PHYSICAL SCIENCES

MATERIAL FOR GRADE 12

SECOND TERM

DOPPLER EFFECT

QUESTIONS

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- Use the general Doppler equation $f_L = \frac{v \pm v_L}{v \pm v_S} f_S$ for any calculation (i.e. when EITHER the source or the listener is moving).

Note: *Only the general Doppler equation, as shown above, or the equation for the specific situation are accepted as correct formulae for a calculation.*

- Teachers need to explain the Doppler equation to learners so that they can understand when and why to add or subtract the velocities of the source or listener to that of sound. **For example**, if the source moves towards a stationary observer, only $f_L = \frac{v \pm v_L}{v \pm v_S} f_S$ or $f_L = \frac{v}{v - v_S} f_S$ are accepted as correct formulae.
- This equation is a combination of **FOUR** scenarios:

  1. **A moving source approaching a stationary listener,**
  2. **A moving source moving away from a stationary listener,**
  3. **A moving listener approaching a stationary source and**
  4. **A moving listener moving away from a stationary source.**
- **When using the general Doppler equation the following approach can be helpful:**
  - If a source of sound waves moves towards a stationary listener, fL will be higher than fs, thus $v_L = 0$ and a ***negative sign*** is used for vs in the ***denominator*** in order to obtain a higher observed frequency value. $\therefore$ $f_L = f_s \frac{v}{v - v_s}$
  - If a source of sound waves moves away from a stationary listener, f_L will be lower than f_s, thus $v_L = 0$ and a ***positive sign*** is used for v_s in the ***denominator*** in order to obtain a lower observed frequency value. $\therefore$ $f_L = f_s \frac{v}{v + v_s}$
  - If a listener moves towards a stationary source of sound waves, f_L will be higher than f_s, thus $v_s = 0$ and a ***positive sign*** is used for $v_L$in the ***numerator*** in order to obtain a higher observed frequency value. $\therefore$ $f_L = f_s \frac{v + v_L}{v}$
  - If a listener moves away from a stationary source of sound waves, f_L will be lower than f_s, thus $v_s = 0$ and a negative sign is used for $v_L$in the numerator in order to obtain a lower observed frequency value. $\therefore$ $f_L = f_s \frac{v - v_L}{v}$
- Describe applications of the Doppler Effect with ultrasound waves in medicine, e.g. to measure the rate of blood flow or the heart of a foetus in the womb.

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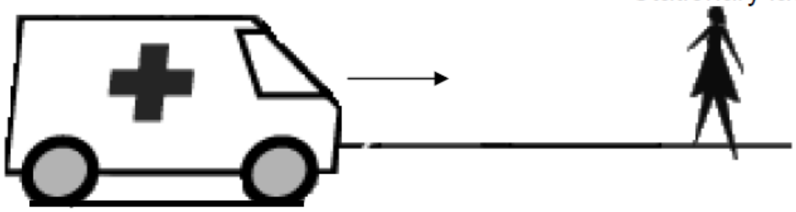
QUESTION 8

An ambulance travelling down a road at constant speed emits sound waves from its siren. A lady stands on the side of the road with a detector which registers sound waves at a frequency of 445 Hz as the ambulance approaches her.

After passing her, and moving away at the same constant speed, sound waves of frequency 380 Hz are registered.



Assume that the speed of sound in air is 343 $m \cdot s^{-1}$.

8.1 Name the phenomenon that describes the change in the frequency observed by the lady. (1)

8.2 Calculate:

8.2.1 The speed at which the ambulance is moving (7)

8.2.2 The frequency at which the siren emits the sound waves (3)
[11]

QUESTION 7

Dolphins use ultrasound to scan their environment.

When a dolphin is 100 m from a rock, it emits ultrasound waves of frequency 250 kHz whilst swimming at 20 $m \cdot s^{-1}$ towards the rock. Assume that the speed of sound in water is 1 500 $m \cdot s^{-1}$.

7.1 Calculate the frequency of the sound waves detected by a detector on the rock. (4)

7.2 When the dolphin is 50 m from the rock, another ultrasound wave of 250 kHz is emitted.

How will the frequency of the detected sound waves compare with the answer calculated in QUESTION 7.1? Write down only HIGHER, LOWER or REMAINS THE SAME. Explain your answer. (2)
[6]

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QUESTION 7 (Start on a new page.)

