9.5 Doppler Effect

Question Paper

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

Time allowed: 50

Score: /36

Percentage: /100

Question 1a

A car passes a stationary police car which is emitting a pure tone. The speed of the car is 130 km h^{-1}.

(a)
Determine the frequency change of the sound heard by the driver as a percentage of the original frequency from the police car, f

[3]

[3 marks]

Question 1b

On the return journey, the driver of the car hears a tone of wavelength 0.607 m. Their speed is 78% of the outward speed.

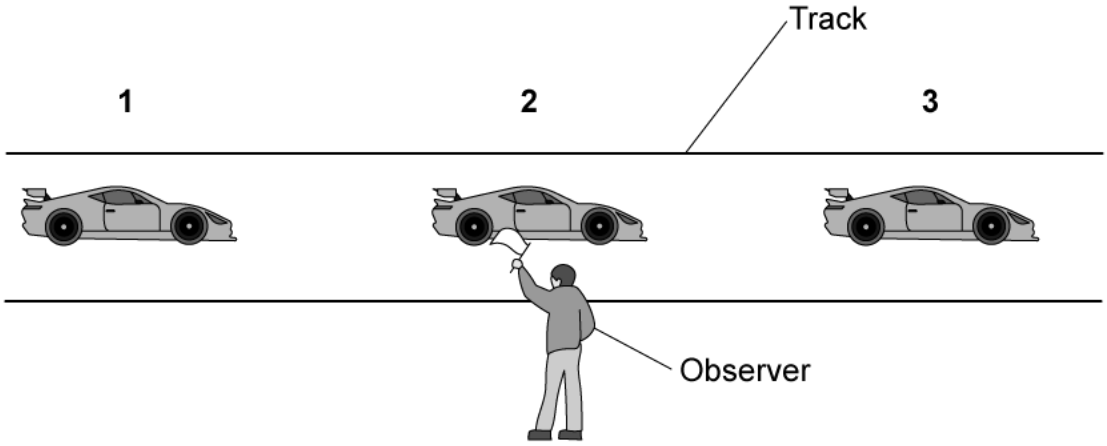
(b)
Determine the frequency of sound emitted by the police car.

[2]

[2 marks]

Question 2a

A racing car is travelling at 300 km h^{-1} on a race track.



The stationary observer hears a frequency of sound of 1550 Hz from the exhaust as the car approaches them (position 1). You can assume the speed of sound to be 340 m s^{-1}.

(a)
Determine the frequency of sound heard by:

(i)
A stationary observer standing next to the track as the car passes (position 2) .

[1]

(ii)
A stationary observer standing next to the track behind the current position of the car (position 3).

[1]

[2 marks]

Question 2b

The car from part (a) opens its Drag Reduction System (DRS) increasing its top speed by 10 km h^{-1}. It then overtakes another car which is travelling at 300 km h^{-1}.

The equation which can be used when both source and observer are moving is:

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

The frequency of the sound emitted by the car exhaust is directly proportional to the speed.

(b)
Calculate the maximum and minimum frequency of sound heard from the faster car, as heard by the driver of the car being overtaken during this manoeuvre.

[5]

[4 marks]

Question 2c

A scientist is doing some experiments on sound from the safety of the stands. An air horn emits a sound of frequency 450 Hz. The sound of the horn reflects off the car, which is moving away from the scientist, who measures the frequency as being 420 Hz.

(c)
Calculate the speed of the car.

[2]

[3 marks]

Question 3a

A train is travelling at 45 m s^{-1} and blows a whistle at a frequency of 750 Hz. A person is waiting at a level crossing for the train to pass. Take the speed of sound in air as 340 m s^{-1}.

(a)
Calculate the frequency observed by the person:

(i)
In still air.

[1]

(ii)
When the wind is blowing at 10 m s^{-1} towards the train and away from the person.

[2]

[3 marks]

Question 3b

After the train passes the level crossing, it slows down as it approaches a tunnel. Wind is funnelled down the tunnel towards the train reaching a velocity of 27 m s^{-1}. The observer at the level crossing hears the whistle at a frequency of 729 Hz.

(b)
Calculate the new speed of the train.

[2]

[2 marks]

Question 3c

After exiting the tunnel, the train stops at a station. The observer from part (a) is now walking to the platform to catch the train at a speed of 1.5 m s^{-1}. The human ear can distinguish between frequency differences of around 3.6 Hz.

