UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For The Following Qualification:-

M.Sci.

Astronomy 4C14: Solar Physics

COURSE CODE	:	**ASTR4C14**
UNIT VALUE	:	**0.50**
DATE	:	**12-MAY-06**
TIME	:	**10.00**
TIME ALLOWED	:	**2 Hours 30 Minutes**

06-C0092-3-50

TURN OVER

Answer THREE questions

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

Relevant symbols and numerical values are as follows -

γ - ratio of specific heats (C_P/C_V); P - pressure; ρ - density; B – magnetic induction; j – current density; t –time; v – velocity; g – acceleration due to gravity; T –temperature; r – radial distance; E – energy; g_s – statistical weight
T_e - electron temperature; ε_λ - emission coefficient;
κ_λ - mass absorption coefficient;
$\tau_\lambda = \kappa_\lambda \rho$ - optical depth; $S_\lambda = \varepsilon_\lambda/\kappa_\lambda$ - source function; I_λ - specific intensity
$\mu = \cos\theta$ where θ is the angle between the radiation slant path and the vertical direction;

1 AU - 1 Astronomical Unit or mean Sun-Earth distance = $1.5\text{x}10^{11}$ m;
$G = 6.67\text{x}10^{-11}$ Nm^2/kg^2 (Universal gravitation constant);
$M_0 = 1.989\text{x}10^{30}$ kg (Solar mass);
$R_0 = 6.96\text{x}10^{8}$ m (Solar radius);
k_B - Boltzmanns constant = $1.38\text{x}10^{-23}$ Joule K^{-1};
$m_p = 1.67\text{x}10^{-27}$ kg (Proton mass);
$c = 2.997\text{x}10^{8}$ m/s (Velocity of light).
$\mu_0 = 4\pi \text{ x } 10^{-7}$ Hm^{-1} (magnetic permeability of free space)
$h = 6.63 \text{ x}10^{-34}$ Js (Planck's constant)
η = magnetic diffusivity
$\varepsilon_0 = 8.85\text{x}10^{-12}$ F/m (electrical permittivity of free space)
$\omega = 2.865 \cdot 10^{-6}$ rad s^{-1} (solar sidereal angular rotation)

Equations given:

Alfven speed:

$$v_A = \frac{B}{(\mu_0 \rho)^{1/2}}$$

PLEASE TURN OVER

1. Explain in physical terms what is meant by the solar constant. Given that its value has been determined to be 1.366×10^3 Wm^{-2}, calculate a value for the Sun's absolute luminosity and hence the effective temperature of the visible surface, where the Stefan-Boltzmann constant $\sigma = 5.67 \times 10^{-8}$ $Jm^{-2}K^{-1}s^{-1}$.

[8]

Assuming the relevant form of the Virial theorem to be:

$$3\int_0^{M_0} \frac{P}{\rho} dM + \Omega = 0$$

where the integral is with respect to mass M, M_o is the total mass of the Sun and Ω is the gravitational potential energy, show that

i) the Sun could not have sustained its luminosity for 4.6×10^9 years on its originally available gravitational potential or thermal energy (you should deduce the characteristic lifetimes for these two energy sources) and that

[6]

ii) the decrease in gravitational potential energy as the primordial gas cloud collapses to form the Sun leads to an increase in the Sun's internal energy.

[3]

By considering the energy of a proton calculate a value for the temperature at the centre of the Sun.

[3]

CONTINUED

2. Assuming that nuclear energy release is required to explain the observed solar luminosity, describe those factors that determine which nuclear reactions are most likely to occur in the solar interior.

[4]

The expression for the reaction rate between two nuclei is given by:

$$P_{1,2} = N_1 N_2 < \sigma v >_{1,2} \text{ reactions m}^{-3}\text{ s}$$

If N_1 and N_2 are the number densities of the reacting nuclei, explain what is represented by the factor $<\sigma v>_{1,2}$ and indicate the physical parameters on which it depends. Why are fusion reactions between nuclei of low atomic number favoured as energy sources?

[8]

What is a neutrino? Explain their significance in helping us to determine the structure of the Sun. What is meant by the solar neutrino problem and what possible scenarios are there for its solution? Which of these has been determined to provide a satisfactory explanation for the problem?

[8]

PLEASE TURN OVER

3. Describe the evolutionary development of solar active regions. List the main characteristics of the magnetic field in emerging active regions. Describe the decay process. Give an account of the migration pattern of the dispersed small-scale fields and how it is related to the magnetic cycle.

[7]

Outline the principal method for measuring magnetic field in the solar atmosphere. Indicate how the magnetic field is manifested in the corona and explain why it is difficult to measure. Give characteristic field strengths in sunspots, pores, polar regions, and coronal loops.

[4]

Calculate the speed at which magnetic disturbances can travel along the magnetic field

(a) at the base of the convection zone along an emerging flux tube ($B=10$ T, $\rho=7.54 \times 10^3$ kg m^{-3})
(b) in the photosphere along a flux tube of the network ($B=0.1$ T, $\rho=3.03 \times 10^{-4}$ kg m^{-3})
(c) in the chromosphere along an expanded flux tube of the network ($B=0.01$ T, $\rho=2.42 \times 10^{-10}$ kg m^{-3})

[4]

Describe the sense of Coriolis rotation for rising and expanding gas parcels in the Northern and Southern hemispheres. How do these values fit with those required in Babcock's dynamo model and for the explanation of the tilt of bipolar sunspot groups with respect to the equator? What is the role of such tilt in the dynamo model and at which stage of the Babcock model does this happen?

[5]

4. Give a brief summary of the properties of the solar wind and describe how its existence was inferred prior to the era of space observations. Why must a solar wind exist?

[3]

The solar wind equation is:

$$\frac{1}{v}\frac{dv}{dr}\left(v^2 - \frac{2kT}{m}\right) = \frac{4kT}{mr} - \frac{GM_\odot}{r^2}$$

Indicate the solutions graphically and show which one is closest to representing the observed solar wind flow?

[7]

Describe the differences in the properties and origins of the fast and slow components of the solar wind based on recent space-born observations by Yohkoh and SOHO. Describe the trajectory of the Ulysses spacecraft and give an account of the properties of solar wind that we learned from its observations. What effect does the solar cycle have on the solar wind?

[5]

Describe the geometry of the interplanetary magnetic field and explain why magnetic field lines take such a shape. Is the field geometry of the fast and slow solar wind different?

[3]

State a definition of the heliosphere and give a rough estimate of its size.

[2]

5. What is a solar flare? Describe, with the aid of a sketch, the current 'standard' flare model. [5]

Assuming the classical conductivity is given by $\sigma_0 = 10^{-3}T^{3/2}$ (ohm m)$^{-1}$ and that a typical pre-flare temperature is $2\text{x}10^6$ K with a length scale of $2\text{x}10^6$ m, use the induction equation to determine the diffusion timescale.

Compare this to observed flare timescales, and discuss under what conditions the magnetic energy could be dissipated on the observed timescales. How could these be achieved?

[5]

Describe what is meant by a coronal mass ejection (CME). Specify the relevant general properties and methods of observation.

[5]

Assuming that a CME can be well represented by a sphere of radius R_0, and that the corona is fully ionised, calculate the mass of a CME for a typical coronal density $N_e=10^{13}$ m^{-3}. If the speed of the CME is 400 km s^{-1}, calculate its kinetic energy. How does this compare to the typical energy of a large solar flare?

[5]

END OF PAPER