The siren of a police car produces a sound of frequency 420 Hz. A man sitting next to the road notices that the pitch of the sound changes as the car moves towards and then away from him.

7.1 Write down the name of the above phenomenon. (1)

7.2 Assume that the speed of sound in air is 340 $m \cdot s^{-1}$. Calculate the frequency of the sound of the siren observed by the man, when the car is moving towards him at a speed of 16 $m \cdot s^{-1}$. (4)

7.3 The police car moves away from the man at constant velocity, then slows down and finally comes to rest.

7.3.1 How will the observed frequency **compare** with the original frequency of the siren when the police car moves away from the man at constant velocity? Write only GREATER THAN, SMALLER THAN or EQUAL TO. (2)

7.3.2 How will the observed frequency **change** as the car slows down whilst moving away? Write only INCREASES, DECREASES or REMAINS THE SAME. (2)

[9]

QUESTION 7 (Start on a new page.)

An ambulance with its siren on, moves **away** at constant velocity from a person standing next to the road. The person measures a frequency which is 90% of the frequency of the sound emitted by the siren of the ambulance.

7.1 Name the phenomenon observed. (1)

7.2 If the speed of sound in air is 340 $m \cdot s^{-1}$, calculate the speed of the ambulance. (5)

[6]

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QUESTION 6 (Start on a new page.)

The siren of a burglar alarm system has a frequency of 960 Hz. During a patrol, a security officer, travelling in his car, hears the siren of the alarm of a house and approaches the house at constant velocity. A detector in his car registers the frequency of the sound as 1 000 Hz.

6.1 Name the phenomenon that explains the change in the observed frequency. (1)

6.2 Calculate the speed at which the patrol car approaches the house. Use the speed of sound in air as 340 $m \cdot s^{-1}$. (4)

6.3 If the patrol car had approached the house at a higher speed, how would the detected frequency have compared to the first observed frequency of 1 000 Hz? Write down only HIGHER THAN, LOWER THAN or EQUAL TO. (1)

[6]

QUESTION 6 (Start on a new page.)

The whistle of a train emits sound waves of frequency 2 000 Hz. A stationary listener measures the frequency of these emitted sound waves as 2 080 Hz. The speed of sound in air is 340 $m \cdot s^{-1}$.

6.1 Name the phenomenon responsible for the observed change in frequency. (1)

6.2 Is the train moving AWAY FROM or TOWARDS the stationary listener? (1)

6.3 Calculate the speed of the train. (4)

6.4 Will the frequency observed by a passenger, sitting in the train, be GREATER THAN, EQUAL TO or SMALLER THAN 2 000 Hz? Explain the answer. (2)

[8]

QUESTION 6 (Start on a new page.)

A train approaches a station at a constant speed of 20 $m \cdot s^{-1}$ with its whistle blowing at a frequency of 458 Hz. An observer, standing on the platform, hears a change in pitch as the train approaches him, passes him and moves away from him.

6.1 Name the phenomenon that explains the change in pitch heard by the observer. (1)

6.2 Calculate the frequency of the sound that the observer hears while the train is approaching him. Use the speed of sound in air as 340 $m \cdot s^{-1}$. (4)

6.3 How will the observed frequency change as the train passes and moves away from the observer? Write down only INCREASES, DECREASES or REMAINS THE SAME. (1)

6.4 How will the frequency observed by the train driver compare to that of the sound waves emitted by the whistle? Write down only GREATER THAN, EQUAL TO or LESS THAN. Give a reason for the answer. (2)

[8]

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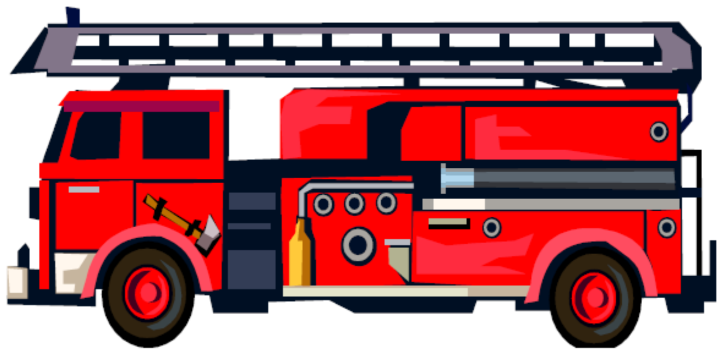
QUESTION 6

