9.4 Resolution

Question Paper

Course	DP IB Physics
Section	9. Wave Phenomena (HL only)
Topic	9.4 Resolution
Difficulty	Medium

Time allowed: 70

Score: /56

Percentage: /100

Question 1a

A woman is rowing a boat towards two ancient statues situated on an island. The woman can just resolve the images of the two statues.

(a)
Describe whether the Rayleigh criterion applies to this scenario.

[3]

[3 marks]

Question 1b

The pupils in the woman's eyes have a diameter of 2.3 mm. The average wavelength of the sunlight is 570 nm.

She can just resolve the images of the two statues when her distance from them is 10 km.

(b)

(i)
Calculate the angular separation of the two statues when the images can just be resolved.

[2]

(ii)
Determine the distance between the two statues.

[1]

[3 marks]

Question 1c

Around the other side of the island, there are two further statues. These are situated at a distance apart of 0.73 m.

(c)
Determine how far the woman can row away from the island before she can no longer resolve these two statues.

[2]

[2 marks]

Question 1d

The sun begins to set and the average wavelength of light is now 500 nm. The woman's pupils dilate to give a wider diameter of 3.1 mm.

(d)
Determine the new distance at which the woman can resolve the second set of statues.

[3]

[3 marks]

Question 2a

Two distant stars are detected on earth using a telescope with a circular receiving dish.

(a)
Outline the criteria to enable light from the two stars to be just resolved.

[3]

[3 marks]

Question 2b

The stars are both situated in a galaxy 5.4×10^{25} m from the Earth and are 3.7×10^{20} m apart.

The wavelength of light received from the stars is 9.3 μm.

(b)
Calculate the minimum size of the circular receiving dish required to resolve the image of the two stars.

[2]

[2 marks]

Question 2c

The same telescope is used to observe a different galaxy at a distance of 3.8×10^{27} m from Earth. The astronomer wishes to resolve two stars with a separation of 2.3×10^{22} m.

(c)
Determine whether the telescope is able to resolve the light from the stars.

[2]

[2 marks]

Question 2d

The astronomer working with the telescope wishes to determine if sodium is present in the stars. To do this they use a diffraction grating to split the light from the star.

The two wavelengths of light they wish to resolve are 589.0 nm and 589.6 nm.

(d)
Determine the resolving power of the diffraction grating required to resolve these wavelengths.

[3]

[3 marks]

Question 3a

Monochromatic light of wavelength 610 nm is incident normally on a single narrow slit. A diffraction pattern is formed on a screen.

(a)
Sketch a graph to show the variation of relative light intensity with angle, measured from the centre of the slit.

[3]

[3 marks]

Question 3b

The single narrow slit is replaced by a diffraction grating.

(b)
Describe how the Rayleigh criterion allows the new diffraction pattern to be predicted.

[4]

[4 marks]

Question 3c

A second monochromatic light source of 630 nm is placed alongside the original monochromatic light source of wavelength 610 nm. The width of the beam of light from these sources is 2.0 mm.

(c)

(i)
Calculate the resolving power of the diffraction grating.

[3]

(ii)
Calculate the minimum number of lines per mm required to resolve the two light sources for the second order maximum.

[2]

[5 marks]

Question 3d

The diffraction grating is replaced with with 200 lines per mm.

(d)
Calculate the resolving power of the new grating under the same conditions

[2]

[2 marks]

Question 4a

A binary star system is observed using a telescope with a circular lens. The images of the two stars can just be resolved according to the Rayleigh criterion.

(a)
Outline what is meant by the statement "just resolved according to the Rayleigh criterion" in this context.

[2]

[2 marks]

Question 4b

The circular lens has a diameter of 4 mm. The distance from the Earth to the binary star system is 6.2×10^{16} m, and the average wavelength of light emitted by the stars is 470 nm.

(b)
Determine the separation of the two stars.

[2]

[2 marks]

Question 4c

The telescope is directed at a different area of the sky to detect further binary systems, using a larger diameter lens. A potential binary system with the same average wavelength of light, and the same separation between the stars is detected at 9.1×10^{18} m distance from the earth.

(c)
Determine the diameter of the new lens.

[2]

[2 marks]

Question 4d

The light from the binary system is passed through a diffraction grating with 430 lines per mm. The difference in wavelength between the two stars is 1.3 nm.

(d)

(i)
Determine the resolving power of the diffraction grating

[1]

(ii)
Hence calculate the width of the beam of light received from the stars to produce resolution of the two stars in the 3rd order spectrum

[2]

[3 marks]

Question 5a

A man stands on an airstrip at night as a car approaches him. His pupils have a diameter of 3.2 mm and the wavelength of the light is 490 nm. He can just resolve the light from the headlights of the car into two distinct points.

The car is moving at 20 m s^{-1} and the headlights are 1.6 m apart.

(a)

(i)
Calculate the Rayleigh criterion for this situation.

[1]

(ii)
Determine the time the man has to leave the airstrip before he is hit by the car.

[2]

[3 marks]

Question 5b

(b)
Draw a labelled sketch of the variation of intensity of light with angle, θ, as it falls on the man's retina at the point where the two headlights can just be resolved.

[3]

[3 marks]

Question 5c

Hovering above the airstrip is a helicopter on which the man can just resolve two light sources. The helicopter is hovering at 25% of the distance at which the car lights were able to be resolved, and the separation between the lights is 0.45 m. The pupil diameter of the man remains unchanged.

(c)
Determine the wavelength of the light emitted by the helicopter's lights.

[3]

[3 marks]

Question 5d

The man is holding blue lights in each hand to guide the helicopter to a safe landing. He switches to using red lights whilst maintaining the same separation.

(d)
Explain the effect on how the helicopter pilot observes the lights

[3]

[3 marks]