Q1.(a) The table summarises some of the properties of Vesta, one of the largest objects in the asteroid belt between Mars and Jupiter.

Diameter / m	**Distance from the Sun / AU**	
	smallest	largest
5.4×10^5	2.15	2.57

(i) Calculate the largest possible distance, in m, between the Earth and Vesta.

distance = ... m

(2)

(ii) Show that when Vesta is at a distance of 1.73×10^{11}d m from Earth, the angle subtended by Vesta to an observer on Earth is about 3×10^{-6} radian.

(2)

(b) Observations of Vesta have been made by the Infrared Telescope Facility (IRTF) in Hawaii.

(i) Draw a ray diagram for a Cassegrain telescope.

(2)

(ii) The IRTF includes a camera capable of detecting infrared radiation with wavelengths in the range 1.0 μm to 5.0 μm.

The smallest angle the telescope can resolve is 3.3×10^{-7} radian.

Calculate the diameter of the objective of the telescope.
Give your answer to a suitable number of significant figures.

diameter of objective = ... m

(2)

(c) Discuss the level of detail the IRTF would be able to detect on the surface of Vesta, when Vesta is 1.73×10^{11} m from Earth.

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(2)
(Total 10 marks)

Q2. 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)

Q3. (a) Draw the ray diagram for a Cassegrain telescope. Your diagram should show the paths of two rays, initially parallel to the principal axis, as far as the eyepiece.

(2)

(b) A telescope design very similar to the Cassegrain was first proposed by James Gregory in 1663. His telescope design was also the first to include a parabolic primary reflector.

(i) The use of a parabolic reflector overcomes the problem of *spherical aberration.* Draw a ray diagram to show how spherical aberration is caused by a concave spherical mirror.

(1)

(ii) The first telescope constructed to this design had a primary mirror of diameter 0.15 m. Calculate the minimum angular separation which could be resolved by this telescope when observing point sources of light of wavelength 630 nm. State an appropriate unit.

answer = ...

(2)

(iii) The astronomer Edmund Halley claimed to have used this telescope to observe the Cassini division, a dark band in the rings of Saturn. Calculate the angle subtended by the width of this band at the Earth, and comment on whether Halley's claim is likely to be valid.

width of Cassini division = 4.8×10^3km

distance from Earth to Saturn = 1.4×10^9km

answer = ...

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(2)
(Total 7 marks)