UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For The Following Qualifications:-

B.Sc. *M.Sci.*

Physics 2B27: Environmental Physics

COURSE CODE	:	**PHYS2B27**
UNIT VALUE	:	**0.50**
DATE	:	**15-MAY-06**
TIME	:	**10.00**
TIME ALLOWED	:	**2 Hours 30 Minutes**

06-C1167-3-70

TURN OVER

Answer ALL SIX questions from Section A and THREE questions from Section B.

The numbers in the right hand margin in square brackets indicate the provisional allocation of the maximum number of marks per sub-section of a question.

The following may be used:

Solar constant S	$= 1353$ W m^{-2}
Temperature of the Sun's surface T_{SUN}	$= 5500$ K
Radius of the Earth R_E	$= 6370$ km
Mass of the Earth M_E	$= 5.97 \times 10^{24}$ kg
Universal gravitational constant G	$= 6.67 \times 10^{-11}$ m^3 kg^{-1} s^{-2}
Acceleration due to gravity g	$= 9.81$ m s^{-1}
Density of air (at STP) ρ_{AIR}	$= 1.225$ kg m^{-3}
Earth's average rainfall rate	$= 0.8$ m per year
Viscosity of air (at STP) η_{AIR}	$= 1.73 \times 10^{-5}$ N s m^{-2}
Boltzmann's constant k	$= 1.38 \times 10^{-23}$ m^2 kg s^{-2} K^{-1}
Stefan's constant σ	$= 5.67 \times 10^{-8}$ Wm^{-2} K^{-4}
Specific heat of water $C_{P\ WATER}$	$= 4184$ J kg^{-1} K^{-1}
Specific heat of air $C_{P\ AIR}$	$= 1005$ J kg^{-1} K^{-1}
Specific latent heat of vaporization/condensation of water L_S	$= 2.5$ MJ kg^{-1}
Universal gas constant R	$= 8.31$ J mol^{-1} K^{-1}
Mean molar mass of air M_{MEAN}	$= 0.0289$ kg
Molar mass of carbon	$= 0.012$ kg
Avogado's number N_A	$= 6.02 \times 10^{23}$

SECTION A

1. (a) Name the four principal forces that can act on a typical parcel of atmospheric air. **[2]**

(b) Provide a qualitative description of what is meant by the term 'geostrophic balance' when applied to weather systems. **[2]**

(c) With the aid of simple diagrams, explain how a region of low pressure can give rise to a rotating weather system, and explain why such a rotating weather system cannot cross the equator. **[3]**

2. (a) A 1 km × 1 km area of sea of surface temperature 35 C, at the equator, is irradiated by sunlight from a clear sky at midday. What mass of water vapour would be produced in one hour? You may assume that all of the incident energy goes to first heating and then evaporating the sea water. **[3]**

(b) Explain qualitatively, in not more than a few sentences, where and why hurricanes form and why they stop developing and start to decay. **[4]**

3. (a) What is meant by a renewable energy source? **[1]**

(b) Derive an expression for the power per unit area, P/A, carried by an incompressible fluid travelling at velocity v. **[3]**

(c) Using the above expression, compare the power of (a) an underwater turbine, of radius 5m, if the speed of the water is 2m s^{-1}, and (b) a wind turbine, of radius 20 m, if the speed of the air (at STP) is 30 m s^{-1}. You may neglect all other effects. **[2]**

4. (a) If the most probable speed v of a molecule in the Earth's atmosphere is given by $v = (2kT/m)^{1/2}$, where m is the mass of the molecule and T is the temperature, calculate the molecular speeds of helium and nitrogen in the Earth's atmosphere. **[4]**

(b) If the escape velocity for the Earth is 11.2 km s^{-1}, explain with the aid of a diagram why helium is almost non-existent in the Earth's atmosphere. **[3]**

5. (a) Name the four lowest layers of the atmosphere, and specify their heights and temperature profiles. A diagram is acceptable. **[4]**

(b) With the aid of a simple diagram, explain what the Hadley, Ferrel and Polar cells are, and explain briefly how they arise. **[3]**

6. (a) A river of lava, 1 km long by 1km wide, and with a surface temperature of 700 C, flows from a volcano. Assuming that it behaves like a perfect black body, and ignoring radiation from the surroundings, calculate the total power emitted as radiation from the upper surface of the lava. **[3]**

