Homework–Module 1 **Name:** Key Copy

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 would lose heat energy over its entire surface. The bridge would cool by radiative heat transfer to the air from its top, its sides and its underside. The net effect is that the bridge's temperature would closely mirror the air's temperature at night.

The road would lose heat quickly by radiative transfer too, but only at its upper surface. If the asphalt becomes colder than the ground underneath it, heat would flow from warmer ground to the roadway through radiative heat transfer and conduction, which in turn would slow the rate at which the asphalt cools compared to the bridge.

Modified version.

2) One of my most humbling experiences as a fledgling meteorologist (a.k.a. early learning experiences) occurred for Corvallis, Oregon during the winter of 1979-80. I forecast 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 it was 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 increased as the low clouds moved overhead.

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

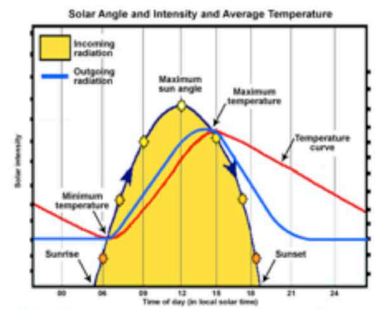
The low clouds would absorb upwelling infrared radiation that is emitted from the earth's surface, and then they would re-radiate some of it back to the surface.

In other words, a greater 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. The net effect on the surface temperature is less cooling or sometimes even warming.

Modified version.

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 omitted from the narrative) where two of the curves are not consistent with the physics of radative heat transfer. Which two curves are in error? Use the laws of radiation to explain what the inconsistency is between the two curves.

(Hint: compare the diagram with Figure 3.02 of 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 t o 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.

Modified version.

Use heat transfer concepts to answer the following two questions. Assume you are wearing the same clothing for every situation.

4) During a very cold, calm, winter night, why would you feel colder near sea level (e.g. 100 meters) than at a high elevation site like a ski resort (3000 meters) when the air temperatures are the same?

The sense of "feeling colder" when the air temperature is the same means your body is 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 skin to the air.

Modified version.

5) On a very cold, calm day, why do you feel warmer at noon on a clear sunny day than you would on an overcast day when the air temperature is the same?

The sense of "feeling warmer" when the air temperatures are the same means your body is experiencing a faster rate of total heat input on the sunny day than the cloudy day.

The additional heat comes from the absorption of more shortwave radiation on a sunny day than on a cloudy day.

It's that simple!

Modified version.