Year 12 Science: Heat transfer in the Earth system

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. How much energy warms 2.0 kg of water by 3.0 °C? Use $c = 4200$ J kg^{-1} °C^{-1}.

2. 8400 J is absorbed by 0.50 kg of dry sand ($c = 800$ J kg^{-1} °C^{-1}). Find its temperature rise.

3. Using NIWA's table, how much bigger is Alexandra's July daily range than Dunedin's?

4. Explain why a cloudy winter night is usually warmer than a clear one.

5. Explain why the sky is blue.

6. Which way does the breeze blow on a beach on a clear night, and why?

Exam-style question: the Canterbury nor'wester

Moist westerly air from the Tasman Sea is forced up over the Southern Alps. The West Coast gets heavy rain, while the Canterbury Plains, on the other side, get a hot, dry nor'wester.

7. Describe what latent heat is.

8. Explain why the air cools as it rises over the Alps, and why rain falls on the West Coast.

9. Discuss why the air reaching the Canterbury Plains is warmer and drier than it was at the same height over the Tasman Sea.

Fix the mistake

10. Correct this statement: "Water has a high heat capacity, so it heats up quickly."

11. Correct this statement: "Greenhouse gases reflect heat back down to Earth."

12. Correct this statement: "The sky is blue because it reflects the colour of the sea."

13. Correct this statement: "Sunsets are red because the Sun cools down in the evening."

Answer key (for parents and tutors)

1. How much energy warms 2.0 kg of water by 3.0 °C? Use c = 4200 J kg^{-1} °C^{-1}.
   Q = mcΔT = 2.0 × 4200 × 3.0 = 25 200 J.
2. 8400 J is absorbed by 0.50 kg of dry sand (c = 800 J kg^{-1} °C^{-1}). Find its temperature rise.
   ΔT = Q ÷ (mc) = 8400 ÷ (0.50 × 800) = 21 °C.
3. Using NIWA's table, how much bigger is Alexandra's July daily range than Dunedin's?
   8.9 − 4.3 = 4.6 °C bigger.
4. Explain why a cloudy winter night is usually warmer than a clear one.
   The cloud absorbs the longwave infrared the ground gives off and re-emits some of it back down, so less heat escapes to space.
5. Explain why the sky is blue.
   Gas molecules scatter short blue wavelengths far more than long red ones, so scattered blue light reaches your eyes from all over the sky.
6. Which way does the breeze blow on a beach on a clear night, and why?
   From the land out to sea: the land cools faster than the sea, so air over the sea is warmer and rises, and denser air from over the land flows out to replace it.
7. Describe what latent heat is.
   Achieved: the energy absorbed or released when a substance changes state without changing temperature; evaporation absorbs it and condensation releases it.
8. Explain why the air cools as it rises over the Alps, and why rain falls on the West Coast.
   Merit: as the air rises, the pressure on it falls, so it expands and cools. Once it has cooled enough, its water vapour condenses into cloud droplets, which grow and fall as rain on the western side of the ranges.
9. Discuss why the air reaching the Canterbury Plains is warmer and drier than it was at the same height over the Tasman Sea.
   Excellence: condensation releases latent heat into the rising air, so above the cloud base it cools more slowly than dry air would. The water falls out as rain on the West Coast, so the air that crosses the main divide has lost much of its moisture. As it descends on the eastern side, the rising pressure compresses it and it warms at the faster rate of dry air all the way down. It therefore reaches the plains warmer than it was at the same height on the western side, and drier, because its water stayed behind as rain while the latent heat that water carried stayed in the air. This is the föhn effect. Describing latent heat earns Achieved; explaining the cooling and condensation earns Merit; linking latent heat release, the loss of water and warming by compression earns Excellence.
10. Correct this statement: "Water has a high heat capacity, so it heats up quickly."
    A high heat capacity means it takes more energy for each degree, so water heats up, and cools down, slowly.
11. Correct this statement: "Greenhouse gases reflect heat back down to Earth."
    They absorb outgoing longwave infrared and re-emit it in all directions, some of it back toward the surface.
12. Correct this statement: "The sky is blue because it reflects the colour of the sea."
    Air molecules scatter short blue wavelengths far more than long red ones, so blue light reaches you from all over the sky.
13. Correct this statement: "Sunsets are red because the Sun cools down in the evening."
    At sunset the light's path through the air is much longer, so the blue is scattered out and mainly red and orange are transmitted.