9.5 Doppler Effect

Question Paper

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

Time allowed: 80

Score: /63

Percentage: /100

Question 1a

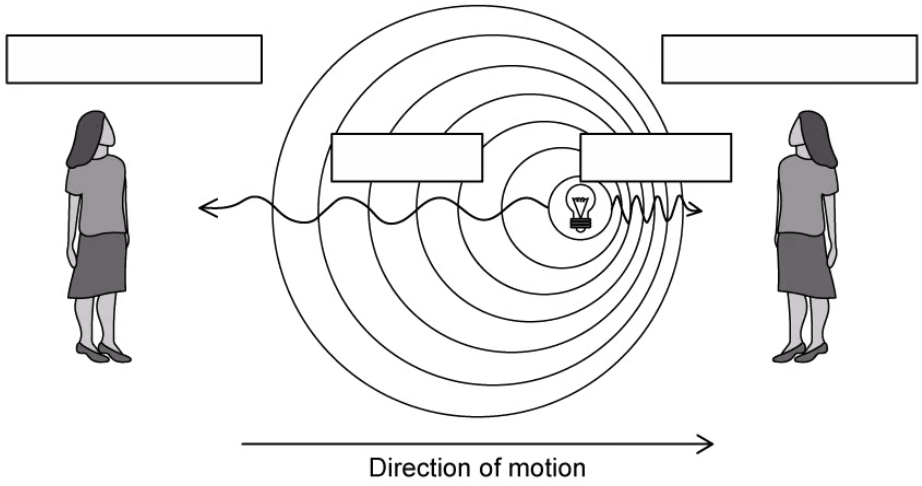
(a)
Define the Doppler effect.

[3]

[3 marks]

Question 1b

The diagram shows two people observing the same light source, which is in motion. The light is moving to the right.



(b)
Complete the boxes on the diagram with words or phrases from the list below.

[4]

higher frequency	lower frequency	phase difference	wavelength
blue shift	relative motion	star	red shift

[4 marks]

Question 1c

The following text is about the Doppler effect.

(c)
Complete the following sentences by circling the correct words:

When a source starts to move **away from / towards** the observer, the wavelength of the wave broadens.

For sound waves, sound therefore appears at a **higher / lower** frequency to the observer.

For light waves, the light shifts towards the **blue / red** end of the electromagnetic spectrum due to its **lower / higher** frequency.

When a source starts to move **away from / towards** the observer, the wavelength of the wave shortens.

For sound waves, sound therefore appears at a **higher / lower** frequency to the observer.

For light waves, the light shifts towards the **blue / red** end of the electromagnetic spectrum due to its **lower / higher** frequency.

This is because **blue / red** light has a longer wavelength than **blue / red** light.

[7]

[7 marks]

Question 1d

(d)
State two uses of the Doppler effect.

[2]

[2 marks]

Question 2a

(a)
Define redshift.

[2]

[2 marks]

Question 2b

For non-relativistic galaxies, Doppler redshift can be calculated using:

$$\frac{\Delta\lambda}{\lambda} = \frac{\Delta f}{f} = \frac{v}{c}$$

(b)

(i)
State what is meant by a non-relativistic galaxy.

[1]

(ii)
Define the symbols λ, f, v and c in the equation above.

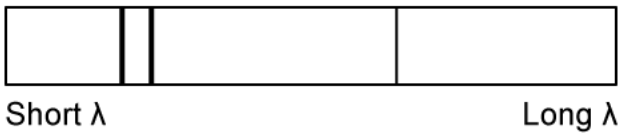
[4]

[5 marks]

Question 2c

The shift in wavelength can be identified using spectral lines in an absorption spectrum.

The following absorption spectrum is generated using light from a source in a laboratory:



(c)
Sketch the spectrum obtained using light from a galaxy moving away from the Earth.

