9.5 Doppler Effect

Question Paper

Course	DP IB Physics
Section	9. Wave Phenomena (HL only)
Topic	9.5 Doppler Effect
Difficulty	Medium

Time allowed: 80

Score: /61

Percentage: /100

Question 1a

The Doppler effect can be used to determine whether a star is moving away from or towards the Earth.

(a)
Outline what is meant by 'Doppler effect' in this context.

[2]

[2 marks]

Question 1b

In a laboratory, the spectrum of atomic hydrogen has a wavelength of 656.61 nm. The spectrum of a star observed on Earth is found to have the same line in the spectrum shifted to 656.54 nm.

(b)

(i)
Calculate the speed of the star relative to the Earth.

[2]

(ii)
Explain whether the star is moving towards or away from the Earth.

[2]

[4 marks]

Question 1c

A second spectral line is observed at 567.34 nm in the laboratory.

(c)
Determine the frequency of the spectral line from the star, as observed on Earth.

[3]

[3 marks]

Question 1d

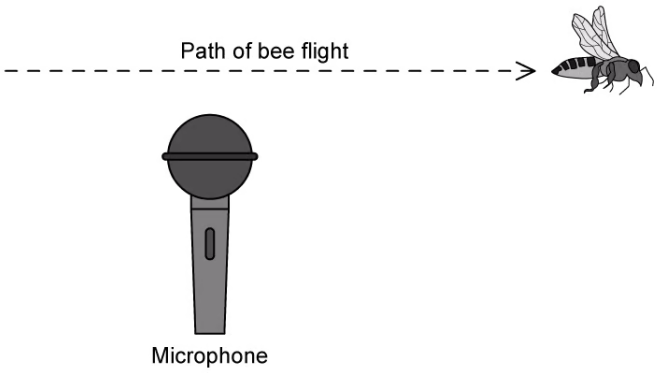
(d)
Explain the effect on the colour of light from the star if it were travelling towards the Earth.

[2]

[2 marks]

Question 2a

A scientist is conducting an experiment on bees. They set up monitoring equipment near a hive, including a microphone which picks up the buzz from individual bees flying past.



A single bee flies at a constant speed in a straight line past the microphone, and the frequency of the buzz is detected.

(a)
Explain the sound pattern detected by the microphone as the bee moves towards and away from the microphone.

[3]

[3 marks]

Question 2b

The speed of the bee is 8.9 m s^{-1}. The maximum frequency of sound recorded by the microphone is 271 Hz. The speed of sound in air is 340 m s^{-1}.

(b)

(i)
Calculate the frequency of sound produced by the bee.

[2]

(ii)
Determine the minimum frequency recorded by the microphone.

[1]

[3 marks]

Question 2c

When bees are about to swarm, they produce a higher pitched buzz, known as 'piping'. The frequency of the piping sound is 550.0 Hz. The scientist moves the microphone closer to the hive during this process. Whilst they are moving the change in observed frequency is 3.4 Hz.

(c)
(i)
Determine the speed at which the scientist walks towards the hive.

[3]

(ii)
Explain the effect of any assumptions made in determining this speed.

[2]

[5 marks]

Question 2d

The swarm moves across the garden in which the hive is situated, travelling a distance of 13 m. The swarm is in flight for 2.1 s.

(d)
Calculate the wavelength of sound detected by the microphone during the flight of the swarm.

[4]

[4 marks]

Question 3a

An ambulance siren emits two pure sounds. The lower of the two sounds has a frequency of 650 Hz. It is travelling towards a stationary observer at 13.4 m/s. The speed of sound in air is 340 m s^{-1}.

(a)
Calculate the change in frequency, Δf, between the source frequency and that heard by the observer.

[2]

[2 marks]

Question 3b

The ratio between the two frequencies emitted by the ambulance is 0.722.

(b)

(i)
Determine the second frequency as heard by the observer.

[3]

(ii)
Explain the effect a change in speed of the ambulance will have on the ratio between the two observed frequencies.

[2]

[5 marks]

Question 3c

As the ambulance approaches a red light at which a number of cars are stopped, it changes its siren to a single monotone sound which the car drivers observe as 700 Hz. The ambulance slows further to 5.3 m s^{-1}.

(c)
Calculate the wavelength of sound emitted by the ambulance.

