PHYSICS: HEAT

NAME ____________________________ SCHOOL __________________________

DATE STARTED_____________________ DATE COMPLETED_________________

PREREQUISITE: Algebra 1A and 1B courses or basic algebra knowledge. Recommended: Intermediate Algebra 2 Part A and Part B courses.

HOW TO DO THIS COURSE: Do the steps one at a time, in order. When you finish a step, put your initials and the date on the sign-off line on the right. A split line means to get a pass (and an initial) from another student (or your Academic Supervisor if it says that). Essays are turned in to the Academic Supervisor.

PURPOSE: Learn what heat is, how it interacts with other physical factors, and how to measure and control it.

ESTIMATED TIME: 20 hours.

MATERIALS NEEDED FOR THIS COURSE

Data Sheet (DS) #8870 Materials List for Physics: Heat (stapled separately)
Study booklet, *Physics: Heat*, with these data sheets (DS):

10	364	321	11	1	8863	8864	7389	363	513	514
515	516	512(drills)		2136 (ans)						

Exams: 2428, 8866 (answers), 8867 (review), 8868 (answers)

Physics: Heat Lab Supervisor Manual, with these data sheets:
8865 8870

Other texts/references:
Handbook of Chemistry and Physics (any recent edition), the Chemical Rubber Company, 18901 Cranwood Parkway, Cleveland, OH 44128. Alternatively, this handbook may be accessed via the Internet (http://www.hbcpnetbase.com; requires a subscription to get full access) or the data needed may be found on other Internet sites by searching for keywords “heat capacity” or “heating values.”

Other materials:
See #8870 Materials List for Physics: Heat. Note: Throughout this course, where measurements are to be taken, it is recommended that Vernier probes or similar equipment capable of recording and displaying the measurement results be used.

A. ENERGY, HEAT, TEMPERATURE

1. READ: Data Sheet (DS) #10 Energy. __________
2. DEMONSTRATE: Show the three things you should know about energy. __________
3. ESSAY: Discuss the three things you should know about energy. Give examples of how you have observed each to be true. __________
4. READ: DS #364 Heat and Temperature. __________
5. DEMONSTRATE:

   a) heat ___

b) temperature ___

c) heat capacity ___

d) one calorie ___

e) one BTU ___ __________

6. READ: DS #321 Thermometers. __________

7. DEMONSTRATE: Correctly read a glass thermometer. Experiment to see if it is possible to read it in such a way as to get a wrong reading. __________

8. PRACTICAL APPLICATION: Measure temperature change, per step A.8 in DS #512 Practical Applications and Drills for Physics: Heat (in the back of your study booklet). __________

9. PRACTICAL APPLICATION: Melt ice and boil the water, per step A.9 in DS #512. __________

10. DRILL: Compute heat loss or heat gain, per step A.10 in DS #512. (After you have done the drills, you may check the answers in DS #2136 Physics: Heat—Answers to Computation Drills in the back of your study booklet). __________

11. READ: DS #11 Matter and Energy in Natural Systems. __________

12. READ: DS #1 Energy in the Physical Universe. __________

13. READ: DS #8863 Thermodynamics. __________

14. DEMONSTRATE: Show each of the three laws of thermodynamics. __________

15. ESSAY: Give two examples that you have experienced of the Second Law in action, and what the consequences are or were. __________

16. READ: DS #8864 The Gas Law. __________

17. DEMONSTRATE: Show how knowledge of the gas law and thermodynamics is used in the design of an air conditioner. __________

18. PRACTICAL APPLICATION: Gas law, per step A.18 in DS #512 Practical Applications and Drills for Physics: Heat. __________

19. DRILL: Use the gas law, per step A.19 on DS #512. __________

B. HEAT TRANSFER

1. READ: DS #7389 Controlling Heat “Loss.” __________

2. PRACTICAL APPLICATION: Calculate heat produced, per step B.2 on DS #512. __________

3. READ: DS #363 Radiation. __________

4. DEMONSTRATE: Show the three listed basic points about radiation. __________

5. DEMONSTRATE: A peculiar aspect of radiation, per step B.5 in DS #512 Practical Applications and Drills for Physics: Heat. __________

6. READ: DS #513 Heat Transfer. __________

7. DEMONSTRATE: Show the three methods of heat transfer, and how they interact. __________

8. READ: DS #514 Heat Capacity and Specific Heat, to heading "Rate of Cooling." __________

9. DEMONSTRATE: Show the relationships of the general formula for calculation of final temperature given in DS #514 Heat Capacity and Specific Heat. __________

10. PRACTICAL APPLICATION: Calculate and measure final temperature, per step B.10 in DS #512. __________

11. DRILL: Calculate the final temperature, per step B.11 in DS #512. __________

12. READ: DS #514 Heat Capacity and Specific Heat, section "Rate of Cooling" to the end of the data sheet. (In this section you are told to "remember that *e* is a mathematical constant." If this meaning of *e* is new to you, read the footnote.[1] You will not be required to fully understand this somewhat-advanced mathematics. Just follow it well enough to see that it offers a way to solve rate of cooling problems with a calculator.) __________

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[1] In case you don't remember—or never knew—"*e*" is "Euler's number," named for the mathematician who discovered it, and is related to the "natural logarithm" discussed in the next paragraph. This "rate of cooling" example is just one of many occurrences, from biology to finance, where powers of *e* are used to show that how much you have of something determines how quickly you can get more of it.