Lolo's grade 3 class visited a fire station. They rode on a fire engine which had a flashing red light on the roof and a hooter that emits a sound with a frequency of 18 kHz. After the ride, the engine went out on call. It raced away from children at 72 km.h^{-1} with its hooter blaring and its red light flashing. Lolo noticed that the sound of the hooter seemed to change when the fire engine moved away from him. (Take the speed of sound to be 340 m.s^{-1})



6.1 Name the phenomenon that is observed by Lolo. (1)

6.2 Calculate the frequency heard by Lolo when the fire engine is moving away at a speed of 72 km.h^{-1}. (4)

6.3 Draw a diagram to show the advancing wave fronts that are produced by the fire engine when it moves away from Lolo. In your diagram indicate Lolo's position and the direction of the fire engine's velocity. (2)

6.4 There is a noticeable change in the hooter's frequency, but not a noticeable change in the colour of the flashing red light as the fire engine changes speed and direction. Briefly explain this observation. (3)

[10]

QUESTION 6 (Start on a new page.)

An ambulance approaches an accident scene at constant velocity. The siren of the ambulance emits sound waves at a frequency of 980 Hz. A detector at the scene measures the frequency of the emitted sound waves as 1 050 Hz.

6.1 Calculate the speed at which the ambulance approaches the accident scene. Use the speed of sound in air as 340 m·s^{-1}. (4)

6.2 Explain why the measured frequency is higher than the frequency of the source. (2)

6.3 The principle of the Doppler effect is applied in the Doppler flow meter. State ONE positive impact of the use of the Doppler flow meter on humans. (2)

[8]

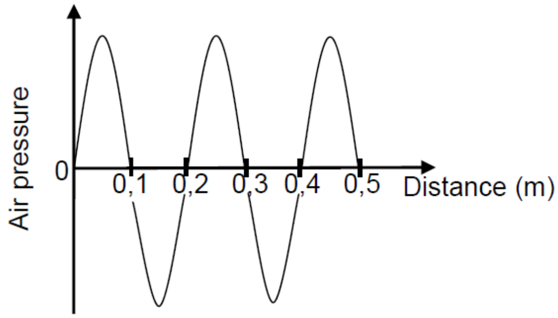
QUESTION 6 (Start on a new page.)

A bird flies directly towards a stationary birdwatcher at constant velocity. The bird constantly emits sound waves at a frequency of 1 650 Hz. The birdwatcher hears a change in pitch as the bird comes closer to him.

6.1 Write down the property of sound that is related to pitch. (1)

6.2 Give a reason why the birdwatcher observes a change in pitch as the bird approaches him. (1)

The air pressure versus distance graph below represents the waves detected by the birdwatcher as the bird comes closer to him. The speed of sound in air is 340 m·s^{-1}.



6.3 From the graph, write down the wavelength of the detected waves. (1)

6.4 Calculate the:

6.4.1 Frequency of the waves detected by the birdwatcher (3)

6.4.2 Magnitude of the velocity at which the bird flies (5)
[11]

QUESTION 6 (Start on a new page.)

An ambulance approaches a stationary observer at a constant speed of 10,6 m·s^{-1}, while its siren produces sound at a constant frequency of 954,3 Hz. The stationary observer measures the frequency of the sound as 985 Hz.

6.1 Name the medical instrument that makes use of the Doppler effect. (1)

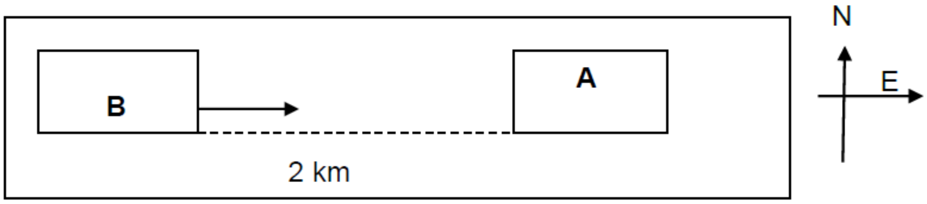
6.2 Calculate the velocity of sound. (5)

6.3 How would the wavelength of the sound wave produced by the siren of the ambulance change if the frequency of the wave were higher than 954,3 Hz? Write down only INCREASES, DECREASES or STAYS THE SAME. (1)

6.4 Give a reason for the answer to QUESTION 6.3. (2)
[9]

QUESTION 5 (Start on a new page.)

