GCE PHYSICS

S21-A420QS

Assessment Resource number 18

Electricity and the Universe Resource I

1

(a) Describe the main features of the spectrum of a star **and** state where in the star they arise. [2]

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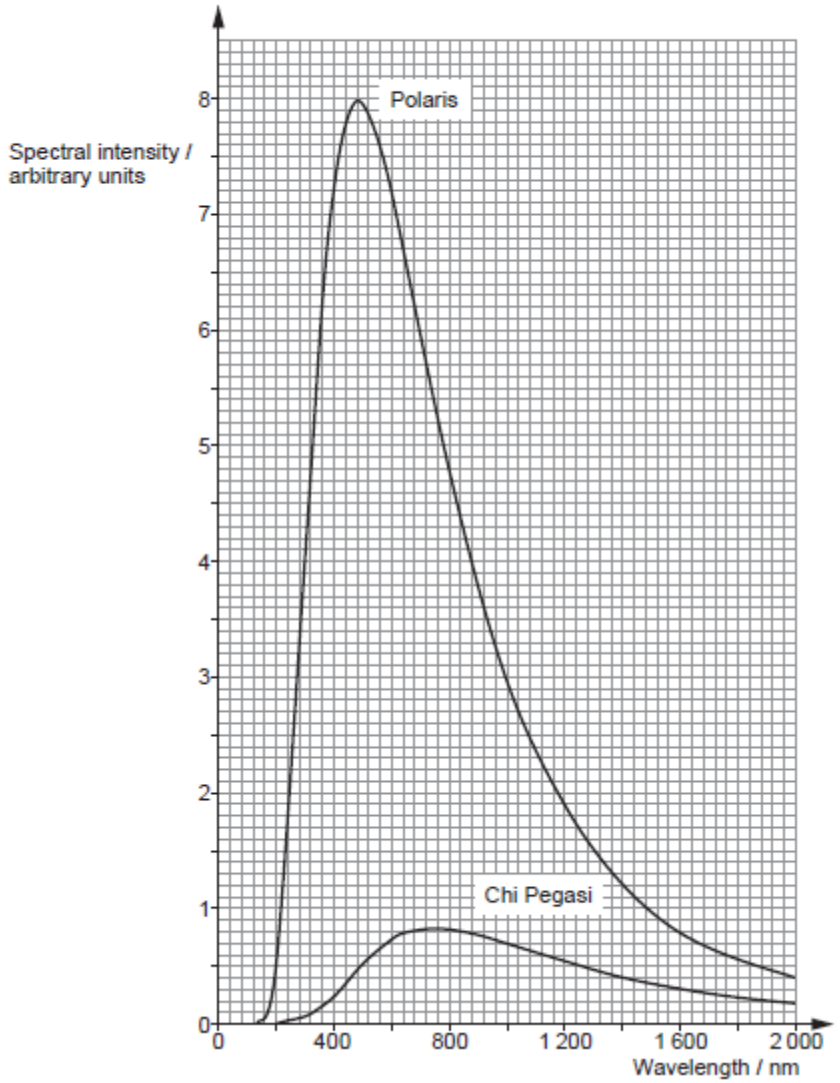
(b) The graph shows the black body radiation curves for the two stars **Polaris** (sometimes called the North Star) and **Chi Pegasi** (a red supergiant in the constellation Pegasus). **The stars are equidistant from Earth.**



(i) Suggest **three** differences between Polaris and Chi Pegasi. [3]

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(ii) Polaris is 431 light years from Earth and the intensity of radiation received on Earth from it is $4.05 \times 10^{-9}\,W\,m^{-2}$. Use this information and the graph to calculate the radius of Polaris. [1 light year = 9.46×10^{15} m] [5]