[2]

[3 marks]

Question 2d

An absorption line in the spectrum of light from a source in a lab in part (c) has a frequency of 5.783×10^{14} Hz. The same line in the spectrum of light from a distant galaxy has a frequency of 5.791×10^{14} Hz.

(d)
Calculate the speed of the distant galaxy in relation to the Earth.

[5]

[5 marks]

Question 3a

This question is about redshift.

(a)
Complete the following sentences by filling in the correct words in the gaps:

After the discovery of Doppler redshift, astronomers began to realise that almost all the galaxies in the universe are _____.

This led to the idea that the universe is must be _____.

This caused the light waves to _____ _____ as they travel through space, shifting them towards the _____ end of the spectrum.

The more shifted the light from a galaxy is, the _____ the galaxy is moving away from Earth.

[4]

[4 marks]

Question 3b

The following equation is used for calculations where the observer is stationary and the source is moving:

$$f' = f\left(\frac{v}{v \pm u_s}\right)$$

(b)
Define each of the terms, f, f', v and u_s in the equation above and give the correct unit.

[4]

[4 marks]

Question 3c

(c)
State the equation used if the source is stationary and the observer is moving, defining any terms which differ from the equation in part (b).

[2]

[2 marks]

Question 3d

A distant galaxy is receding from the Earth at a velocity of 4.5×10^5 m s^{-1}. The galaxy emits light of frequency 5.5×10^{14} Hz.

(d)
Using the equation $f' = f\left(\frac{v}{v + u_s}\right)$, calculate the frequency of this light as observed from the Earth.

[3]

[3 marks]

Question 4a

The equation for the Doppler effect can be written as follows:

$$\lambda' = \lambda\left(1 \pm \frac{u_s}{v}\right)$$

(a)

Draw lines to match the symbol with the correct definition.

λ	Velocity of the source
λ′	Wavelength of the source
u_s	Wave velocity
v	Observed wavelength

[3]

[3 marks]

Question 4b

(b)

State the conditions for the equation in part (a) which result in the term in brackets being:

(i)

$$1 - \frac{u_s}{v}$$

[1]

(ii)

$$1 + \frac{u_s}{v}$$

[1]

[2 marks]

Question 4c

An ambulance is racing towards the scene of an emergency at a speed of 20 m s^{-1}. The siren on the ambulance produces a sound of wavelength 0.2 m. The speed of sound in air is 340 m s^{-1}.

(c)
Using the equation in part (a), determine the wavelength of sound as heard by an observer at the scene.

[3]

[3 marks]

Question 4d

(d)
State and explain the effect of the wavelength of the sound calculated in part (c) with reference to what the observer hears.

[2]

[2 marks]

Question 5a

A team of naturalists are researching the movement of whales in the ocean. They plan to calculate the velocity of a whale using the Doppler effect. The whale pod is moving towards the research team.

(a)
State an equation which will allow the researchers to investigate the velocity of the whales using the frequency of sound in water using the following variables:

λ, λ', u_s, v, f, f'

You may use each variable once, more than once or not at all.

[2]

[2 marks]

Question 5b

(b)
State and explain the difference between the sound produced by the whales and sound observed by the researchers.

[2]

[2 marks]

Question 5c

The whales are producing a monotone sound of frequency 50 Hz. The speed of sound in water is 1480 m s^{-1}. The whales are moving at 10 m s^{-1}.

(c)
Use the equation from part (a) to calculate the frequency of the sound from the whales as observed by the research team.

[2]

[2 marks]

Question 5d

The whales stop moving when they detect the boat. The researchers, not wanting to scare the whales, start to move away from the pod, accelerating over a period of time until reaching a steady speed of 20 m s^{-1}. The boat comes to a stop 500 m from the whale pod.

(d)
Order the phrases below from 1–3 to describe how the observed sound from the whales changes over this period.

The frequency of sound observed decreases gradually	
The sound observed is 50 Hz	
The sound observed is at a steady frequency lower than 50 Hz	

[3]

[3 marks]