(b) Use Wien's Law to estimate the approximate wavelength at the maximum of the thermal radiation emitted by the Earth, given that the peak of the Sun's spectrum is at 550 nm. **[3]**

SECTION B

7. (a) With the aid of simple diagrams, briefly explain the theory of Croll-Milankoviç cycles. **[7]**

(b) Draw a labelled diagram to show the Earth's energy balance between incoming and outgoing radiation. Insert approximate numerical values for the main components of the radiation. **[11]**

(c) Name or specify four other mechanisms that might cause, or have caused, significant short- or long-term changes in the average temperature at the Earth's surface. **[2]**

8. (a) State three mechanisms for heat transfer across the boundary between two different media at different temperatures. Write down formulae for each of them, defining the symbols involved. **[9]**

(b) Explain what is meant by the 'U value' of a material. **[2]**

(c) A simple building is 5 m long by 4 m wide by 2.5 m high. The walls contain one window of 1.5 m^2 area and one door of 2 m^2 area. The construction has the following U values (in units of W m^{-2} K^{-1}): walls = 2.5, windows = 6.0, door = 2.5, roof = 3.0, floor = 1.5. The inside of the building is kept at 20 C while the outside temperature is 2 C. Calculate the total rate of energy loss, ignoring boundary layer effects and any other heat transfer mechanisms. **[7]**

(d) Give approximate numerical values for the heating efficiency of (a) a domestic central heating system (gas, oil) and (b) an electric fire. What would the efficiency of the electric fire fall to if the power station efficiency is taken into account? **[2]**

9. (a) Explain what the term 'residence time' means, and derive an approximate estimate for the residence time of water in the atmosphere. You may take the average mass of water vapour above 1 km^2 of the Earth's surface to be 3×10^7 kg. **[4]**

(b) The frictional force acting on a spherical droplet of radius r falling with velocity v in air is given by Stokes' law: $F_v = 6\pi\eta r v$, where η is the viscosity of air. Provide an estimate for the radius of a typical small cloud droplet and calculate its terminal velocity. Name two mechanisms by which cloud droplets become raindrops. **[6]**

(c) If a thunderstorm, with base area 4 km^2, produces rain at the rate of 3 cm per hour, which lasts for three hours, what is the total mass of water that has fallen as rain? Calculate the total latent heat of condensation of the water contained in the rainfall. Compare this value with the amount of energy from sunlight that falls on it during the rainfall period. You may assume that the sun is approximately directly overhead for the whole time. **[6]**

(d) Explain, in not more than a few sentences and with the aid of simple diagrams, one mechanism for the formation of lightning strokes between clouds and the ground.
[4]

10. (a) Define what is meant by a black body. **[2]**

(b) Write down an equation for Stefan's Law for the power radiated by a black body. **[2]**

(c) Calculate the mean temperature of the Earth in the absence of the greenhouse effect, but taking the albedo a (= 0.31) of the Earth into account . **[5]**

(d) Using a simple model of the greenhouse effect, calculate the mean temperature of the Earth. Give a reason why your model over-estimates the mean temperature. **[11]**

11. (a) What is meant by the term 'hydrostatic equilibrium'? **[2]**

(b) Derive an expression for hydrostatic equilibrium and show that for an isothermal atmosphere in hydrostatic equilibrium the pressure at height z can be written as:

$$p(z) = p(0)\exp(-z/H)$$

where M_{MEAN} is the mean molar mass of the air in kg and $H = RT/(gM_{MEAN})$. **[8]**

(c) Using the first law of thermodynamics as a basis, explain qualititatively, and in no more than a few sentences, what the term 'adiabatic process' means. **[3]**

(d) For a non-isothermal atmosphere, the dry adiabatic lapse rate is given by:

$$dT/dz = -g/C_{P\ AIR}$$

Calculate the temperature of the Earth's atmosphere at 5 km if the temperature at z = 0 is 280 K. **[2]**

(e) Discuss how this temperature might compare with that obtained from direct atmospheric measurements at the same height, and comment briefly, with the aid of a simple diagram, on how and why the lapse rate might be expected to vary with altitude in the troposphere. **[5]**