Q1. The concave mirrors used in some reflecting telescopes can suffer from spherical aberration.

(a) Draw a diagram to show what is meant by spherical aberration when produced by a concave mirror.

(2)

(b) The International Ultraviolet Explorer (IUE) and the Gran Telescopio Canarias (GTC) are two examples of reflecting telescopes.

The table below summarises some of the properties of the two telescopes.

Name	IUE	GTC
Objective Diameter	0.45 m	10.4 m
Location	Geosynchronous Earth orbit	Earth's surface, 2300 m above sea level
Spectrum detected	Ultraviolet	Visible and Infrared
Typical wavelength detected	2.0×10^{-7} m	1.0×10^{-6} m

Compare the two telescopes in terms of their location, collecting power and minimum angular resolution.

Include calculations to support your comparisons.

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(6)

(c) The Charge Coupled Device (CCD) is an important part of the detection system of many modern telescopes due to its high quantum efficiency.

Explain what is meant by quantum efficiency and compare the quantum efficiency of a CCD with that of the eye.

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(2)
(Total 10 marks)

Q2. Many astronomical observations rely on a Charge Coupled Device (CCD) to obtain an image. Describe the structure and operation of the CCD and discuss the advantages of using a CCD for astronomical observations.

The quality of your written communication will be assessed in this question.

(Total 6 marks)

Q3. The last refracting telescope that could be called 'the largest optical telescope in the world' was one with an objective lens of diameter 0.90 m. It was superseded in 1889 by a reflecting telescope with an objective mirror of diameter 1.52 m.

(a) Calculate

(i) the ratio $\frac{\text{resolving power of the reflector}}{\text{resolving power of the refractor}}$,

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(ii) the ratio

$$\frac{\text{the amount of light energy that can be collected per second by the reflector}}{\text{the amount of light energy that can be collected per second by the refractor}}.$$

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(3)

(b) Spherical aberration can be a problem with reflecting telescopes.

(i) Draw a ray diagram to show how spherical aberration arises in a reflecting telescope.

(ii) State how this problem can be prevented.

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(2)

(c) The image produced by a refracting telescope can be clearer than that of a similar diameter reflector because of the position of the secondary mirror.

(i) Sketch a diagram to show the position of the mirrors in a Cassegrain telescope.

(ii) Give **two** reasons why the secondary mirror in the Cassegrain telescope affects the clarity of the image.

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(3)
(Total 8 marks)

Q4. (a) Draw a ray diagram to show the path of two rays, parallel to the axis, through a Cassegrain telescope, as far as the eyepiece.

(2)

(b) The UKIRT is a Cassegrain telescope capable of detecting both infrared and visible radiation. It has an objective diameter of 3.8 m.

(i) Calculate the resolving power of this telescope for infrared light of wavelength 2.0 μm.

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(ii) Explain why the resolving power of this telescope is better in the visible region than in the infrared region.

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(4)

(c) To reduce atmospheric absorption problems, the telescope was built at the top of Mount Mauna Kea in Hawaii.

(i) What, in the atmosphere, is responsible for absorbing infrared radiation?

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(ii) The spectrum of light from a star can be used to determine its temperature. Explain why this absorption can lead to errors in the value.

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(3)
(Total 9 marks)