Truck B travelling at a velocity of 30 $km.h^{-1}$ east, approaches a stationary truck A. At a distance of 2 km from A, the driver of truck B presses the hooter which produces a sound of frequency 13 kHz. The speed of sound in air on that day is 343 $m.s^{-1}$.



5.1 Will the frequency observed by the driver in truck A be higher or lower than 13 kHz? Give a reason for your answer. (2)

5.2 Calculate the frequency of the sound that the driver in truck A hears. (4)

5.3 A woman is standing 1 km from the approaching truck B. When will she hear the actual frequency of the truck? (1)

5.4 Name and explain the phenomenon in words that explains the change in the observed frequency calculated in QUESTION 5.2. (3)

5.5 Truck B is still approaching the stationary truck A at the same velocity. The driver presses the hooter again at a distance of 1,5 km from truck A. How does the frequency heard by the driver in truck A differ from your answer as calculated in QUESTION 5.2? Only write HIGHER THAN, REMAIN THE SAME or LESS THAN. (2)

[12]

QUESTION 6 (Start on a new page.)

The siren of a stationary police car emits sound waves of wavelength 0,55 m.

With its siren on, the police car now approaches a stationary listener at constant velocity on a straight road. Assume that the speed of sound in air is 345 $m{\cdot}s^{-1}$.

6.1 Will the wavelength of the sound waves observed by the listener be GREATER THAN, SMALLER THAN or EQUAL TO 0,55 m? (1)

6.2 Name the phenomenon observed in QUESTION 6.1. (1)

6.3 Calculate the frequency of the sound waves observed by the listener if the car approaches him at a speed of 120 $km{\cdot}h^{-1}$. (7)

6.4 How will the answer in QUESTION 6.3 change if the police car moves away from the listener at 120 $km{\cdot}h^{-1}$? Write down only INCREASES, DECREASES or REMAINS THE SAME. (1)

[10]

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QUESTION 6

An ambulance with its siren on, is moving at a constant speed of 37,5 $m.s^{-1}$, towards an accident scene. A police officer, seated in his stationary car at the accident scene holds a detector in his hands. The detector can measure a maximum frequency of 580 Hz. Ignore the effects of wind when answering the following questions.

6.1 Calculate the frequency of the sound waves produced by the sound source in the ambulance so that the detector registers a maximum reading. Take the speed of sound in air as 340 $m.s^{-1}$. (4)

6.2 The phenomenon observed here, is the Doppler effect. Define the Doppler effect. (2)

6.3 The speed of the ambulance is increased to 41,5 $m.s^{-1}$. Will the detector now register a reading? Give a reason for your answer. (3)

6.4 How will the frequency of the sound wave observed by the driver in the ambulance compare to that emitted by the siren in the ambulance.
(Write down LESS THAN, EQUAL TO or GREATER THAN).
Give a reason for your answer. (2)

6.5 How is Doppler effect noticed with …

6.5.1 sound waves? (1)
6.5.2 light waves? (1)

6.6 Describe ONE positive impact of the Doppler effect in medicine. (3)

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QUESTION 6 (Start on a new page.)

The Doppler effect is applicable to both sound and light waves. It also has very important applications in our everyday lives.

6.1 A hooter on a stationary train emits sound with a frequency of 520 Hz, as detected by a person standing on the platform. Assume that the speed of sound is 340 $m \cdot s^{-1}$ in still air.

Calculate the:

6.1.1 Wavelength of the sound detected by the person (2)

6.1.2 Wavelength of the sound detected by the person when the train moves towards him/her at a constant speed of 15 $m \cdot s^{-1}$ with the hooter still emitting sound (6)

6.2 Explain why the wavelength calculated in QUESTION 6.1.1 differs from that obtained in QUESTION 6.1.2. (2)

6.3 Use your knowledge of the Doppler effect to explain *red shifts.* (2)
[12]

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QUESTION 6 (Start on a new page.)

6.1 The data below was obtained during an investigation into the relationship between the different velocities of a moving sound source and the frequencies detected by a stationary listener for **each** velocity. The effect of wind was ignored in this investigation.

