Q1. In 1999 a planet was discovered orbiting a star in the constellation of Pegasus.

(a) State **one** reason why it is difficult to make a direct observation of this planet.

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(1)

(b) The initial discovery of the planet was made using the radial velocity method which involved measuring a Doppler shift in the spectrum of the star.

Explain how an orbiting planet causes a Doppler shift in the spectrum of a star.

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(2)

(c) The discovery was confirmed by measuring the variation in the apparent magnitude of the star over a period of time.

Explain how an orbiting planet causes a change in the apparent magnitude of a star. Sketch a graph of apparent magnitude against time (a light curve) as part of your answer.

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(3)
(Total 6 marks)

Q2. Treated as a single source, the Andromeda galaxy has an apparent magnitude of 3.54 and an absolute magnitude of –20.62.

(a) Calculate the distance to the Andromeda galaxy.

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(2)

(b) The Andromeda galaxy is believed to be approaching the Milky Way at a speed of 105 km s^{-1}.
Calculate the wavelength of the radio waves produced by atomic hydrogen which would be detected from a source approaching the observer at a speed of 105 km s^{-1}.

wavelength of atomic hydrogen measured in a laboratory = 0.21121 m.

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(2)

(c) Some astronomers believe the Andromeda galaxy may collide with the Milky Way in the distant future. Estimate a time, in s, which will elapse before a possible impact with the Milky Way.

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(2)

(Total 6 marks)

Q3. The red shift of a galaxy's spectrum can be used to determine its velocity, relative to the Earth.

(a) The wavelength of the hydrogen alpha line in the spectrum of the galaxy NGC 1357 is 660.86 nm. The wavelength of the same line from a laboratory based source is 656.28 nm. Calculate the velocity of galaxy NGC 1357.

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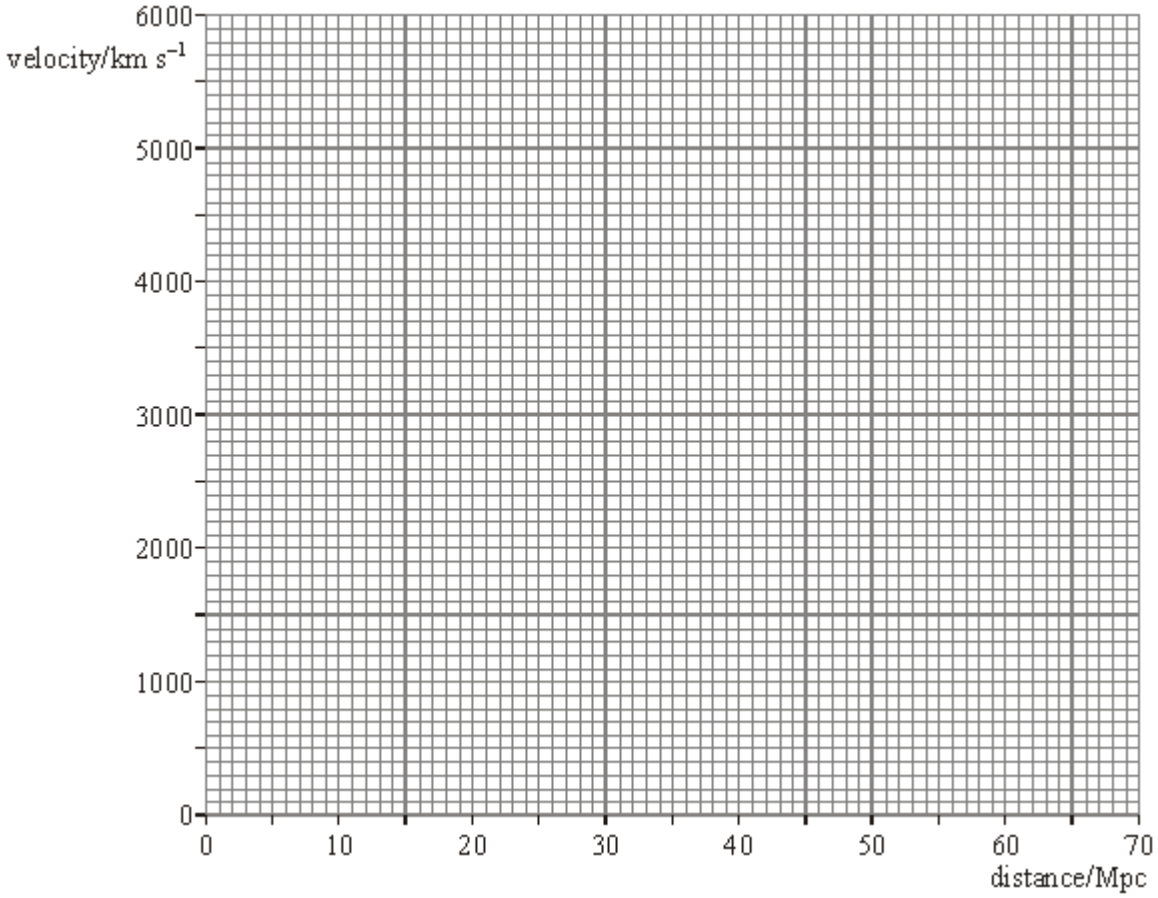
(2)

(b) Use the value obtained in part (a) to complete the table. Plot a graph of the data in the table below and use the graph to determine a value for the Hubble constant.

galaxy	velocity/km s^{-1}	distance/Mpc
NGC 1357		28
NGC 1832	2000	31
NGC 5548	5270	67
NGC 7469	4470	65



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(3)
(Total 5 marks)

Q4. The Earth's atmosphere absorbs electromagnetic radiation of certain wavelengths. Detectors on the surface of the Earth are largely restricted to the visible and radio regions.

(a) (i) On the axes below, draw the black body radiation curve for the Sun.

(ii) Mark on the wavelength axis the region affected by the atmosphere's absorption of ultra violet radiation.

(iii) What is responsible for this absorption?

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(iv) What effect can this absorption have on the measured temperature of a star? Explain your answer.

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(4)

(b) The atmosphere has little effect on radio waves between 30 MHz and 300 GHz. This radio window was first exploited in 1946 when a short pulse of radio waves of wavelength 2.7 m was transmitted from the Earth and reflected back by the Moon.

(i) Show that the frequency of the transmitted waves falls within the radio window.

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(ii) The experimenters had to take into account the relative movement of the Earth and Moon when tuning the receiver. The maximum difference between the frequency of the detected and transmitted waves was 300 Hz.

What is the name of this effect?

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(iii) Calculate the relative velocity of the Earth and Moon when the frequency of the received signal was 300 Hz greater than the transmitted frequency.

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(5)
(Total 9 marks)

Q5. Photographs of lines in the spectrum of the Sun show changes in wavelength due to the Doppler effect. Due to the rotation of the Sun about its axis, one edge of the Sun is approaching the Earth, and the other edge is receding.

(a) Give expressions for the observed change in the wavelength of a line of original wavelength, λ,

(i) for light coming from the edge which is moving away from the observer at speed v,

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(ii) for light coming from the edge which is moving towards the observer at speed v.

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(2)

(b) The apparent wavelength of a line of original wavelength 589 nm is measured from photographs showing opposite ends of the diameter of the Sun. The difference between the readings is 78×10^{-3} nm.

Calculate

(i) the speed, v, of a point on the edge of the Sun,

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(ii) the angular speed of rotation of the Sun.
radius of Sun = 7.0×10^{8} m

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(4)
(Total 6 marks)