(c)
Show that the change in frequency of the train's whistle, as heard by the running observer, can be considered negligible.

[2]

[2 marks]

Question 3d

Once the train has left the station, it travels down a line with two tracks. Another train is approaching on the opposite track with a speed of 7.6 m s^{-1}. The speed of the departing train is 83% of the speed of the second train.

When both observer and source are moving, the following equation can be used to determine the new frequency:

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

(d)
Calculate the frequency of the whistle as observed by a passenger on the approaching train as a percentage of f.

[3]

[3 marks]

Question 4a

A ship is using low frequency sonar to map the sea bed. It sends out a pulse of sound which startles a nearby school of fish. The fish start to swim away at a speed of 20 km h^{-1}. The ship then sends out a second pulse with a wavelength that is 15 cm less than that of the original pulse. The fish perceive the two pulses to have the same frequency.

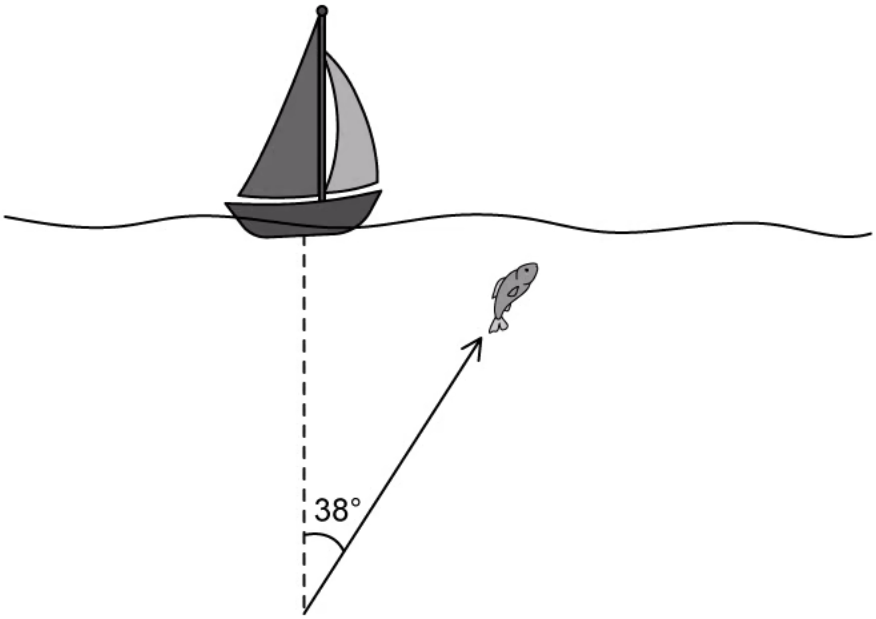
(a)
Determine the wavelength of the initial pulse.

[3]

[3 marks]

Question 4b

The school of fish approach a second ship which is emitting the same frequency of pulse as the first ship. They approach this boat at an angle of 38 °.



(b)

Calculate the frequency of sound as observed by the fish, f'.

[3]

[3 marks]

Question 4c

The boat uses the stars to navigate. The captain uses a diffraction grating on her telescope to observe the light from a nearby asteroid she has spotted. She observes a spectral absorption line with a frequency of 673.7 nm.

The absorption line for that element is given as 673.8 nm from tests in the laboratory.

(c)
Through use of a calculation, explain why the captain might be concerned.

[3]

[3 marks]

Question 5a

Two stars, A and B, in a binary system move in an anti-clockwise direction. Both stars emit light with wavelength, $\lambda = 5.89 \times 10^{-7}$ m, which reaches an observer on Earth. In the laboratory, the light is shown to fluctuate between wavelengths of 5.86×10^{-7} m and 6.02×10^{-7} m.

Assume they orbit in a circle around their common centre of mass.

(a)
Draw a diagram which indicates the position of the stars relative to the Earth when:

(i)
There is no redshift.

[1]

(ii)
The wavelength is recorded as 5.86×10^{-7} m from both stars.

[2]

[2 marks]

Question 5b

The radius of orbit of star B is 4.98×10^{11} m.

(b)
Calculate the time taken for one orbit of star A about the common centre of mass.

[2]

[1 mark]