
d. Will the schedule work for 1200 kWh?

Solution:

ACTIVITY 2

Solving Power Problems that Appear In Electrical Energy Systems

Problem 2: Given: An electric motor does 500,000 joules of work as it pumps liquid through a sprayer in a 5-minute time interval.

Find: The power supplied to the motor if the motor is 100% efficient.

Solution:

Problem 3: Given: The conditions of Problem 2.

Find: The current drawn by the motor described, if the voltage source is 120 V AC.

Solution:

Problem 4: Given: An incandescent lamp has a current flow of 625 mA when connected to a 120-volt source.

Find: The power rating stamped on the bulb.

Solution:

Problem 5: Given: Any device that offers resistance to the flow of current changes some electrical energy to heat energy. The rate at which electrical energy is dissipated as heat energy is called ***"power dissipation."***

Find:

a. How much power is dissipated by a 5-kΩ resistor that has 4 mA of current through it?
b. How much power is dissipated by a 300-Ω resistor if the voltage drop across it is 10 V?

Solution:

ANSWERS TO PROBLEMS, Continued

Problem 6:

$$P = \Delta V \times I = \frac{(\Delta V)^2}{R}$$

$$P = \frac{(\Delta V)^2}{R} \qquad \text{where: } \Delta V = 10 \text{ V and } R = 4\ \Omega$$

$$P = \frac{(10\text{ V})^2}{4\ \Omega} = \frac{100}{4}\frac{\text{V}^2}{\Omega} \qquad (1\ \frac{\text{V}^2}{\Omega} = 1 \text{ watt})$$

P = 25 watts (power dissipation).

Safe power ratings for resistors should be two times the power dissipation. The power rating for a resistor should be:

P_{rating} = 2 x power dissipation

P_{rating} = 2 x 25 watts

P_{rating} = 50 watts

This means the 30-watt power rating of the resistor being used is too low.

Problem 7:

a. Voltage drop along lines from transformer to motor.

$\Delta V = I \times R$

ΔV = 20 A x (0.5 Ω x 2 wires) (resistance in each of 2 wires)

ΔV = 20 V (total voltage drop along lines).

Voltage difference across motor.

$V_{difference} = T_{tot} - V_{drop}$ along lines

$V_{difference}$ = 120 V - 20 V

$V_{difference}$ = 100 V (voltage available for operating the motor).

(Answer to Problem 7 continued on page T-78c.)

ANSWERS TO PROBLEMS, Continued

Problem 7:

b. $P = \Delta V \times I$

$P = 100\ V \times 20\ A = 2000\ V{\cdot}A$ ($1\ V{\cdot}A = 1$ watt)

$P = 2000$ watts (2 kW).

c. $P = \Delta V \times I = I^2 \times R$

$P = I^2 \times (R \times 2 \text{ wires})$

$P = (20\ A)^2 \times (0.5\ \Omega \times 2) = 400\ A^2 \cdot 1\ \Omega$

$P = 400\ A^2{\cdot}\Omega$ ($1\ A^2{\cdot}\Omega = 1$ watt)

$P = 400$ watts (total line loss).

d. $P = \Delta V \times I$

$P = 120\ V \times 20\ A = 2400\ V{\cdot}A$ ($1\ V{\cdot}A = 1$ watt)

$P = 2400$ watts.

Power Check...

Output Power Available at Transformer	=	Power Loss in Lines	+	Power Used at Drill Press Motor

2400 watts = 400 watts + 2000 watts

2400 watts = 2400 watts!

Problem 6: Given: A resistor in a motor-control circuit appears to have overheated and failed. The technician troubleshooting the circuit believes that the 30-watt power rating of the resistor is too low. The technician finds that there's a 10-V voltage drop across the 4-Ω resistor in the circuit. The technician knows that a safe power dissipation rating for resistors is twice the power value.

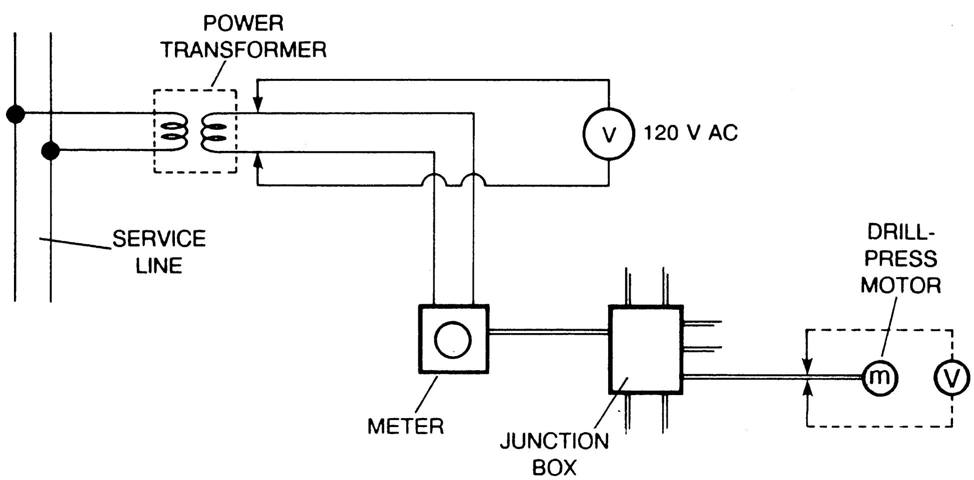
Find: Is the 30-watt power rating too low?

Solution:

Student Challenge

Problem 7: Given: Swanson Manufacturing employs several electromechanical technicians who maintain the company's manufacturing equipment. One technician has been asked to find the amount of electric power consumed by a multiple-spindle drill press. The technician knows that the total power required to operate the machine ***includes*** the power used to move electric charge through the line from the electric company's power transformer to the drill press. (See drawing of circuit below.) Electrical measurements made by the technician provide the following information:

1. A voltage of 120 volts is available at the power transformer.
2. There's a total of 0.5 ohm of resistance in ***each*** of the two wires from the transformer to the motor.
3. Twenty amperes of current flow through the wires when the drill press is operating.



Find:
a. The voltage drop (difference) across the drill-press motor.
b. The power input to the drill-press motor (in watts).
c. The total power loss in the two lines (in watts).
d. The total power output (available at the power transformer panel) in watts.

Note: Verify from your answers to "b," "c" and "d" that:

$$\left\{\begin{array}{c}\text{Power}\\ \text{Available at}\\ \text{Transformer}\end{array}\right\} = \left\{\begin{array}{c}\text{Power}\\ \text{Loss in}\\ \text{Lines}\end{array}\right\} + \left\{\begin{array}{c}\text{Power Used}\\ \text{at Drill-Press}\\ \text{Motor}\end{array}\right\}$$

Solution: