PRIFYSGOL ABERYSTWYTH UNIVERSITY

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DEPARTMENT OF PHYSICS

SEMESTER 2 EXAMINATIONS, MAY 2026

PH38820 – Physics of Planetary Atmospheres

Time allowed – 3 hours

- Full marks can be attained for complete answers to ALL eight questions in Section A and TWO questions from Section B.
- The numbers in brackets after the questions indicate the allocation of marks for each question.
- Only calculators from the Casio FX83, FX85 or FX991 range may be used.
- A booklet of mathematical formulae and standard constants will be provided.
- Only a 1 side of A4 summary sheet is allowed.
- Mae modd I fyfyrwyr gyflwyno atebion i'r papur hwn naill ai yn y Gymraeg neu'r Saesneg.
- Students may submit answers to this paper in either Welsh or English.

Once seated, students may complete the front cover of the answer book(s) and the attendance slip ONLY.

Do NOT turn the examination question paper over until instructed to do so.

Section A

Attempt ALL questions in the booklet provided.

1 Give an example of each of the following, with very brief reasons for your choice: [5]

a) A planet whose magnetospheric activity is strongly driven by solar wind changes

b) A planet whose magnetospheric activity is largely unaffected by solar wind changes

c) A planet with a stable ring current

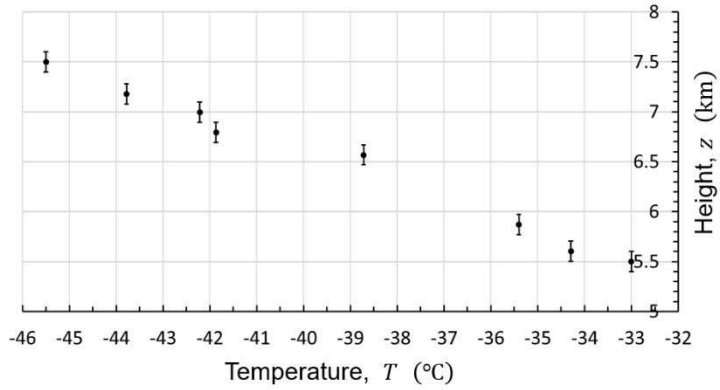
d) A planet with a comet like magnetosphere

e) A planet where aurora is produced by localised magnetic fields

2 Describe what is meant by relativistic ("killer") electrons. How and where are they produced, what are their effects and how can they be predicted and mitigated? [5]

3 Describe briefly the gradient wind in an anti-cyclone in the Northern hemisphere (or make a sketch of it); and explain the difference between gradient winds and gradient surface winds. [5]

4 In a tropospheric layer, the temperature was measured at eight heights as shown in the plot. [5]



Based on the measured temperatures and knowing that the mean specific heat capacity of the atmospheric layer is: $c_{\mathrm{P}} \approx 1.4\ \mathrm{J\ g^{-1}\ ^{\circ}C^{-1}}$, find out whether the tropospheric layer is convectively stable or unstable.

5 Find the centrifugal force that acts on an air parcel of mass $m = 50\ \mathrm{kg}$ in the mesosphere above Aberystwyth at altitude $z = 65\ \mathrm{km}$. [5]

The geographical coordinates, latitude and longitude, of Aberystwyth are $(\vartheta, \lambda) \approx (52.3°\ \mathrm{N}, 4°\ \mathrm{W})$. The Earth's radius is: $R \approx 6365\ \mathrm{km}$

6 Describe briefly the colours of the aurora, and at which heights are different colours dominant. Explain why there is a difference in the emission at different heights. [5]

7 Explain how an ionised layer can be formed in an atmosphere from UV photons. Draw an appropriate plot of the number density of photons, atmospheric particles and the electrons. [5]

8 Sketch the altitude profiles of the electron density for daytime when it is: [5]

i) solar maximum

ii) solar minimum

Explain why there is difference between the two.

Section B

Answer **TWO** of the three sets of questions.

9 In hydrostatic equilibium, the vertical pressure profile of a one-kilometer thick layer of the Earth's atmosphere with its base being at altitude $z_0 = 3\ \mathrm{km}$ is:

$$P(z) = A + \frac{B}{z}$$

The constants are: $A = 52\ \mathrm{kPa}$ and $B = 8.5 \times 10^7\ \mathrm{kg\ s^{-2}}$

The molar mass of the air in the layer is $M = 29\ \mathrm{g\ mol^{-1}}$; and $g = 9.8\ \mathrm{m\ s^{-2}}$.

a) At the base, z_0, of the layer, find the following state variables of the atmosphere:

i) Pressure, $P(z_0)$

[2]

ii) Density, $\rho(z_0)$

[6]

iii) Temperature, $T(z_0)$

[3]

b) Work out how much the above three quantities decrease in $\Delta z = 100\ \mathrm{m}$ height. That is, find $\Delta P = P(z_0 + \Delta z) - P(z_0)$, $\Delta\rho = \rho(z_0 + \Delta z) - \rho(z_0)$, and $\Delta T = T(z_0 + \Delta z) - T(z_0)$.

[9]

10 a) In an atmospheric model, we can derive the following equation, which relates the angular frequency, ω, and wave vector, $\mathbf{k}$, of an atmospheric wave:

$$\omega = Ak_{\mathrm{h}}k_{\mathrm{v}}$$

Here, k_{h} and k_{v} are the horizontal and vertical components of the wave vector, respectively: $\mathbf{k} = (k_{\mathrm{h}}, k_{\mathrm{v}})$

i) Name the equation.

[1]

ii) Give the physical unit of constant A.

[1]

iii) Derive the phase- and group velocities, $\mathbf{v}_{\mathrm{ph}} = (v_{\mathrm{ph\,h}}, v_{\mathrm{ph\,v}})$ and $\mathbf{v}_{\mathrm{gr}} = (v_{\mathrm{gr\,h}}, v_{\mathrm{gr\,v}})$, where 'h' and 'v' in the indices indicate the horizontal and vertical components of the vectors, respectively.

[4]

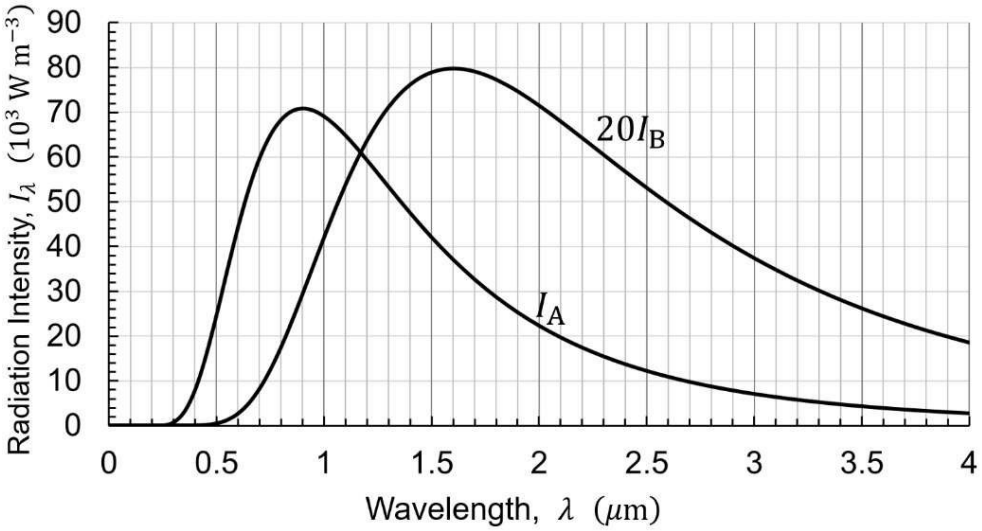
iv) Work out the phase speed and group speed, that is, the magnitudes of the two characteristic velocities.

[2]

v) Can you say anything about the angle between the two velocities: are they parallel, anti-parallel, or perpendicular to each other, or not?

[2]

b) The two graphs show the spectral irradiance, I_A and I_B, of two sides of exoplanet WASP 121b against wavelength for $\lambda \leq 4\ \mu\text{m}$.
(I_B is multiplied by 20 to be able to see the two spectra together, in one panel.)



i) Which of the two radiation spectra is from the dayside and which is from the nightside of the planet? Explain your answer.

[2]

ii) Determine the surface temperatures of the two sides of the planet by using Wien's displacement law.
Wien's constant is: $b \approx 2.9 \times 10^{-3}\ \text{K m}$

[4]

iii) What could be the reason for such a big temperature difference between the two sides?

[2]

iv) Using Stefan-Boltzmann law, $E = \sigma T^4 A t$, estimate the total energy radiated by the planet on its nightside every second, $t = 1\ \text{s}$, and per unit area, $A = 1\ \text{m}^2$;
$\sigma = 5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$

[2]

11 a) Explain what the kp, AE and DST geomagnetic indices are. How are they derived? What does each index tell us?

[5]

b) For ground-based magnetometers explain the DZH coordinate system.

[2]

c) A westward electrojet is above a magnetometer chain with five stations running from magnetic north to south.

i) Sketch this situation with the direction of the current and the magnetometer chain and indicate the direction of the magnetic field.

[3]

ii) Describe what each magnetometer station would measure in the H and Z components for a station that is:

1. Far south of the electrojet
2. At the south edge of the electrojet
3. Directly below the electrojet
4. At the north edge of the electrojet
5. Far north of the electrojet

[6]

d) Suppose you have a maximum deflection of the H component that is 200nT, and the estimated altitude is 100km. By using Ampere's law:

$$\oint B \cdot dl = \mu_0 I_{\text{enc}}$$

and approximating the current as a long wire, give an estimate of the current.

[4]

END OF PAPER