Experiment number	1	2	3	4
Velocity of the sound source ($m \cdot s^{-1}$)	0	10	20	30
Frequency (Hz) of the sound detected by the stationary listener	900	874	850	827

6.1.1 Write down the dependent variable for this investigation. (1)

6.1.2 State the Doppler effect in words. (2)

6.1.3 Was the sound source moving TOWARDS or AWAY FROM the listener? Give a reason for the answer. (2)

6.1.4 Use the information in the table to calculate the speed of sound during the investigation. (5)

6.2 The spectral lines of a distant star are shifted towards the longer wavelengths of light. Is the star moving TOWARDS or AWAY FROM the Earth? (1)

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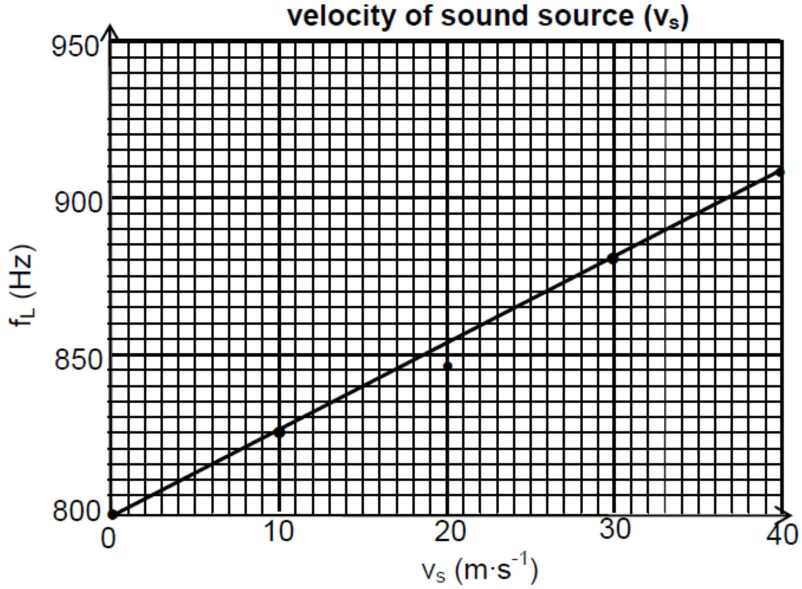
QUESTION 6 (Start on a new page.)

The graph below shows the relationship between the apparent frequency (f_L) of the sound heard by a STATIONARY listener and the velocity (v_S) of the source travelling TOWARDS the listener.

Graph showing apparent frequency (f_L) versus velocity of sound source (v_s)



6.1 State the Doppler effect in words. (2)

6.2 Use the information in the graph to calculate the speed of sound in air. (5)

6.3 Sketch a graph of apparent frequency (f_L) versus velocity (v_S) of the sound source if the source was moving AWAY from the listener. It is not necessary to use numerical values for the graph. (2)

[9]

QUESTION 6 (Start on a new page.)

A siren of a stationary ambulance emits sound waves of frequency 280 Hz. A car is moving towards a stationary ambulance at a constant speed that is 310 $m.s^{-1}$, **lower** than the speed of sound in air.

6.1 Define the *Doppler Effect*. (2)

6.2 Calculate the frequency of sound detected by the driver of the car. Use the speed of sound in air as 340 $m.s^{-1}$. (5)

6.3 How will the answer in QUESTION 6.2 be affected if the car moves away from the ambulance at the same constant speed?

Write down only GREATER THAN, SMALLER THAN or EQUAL TO.

Explain the answer. (3)

6.4 Give ONE use of the Doppler flow meter. (1)

6.5 When a line in a hydrogen spectrum is measured in a laboratory, it has a wavelength of $1,32 \times 10^{-15}$ m. The same line in the light of a star has a wavelength of $1,38 \times 10^{-15}$ m.

Is the star moving TOWARDS, or AWAY from the earth?

Explain your answer. (2)
[13]

QUESTION 6 (Start on a new page.)

Reflection of sound waves enables bats to hunt for moths. The sound wave produced by a bat has a frequency of 222 kHz and a wavelength of $1,5 \times 10^{-3}$ m.

6.1 Calculate the speed of this sound wave through the air. (3)

6.2 A stationary bat sends out a sound signal and receives the same signal reflected from a moving moth at a frequency of 230,3 kHz.

6.2.1 Is the moth moving TOWARDS or AWAY FROM the bat? (1)

6.2.2 Calculate the magnitude of the velocity of the moth, assuming that the velocity is constant. (6)
[10]

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