[3]

[3 marks]

Question 3d

The ambulance pulls to a stop but continues to emit the 700 Hz tone. A car passes the ambulance. As it moves away the sound heard by the car driver has a frequency of 682 Hz.

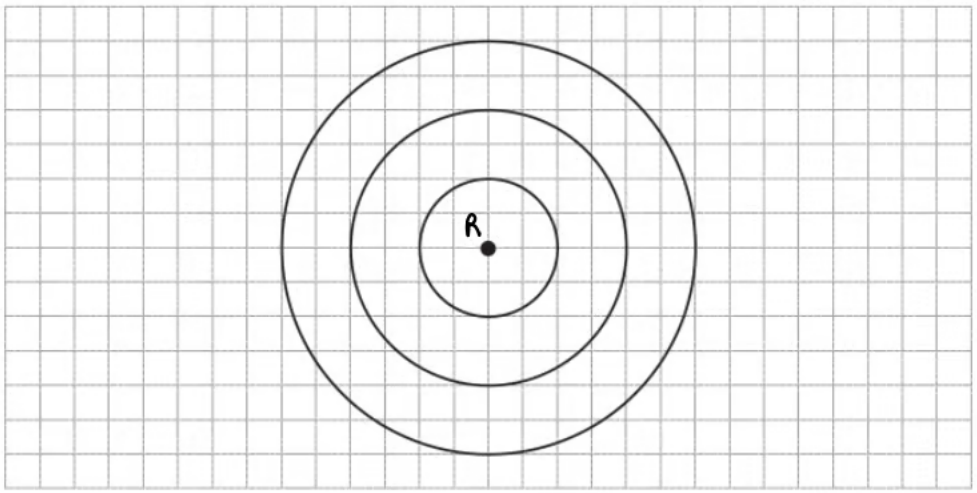
(d)
Determine the speed of the car as it drives away from the ambulance

[2]

[2 marks]

Question 4a

The diagram shows a stationary wave source, R, in water. The source produces waves with a constant frequency. The distance between each successive wavefront is equal to the wavelength of the waves produced by R.



The speed of the waves in water is v.

(a)
Sketch three successive wavefronts produced when the source is moving to the right at a speed of $0.75v$.

[2]

[2 marks]

Question 4b

A scientist sits on a boat to the right of the source and measures the frequency of the waves as they approach.

(b)
Explain the observations the scientist will make.

[2]

[2 marks]

Question 4c

The speed of the waves is 2.5 m s^{-1}. The wavelength of the waves as emitted by the source is 3.45 m.

(c)
Calculate the frequency of the waves as observed by the stationary boat.

[2]

[2 marks]

Question 4d

The boat starts to move. Source R is still moving at 0.75v to the right.

(d)
Discuss the effect the motion of the boat will have on the observed frequency of the water waves. Assume there is no acceleration.

[4]

[4 marks]

Question 5a

Every year, an alien species holds a race between two teams. One of the teams has green lights on its spaceships and the other has purple light. During the race the two ships approach a space station.

From the point of view of the space station commander, on the space station, the two colours appear to be identical. as the ships approach the station.

(a)
Explain how the commander knows which spaceship is travelling faster.

[2]

[2 marks]

Question 5b

The wavelength of light from the purple ship is 420 nm and from the green ship is 550 nm. The observed frequency of both ships from the space station is 405 nm.

(b)

(i)
Determine the speed of the purple ship.

[2]

(i)
Determine the ratio of speeds between the two ships.

[2]

[4 marks]

Question 5c

The green space ship enters the atmosphere of a planet near the spaceship for the victory ceremony, which has amassed a large crowd. It slows down to 0.005% of its speed during the race. As it nears the surface it emits a continuous tone of frequency 2320 Hz. The speed of sound in the atmosphere of this planet is 5690 m s^{-1}.

(c)
Calculate the frequency of sound observed by the crowd.

[2]

[2 marks]

Question 5d

The space station also has the capacity to detect light from other galaxies. In a laboratory, the frequency of electromagnetic radiation from a distant galaxy has been redshifted by 4.2×10^{9} Hz. In the laboratory, the same light has a frequency of 1.9×10^{12} Hz.

(d)

(i)
Calculate the speed of recession of the galaxy.

[1]

(ii)
Discuss the implications of the recession of the galaxies in the universe.

[4]

[5 marks]