Topics for essays (section D), with ingredients of what you could discuss in an answer.

1 *Greenhouse effect*

Blackbody temperature. Stefan–Boltzmann law. Solar flux roughly $1\,\mathrm{kW/\,m^2}$. Factor of one-fourth due to night and non-perpendicular incidence. Balance of fluxes: incoming from sun versus lost via blackbody radiation. Surface temperature of Earth with no atmosphere. How an atmosphere (via carbon dioxide and water vapour) raises surface temperature. (Lecture 1; Sheet 3/A4)

2 *Carnot cycle*

Diagrams! Four steps in the cycle. Whether each is adiabatic or isothermal. Purpose of the hot and cold reservoirs in each step. Heat flow and work done in each step (take care to understand the signs). Heat flow and work done during one cycle. Carnot efficiency. $\Delta S = 0$ for one cycle. (Lecture 10)

3 *Random walks*

One-dimensional random walk. Expected location $\langle x \rangle$ remains fixed. Expected squared location $\langle x^2 \rangle$ increases linearly with time (numerical argument and because variances add). Compare with regular walk. Molecular motion as a random walk. Diffusion constant. Heat flow in a gas as a random walk. Why, using dimensions and/or using $\langle x^2 \rangle \propto t$, thermal diffusivity $\kappa \sim c\ell$. (Revision problem 19; Lecture 4)

4 *Rain shadows*

Wet parcel of air cools as it rises up a mountain because of adiabatic expansion due to pressure decrease. Quickly explain adiabatic atmosphere (for the next question you'd give lots more details) – how pressure and temperature are related by adiabatic law – and quote resulting rate of temperature decrease ($1\,^\circ\mathrm{C}$ per $100\,\mathrm{m}$). Vapour pressure of water versus temperature (Boltzmann factor or Clausius–Clapeyron). What happens to the excess water as vapour pressure drops? Fraction of water lost rising up a particular mountain. What happens as parcel descends other side of mountain? (Revision problem 16; Sheet 3/B1; Lecture 10)

5 *Adiabatic atmosphere*

Parcel of air rises. Pressure drops with height (gravity). Parcel expands. Why expansion is adiabatic. Parcel cools, and lowers temperature of surrounding air until 'convective equilibrium' is reached. Pressure and temperature then related by adiabatic law. Along with ideal gas law and force balance, have enough equations to solve for temperature versus height. Work out rate of temperature decrease by putting in the constants. (Sheet 3/B1; Lecture 10; redone adiabatic atmosphere solution on revision page)

6 *How do clothes (or blankets) keep you warm?*

How they trap a layer of air near you; air a good insulator. Heat flux $F = K\Delta T/\Delta x$. What is flux? Meaning of K, ΔT, and Δx. Why Δx in the denominator, from how random walks work. Warmer clothes have larger Δx. Estimate heat loss through a thin shirt or sheet and a thick one. What is a large loss (one that makes you feel cold)? (Revision problem 18; Lecture 5)

7 *Physics and war (sadly, it won't be on the exam)*

Discuss one of the following statements. Research is essential so that we know what threatening weapons are possible. I only work on defensive, not offensive weapons. By being involved in the weapons program I can be an effective influence on the government. I am just a scientist doing my job; I stay out of politics. I don't use MoD money; EPSRC fund my research. I don't have any government research funds; I am just a physics teacher.

8 *Thermal conductivities of air vs water (or water vs ice)*

Meaning of variables in $K = \rho c_\mathrm{p} \kappa$. Break comparison (ratio) into pieces: ρ, c_p, and κ. Why diffusivity κ is given by speed $\times$ length (random walk and using dimensions).

Air vs water. In a gas, how is heat diffused? Hence for κ the relevant speed is the sound sound (or thermal speed). What is the relevant length? In liquid, how is heat diffused? Hence for κ, speed is again sound speed but length is phonon mean-free path. Compare κ for air and for water by comparing these two pieces. Density ratio is easy. Specific-heat ratio: Specific heat of an ideal gas from degrees of freedom. Specific heat of a solid or liquid (Dulong and Petit value); water's c_p is double that value (has extra, rotational modes, or use the definition of a calorie and its conversion to Joules). Put the pieces together.

Water vs ice. Density ratio is easy. Specific heat ratio: Dulong and Petit value for ice vs higher value for water. Sound speeds same. Why phonon mean-free path longer in ice (a solid) than in water (a liquid). Put the pieces together.

(Lecture 6)

9 *Heat of vaporisation of water by two methods, compare them*

Many methods possible: boiling kettle dry, annual rainfall, puddle evaporation, ... Don't confuse boiling kettle dry (evaporating the water) with bringing to a boil (which estimates the specific heat). For details of various methods: Sheet 1/Q4; Revision problem 13; Lecture 3.