Homework–Module 1 **Name:** Key

1) Warning signs such as the one to the right are common before bridges. And they are put there for good reason.

   Why does the bridge get icy before the pavement on the ground when air temperatures drop below freezing? Use heat transfer concepts to explain your answer. Assume calm winds to simplify the discussion.

   There is a 600-character limit for all questions.

The bridge would become icy first because it loses heat over its entire surface. The bridge would lose heat by radiation, conduction and convection to the colder air from its top, sides and underside. The net result is that the bridge's surface temperature would closely trend the air temperature.

The road too would lose heat quickly, but mostly at its upper surface. Once the asphalt becomes colder than the ground underneath it, heat flows from warmer ground to the roadway through radiation transfer and conduction, which in turn would slow the rate at which the asphalt cools.

2) One of my most humbling experiences as a fledgling meteorologist (a.k.a. early learning experiences) occurred for Corvallis, Oregon during the winter 1980. I forecast mostly clear, calm conditions overnight and a low near freezing (33˚F). It was indeed calm all night with cold air trapped in the Willamette Valley, and clear too…most of the night. Unfortunately for my forecast, low-clouds (stratocumulus) began to drift overhead after midnight, at which time the temperature warmed to 45˚F and stayed there through the rest of the night. My forecast low ended up 8˚F too cold, a major bust!

   Use heat transfer concepts to explain why the surface temperature warmed when low clouds moved overhead.

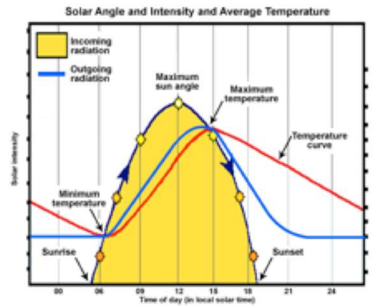
   (Hint: infer from Figs. 2.12 and 2.18 of textbook the impact of clouds on radiative heat transfer.)

The low clouds would absorb infrared radiation that is emitted from the earth's surface, then re-radiate it back to the surface.

In other words, a portion of the infrared radiation lost by the earth to the atmosphere is absorbed by the low clouds and re-emitted to the surface where it is absorbed.

3) The schematic to the right was shown in the overview slides to explain the diurnal cycle of temperature in terms of radiative balance. Unfortunately, the diagram has an error (that I intentionally did not mention in the narrative) where two of the curves are not consistent with the physics of radiative heat transfer. Which of two curves are inconsistent? Use the laws of radiation to explain what the inconsistency is between the two curves.

(Hint: compare the diagram with Figure 3.02 in the text.)



Black curve-incoming solar radiation
Blue curve-outgoing IR radiation
Red curve-temperature

The inconsistency is between the temperature curve (red) and the outgoing radiation curve (blue). The temperature curves shows cooling between the hours of 1400 (time of max temperature) to 0600 the following morning. On the other hand, the outgoing radiation curve is constant through the hours of 2200 to 0600 (next morning) when the temperature is cooling.

A constant rate of radiative heat loss by an object when the temperature of the object is cooling is inconsistent with the Stefan-Boltzmann law.

4) During a very cold, calm night during winter, why might you feel colder at low elevations (100 meters) than at a high elevation, ski resort (3000 meters) when the air temperatures are the same?

The sense of "feeling colder" means your body undergoing a faster rate of total heat transfer to the surrounding environment.

Because the difference in the air temperature and your body temperature is the same, the net heat loss by radiation would be the same. It follows that heat loss through conduction and convection must be greater at lower elevation, but why? Air density is approximately 30% greater near sea-level than at 3 km. The presence of more air molecules (greater air density) would increase the efficiency of heat loss by conduction and convection from your body to the air.