Workshop Tutorials for Introductory Physics

TI7: **Blackbody Radiation**

A. Review of ideas in basic physics.

Use the following words to fill in the blanks:
temperature, $P = \sigma AT^4$, electromagnetic, warmth, stars, spectrum, absorbed, emissivity,

Blackbody Radiation

Try holding your hands close to but not touching a mug of hot coffee – you can feel the _______. This warmth is actually _________ radiation emitted from the mug. The amount and wavelength of radiation will depend on certain characteristics of the mug including its temperature. As you already know a hot body will radiate more than a cold one. The surface of the body will also affect the amount of radiation leaving the body. In fact each object has a characteristic ________ of emitted radiation.

To provide a standard for the amount of radiation emitted from a body we define an ideal object called a blackbody. A blackbody is one where all the radiation hitting the body is _______, a perfect absorber. It is also a perfect emitter, emitting the maximum amount of radiation possible for a body at a given temperature.

The Stefan-Boltzmann law tells us that the rate at which energy is radiated from a body is ________ for a perfect blackbody, where σ = Stefan-Boltzmann constant and A = surface area. For any other body, the power is $P = \varepsilon\sigma AT^4$, where ε is the _________ of the body – a characteristic of the surface.

Wien's Law relates the wavelength λ_m at which emitted radiation is a maximum to the temperature of the body. It states that $\lambda_m \times T$ = constant. A body with a lower temperature will emit more radiation of longer wavelength. This provides a useful way of measuring the ________ of things without having to get close enough to them to reach thermal equilibrium with them. This is particularly useful for astronomers as it gives them a means of measuring the surface temperatures of distant _______. It can also provide a warning not to touch something – if it is hot enough to be glowing, like an electric hot plate, then it is much too hot to touch.

Discussion Question

All bodies emit and absorb radiation but, as we have seen, rates will vary. Can you explain why a white car parked in the sun does not get as hot as a dark coloured one? Is it because dark colours attract more heat?

B. Activity Questions:

1. Thermal radiation – the Leslie Cube.

Use the thermopile detector to look at the radiant heat from the different surfaces of the cube.
Which surface radiates the most? Which surface radiates the least?

2. The Black Box

Look into the hole. What colour do you see?
Now open the lid. What colour is the inside of the box?
Why is it so? How can you explain your observation?

3. Blackbody radiation.

Gradually turn up the power passing through the graphite.
What happens as you increase the power?
Explain your observations.

C. Qualitative Questions.

1. It took a long time for someone to come up with an explanation of black body radiation. Eventually Max Planck came up with an explanation, and it led to the development of quantum physics, which changed not only how we understand the universe, but also led to the development of all modern electronics, including TVs, mobile phones and computers.

a. Explain the meaning of the term *black body radiation*.

Consider two black bodies at different temperatures.

b. Sketch, on a single set of axes, graphs showing the relation between the power emitted per unit area, per unit wavelength interval and the wavelength. Indicate which graph represents the higher temperature.

If the temperature of the sun were suddenly to *increase* (but its size were to stay the same) how would the following quantities change at the surface of the earth?

c. The total radiant power received.

d. The wavelength for maximum spectral intensity of received radiation.

e. The radiant power received in the visible range.

2. A thermos bottle consists of an inner bottle and an outer bottle, usually with the space between them evacuated. This prevents heat loss by conduction. What sort of material should be used to coat the walls of the thermos? Should the material behave like a blackbody radiator?

D. Quantitative question:

In the movie "2001: a space odyssey" an astronaut walks briefly in space with no space suit. If you did this you would radiate thermal energy, but absorb almost none from your environment.

a. At what rate would you lose energy? Assume that your emissivity is 0.90 and estimate the other data that you need.

b. How much energy would you lose in 30 s?

Construction work on the International Space Station can be very mentally draining...