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	:	**11-MAY-04**
TIME	:	**10.00**
TIME ALLOWED	:	**2 Hours 30 Minutes**

TURN OVER

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

The numbers at 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:

Radius of the Earth (R_E)	= 6370 km.
Atmospheric pressure (at ground level)	= 10^5 Pa
Coriolis parameter (f_c)	= 10^{-4} s^{-1}
Density of air (at ground level)	= 1.2 kg m^{-3}
Specific heat capacity of air (C_P)	= 1000 J K^{-1} kg^{-1}
Acceleration due to gravity (g)	= 9.81 m s^{-2}
Density of water	= 1000 kg m^{-3}
Latent heat of evaporation of water	= 2.5 MJ kg^{-1}

SECTION A

1. Show that the *escape velocity*, v_e for a planet is given by $v_e = \sqrt{2gR}$ where g is the acceleration due to gravity at its surface and R is the radius of the planet and hence calculate the escape velocity of a particle from the Earth. **[5]**

Briefly discuss why the Earth has been able to retain nitrogen and oxygen in its atmosphere but not hydrogen or helium. **[2]**

2. What is meant by the *solar constant*? **[2]**

The mean distance from the Earth to the Sun is approximately 215 solar radii and the maximum and minimum distances from the Earth to the Sun are ± 2 solar radii with respect to this. Calculate the percentage change in the solar constant (with respect to the maximum value). **[3]**

Give two reasons why this effect cannot account for the seasons of the year. **[2]**

3. Discuss the mechanisms that are responsible for the separation of charge within a thunder-cloud and the production of a cloud to ground lightning strike. Why are these strikes associated with large cumulo-nimbus clouds, but not thin strato-cumulus clouds? **[7]**

4. What are the four forces that act on air parcels to produce a wind? **[2]**

Explain what is meant by a *geostrophic wind*. Your explanation should include a brief discussion of why these winds occur. **[3]**

What is the direction of rotation of the winds round an anticyclone in the Southern hemisphere? Give reasons for your choice. **[2]**

5. Discuss two advantages and two disadvantages of the use of solar power as a source of energy. [4]

A solar house has a large window on the South side and a blackened wall on the North side. Heat loss is only through the window, which has a thermal conductivity (U-value) of 10.0 $Wm^{-2}K^{-1}$. If the transmittance of the window is 0.9 and the absorbance of the wall is 0.8, what is the solar irradiance needed to maintain the room at a temperature 20C above the outside temperature? [2]

6. Define the *decibel* unit of noise. Discuss two factors that need to be taken into account when considering the impact of noise on humans. [4]

If a fast car produces a noise level equivalent to 75dB and a heavy lorry produces a noise level of 90dB, what is the total noise level experienced at the side of the road when a car overtakes a lorry? [2]

SECTION B

7. Describe the mechanisms that are responsible both for maintaining and destroying the ozone layer. [6]

Why is the "hole" in the ozone layer that appears over the Arctic Ocean in the Northern spring much smaller than the "hole" that appears over the Antarctic in the Southern spring? [5]

State the Beer-Lambert absorption law, explaining all the terms. Use this law to derive the expression

$$\ln \frac{I_G}{I_0} = -KN_t$$

where I_G is the intensity of ultra-violet radiation at ground level, I_0 the intensity of this radiation at the top of the atmosphere, K is the extinction coefficient for ozone and N_t is the total number of ozone molecules above 1 m^2 of the Earth's surface. [5]

A Dobson unit (DU) corresponds to 2.43×10^{20} ozone molecules over 1 m^2 of surface. If the ozone level is 125 DU when the "hole" is present compared with a normal ozone level of 325 DU, calculate the ratio of ultra-violet intensity when the "hole" is present compared to normal. Take the ozone extinction coefficient to be 10^{-22} m^2. [4]

8. Describe the main features of a dew-point meter and explain why it gives a direct measurement of the relative humidity of the surrounding air. **[6]**

The partial vapour pressure of water at the triple point is 610 Pa. Explain why air with a greater partial vapour pressure of water than this value should first deposit dew when cooled at constant pressure whereas air with a lower partial vapour pressure than this should deposit frost on cooling. Why, in practice, is dew often deposited under conditions when you would predict frost to form? **[5]**

If rain falls through a thick cold layer of air (that is below the freezing point) before hitting the ground, the ground is often covered with a layer of clear ice known as "glaze ice". Discuss the reasons for the formation of this layer. **[4]**

Local winds often blow from the (warm) Tasman Sea up the slopes of the mountains of the Great Dividing Range. Explain why fog is frequently found in the upper valleys of the mountains, but not so often in the lower ones. **[5]**

9. Draw labelled diagrams showing the main features of both the vertical and horizontal (ground level) global circulation of the atmosphere. Explain in detail the physical origin of the vertical circulation. **[12]**

Show that the longitudinal component of the velocity of the winds for a Hadley cell is given by

$$V = \Omega R_E \tan\phi \sin\phi$$

where Ω is the angular rotational velocity of the Earth, R_E is the radius of the Earth and ϕ is the latitude. Calculate this velocity when the latitude is 30^0. **[5]**

What physical feature of the circulation of the upper troposphere can be ascribed to this effect? Why are winds at ground level only a fraction of this value? **[3]**

10. Compare and contrast the advantages and disadvantages of hydro-electric and tidal power. Hence suggest reasons why the use of hydro-electric power is common, but the use of tidal power is very rare. **[10]**

Show that the maximum power available from a hydro-electric installation depends on $H^{3/2}$ where H is the head of water. A pumped storage system works by first filling the upper reservoir and then allowing the water to run through the turbines. Show that, provided that the change in depth of the reservoir during the cycle is negligible compared to the height of the reservoir above the turbine, the total time that the maximum power can be extracted from the reservoir varies as $H^{-1/2}$. **[6]**

Show that the mean power output from a tidal barrage is given by $AR^2 g\rho/2\tau$ where A is the area of the estuary, R the tidal range, ρ the density of water, g the acceleration due to gravity and τ the mean interval between tides. Discuss the approximations made in deriving this equation. **[4]**

11. Show that the dry adiabatic lapse rate is given by $\frac{dT}{dz} = -\frac{g}{C_P}$ where g is the acceleration due to gravity and C_P is the specific heat (heat capacity) of air at constant pressure. (You may assume the hydrostatic equation $\frac{dP}{dz} = -g\rho(z)$, where $\rho(z)$ is the density of air as a function of height). **[5]**

Calculate the lapse rate and explain the discrepancy between the result you obtain and that obtained experimentally (typically about 6.5×10^{-3} K m^{-1}). What evidence suggests that your explanation is correct? **[6]**

Explain what is meant by the *residence time* of a gas. The mole fraction of water in the atmosphere is 5.54×10^{-3}. The annual rainfall (averaged over the planet) is 800mm. Calculate the residence time of water in the atmosphere and the power required to maintain the atmospheric water cycle. The molecular weight of water is 18; the mean molecular weight of air is 28.96. **[9]**

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