A "natural logarithm" (also mentioned in the data sheet) is a logarithm using *e* as the base, so ln means $\log_e$, where *e* is approximately 2.718 as noted above. It is called "natural" because examples occur in nature, in things like the spiral patterns of seashells and flowers. As the example above illustrates, it makes problems involving exponentials easier to solve by turning them into linear algebra. Some calculators have a button for ln, on some others the "log" button means "ln" or is programmable to mean either $\log_e$ or $\log_{10}$. If you are following along on a calculator and have buttons for both *e* and ln (or a button that means that), then you can test it to show that $\ln(e^a) = a$ for any *a*.

There is a problem in the *Algebra and Trigonometry* text, Problem 21 in Section 6-11, where this is discussed. You may refer to that if you wish.

13. PRACTICAL APPLICATION: Calculate rate of cooling, per step B.13 in DS #512 (You may omit step 13.e) if you haven't mastered the math.) __________

14. READ: DS #515 Control of Heat Transfer—Theory. __________

15. PRACTICAL APPLICATION: Find four methods of controlling heat transfer in use in your surroundings. Look for and be sure to include examples of both types (increasing as well as reducing the transfer rate). Write an essay describing them and why they work. __________

16. PRACTICAL APPLICATION: Control heat, per step B.16 in DS #512. __________

17. READ: DS #516 Control of Heat Transfer—Computation. __________

18. DEMONSTRATE: Show the unit of Thermal Conductivity (BTU/HR-°F-Sq.Ft.). __________

19. PRACTICAL APPLICATION: Calculate heat transfer, per step B.19 in DS #512. __________

20. DRILL: Calculate multi-layer heat transfer, per step B.20 in DS #512. __________

C. FINAL APPLICATION SECTION

1. PRACTICAL APPLICATION: Design a dome to maintain a temperature of 70°F in a climate with an average outside temperature of 45°F. You may design the dome in any size and shape as long as you can fairly accurately compute the surface area. Include all insulating materials used and their costs. Compute, on an annual basis, how much natural gas would be needed for heating and the cost. Compute the yearly cost of heat without insulation as well and over what period of time the insulation will pay for itself in reduced heating costs. To get cost data, you will have to get in contact with retail distributors and the gas company. You may find some of the data on the Internet.

   You may find that the gas company computes cost in terms of heating value rather than amount of gas. For example, the cost might be $ 0.75 per therm (a therm is equal to 100,000 BTU's). This actually makes your computation easier—you don't have to figure out the volume of gas needed to determine the cost of heating.

   Submit your design and calculations to your supervisor, who will check your design or have it checked. **Supervisor pass.** ____ ____

2. PRACTICAL APPLICATION: Do an evaluation of the heating (or cooling) of the building you are in.

As a preliminary action, tour the building and note a particular target area where you suspect that heat might be better conserved or conversely where cooling is a problem (perhaps a room with a lot of windows).

The point of this practical is to examine an actual scene and gain some understanding of the control of heat transfer in it. Remember that heat transfer is not only about conduction through walls. There can be convection flow through leaky door and window seals, or other factors to consider.

Then do something like this:

a) Make inquiries to find out a part of the building (or the whole building) for which you can get heating/cooling billings (we'll call that part "the building"). Estimate the exterior surface area of the building. (Make whatever assumptions you feel are valid, but be sure to note them.)

b) Find out the annual heating/cooling bill and calculate the average BTUs used and from that get as good an estimate as you can of the conductivity or R value of the building as a whole (using your estimate of the total surface area). (Again be sure to note any assumptions.)

c) Compare your target area to the building. Do whatever research and computations are needed to compare the heat transfer through the walls (and windows) of the target area to the average heat transfer of the whole building (is the target area really worse than average, and by how much).

   For example, you might have gathered energy use and inside and outside temperature data, and determined that the average heat loss in the building is 2 BTU per square foot per degree F per hour. Using estimates from your research for the approximate conductivity of the walls in the target area, you might find that in a particular large room the windows alone account for more than half the exterior wall area, and compute their heat transfer rate to be 5 BTU per square foot. Even if the rest of the wall had zero loss, the room as a whole is worse than average.

d) Consider what you think might be done to better control the heat transfer in the target area, if you determine it is actually needed. In the example above, you might consider replacing single pane glass with Thermopane windows or finding a way to limit the losses at night, etc. Also note any other realizations you have had that might improve the efficiency of the heating/cooling of the building.

e) Write a report on what you found, with specific recommendations. Submit your report to your supervisor for review. **Supervisor pass.** ____ ____

I have completed the steps of this course. I understand what I studied and can use it.

Student ____ Date ____________________________

The student has completed the steps of this course and knows and can apply what was studied.

Academic Supervisor ____________________________ Date ____________________________

The student has passed the exam for this course.

Examiner ______________________________________ Date ____________________________

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