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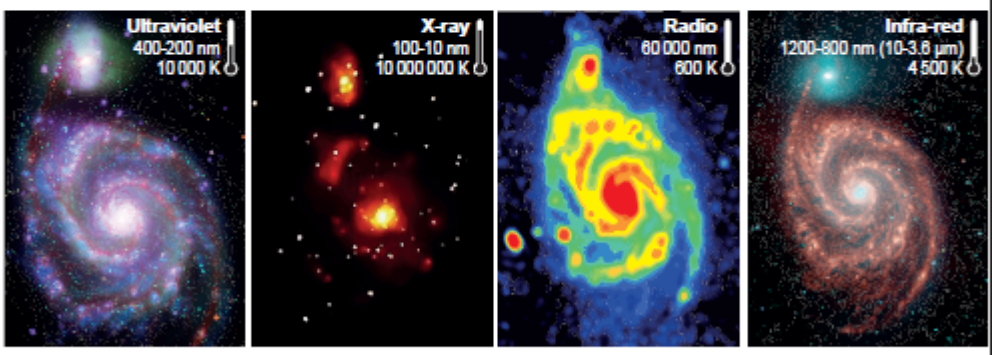
(c) The image below is of the whirlpool galaxy, M51 (or NGC 5194). This is one of the first images of the galaxy taken by astronomers.

Subsequent images of the **same galaxy** are shown below.



Describe how these developments in observational astronomy have advanced the study of the whirlpool galaxy. [3]

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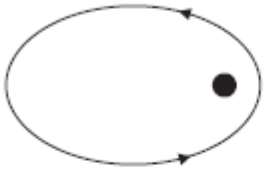
(a) The diagram shows the elliptical orbit of a planet around a star. Use the diagram (by adding to it) to explain Kepler's second law of planetary motion. [2]



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(b) Starting with Newton's law of gravitation, show that for a circular orbit, the period of orbit, T, of a planet around a star is related to its distance, r, from the centre of the star by the relationship $T^2 \alpha r^3$. [Assume the mass of the planet is much less than the mass of the star.] [3]

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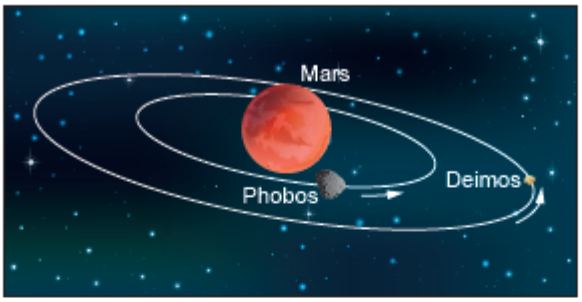
(c) Mars has two small moons, Phobos and Deimos. The diagram shows their orbital paths around Mars.



(i) Phobos has an orbital period of 7.7 hours and the radius of its orbit is 9400 km. Show that the mass of Mars is approximately 6.4×10^{23} kg. [3]

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(ii) It is proposed to send a space-probe to study Phobos and Deimos. The first part of the mission will be to place the probe in orbit around Phobos.

I. Show that the gravitational potential due to Mars at the Phobos orbit is approximately $-4.5\,\text{MJ kg}^{-1}$. [2]

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II. The second part of the mission involves manoeuvring the space-probe into a higher orbit to enable it to study Deimos. However, on the journey to Mars the probe used more fuel than was expected. Scientists are now unsure as to whether or not the probe has enough fuel to enable it to reach the orbit of Deimos. The following information is available:

Energy available per kg of space-probe: 4.4 MJ kg^{-1}
Efficiency of fuel-burn process: 60 %
Distance of Deimos from centre of Mars: 23 500 km

Assuming the mass of the fuel is very small compared to the mass of the probe itself, and ignoring the gravitational effects of both moons, determine whether or not the scientists should attempt the manoeuvre. [4]

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(iii) Explain why it is not possible to use the equation $\Delta E_p = mg\Delta h$ when determining the change in the gravitational potential energy of the probe as it moves between these orbits. [1]

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(a) Calculate the critical density of the universe giving appropriate units. [2]

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(b) An astronomer makes the following statement:

Assuming that the rate of expansion of the universe is constant, two objects a distance R apart in space will increase their separation by nearly 15% over a 2 billion year period.
[1 billion = 1×10^9 years]
Justify this statement. [3]

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(c) A star in a distant galaxy shows a bright hydrogen emission line at 475 nm. The equivalent emission line on Earth has a wavelength of 410 nm.

(i) Calculate the radial velocity of the star. [2]

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(ii) Calculate the distance of the star from the Earth. [2]

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(iii) The temperature of the photosphere of the star is 7 100 K. Calculate the mean kinetic energy of particles in the photosphere. Give your answer in eV. [2]

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