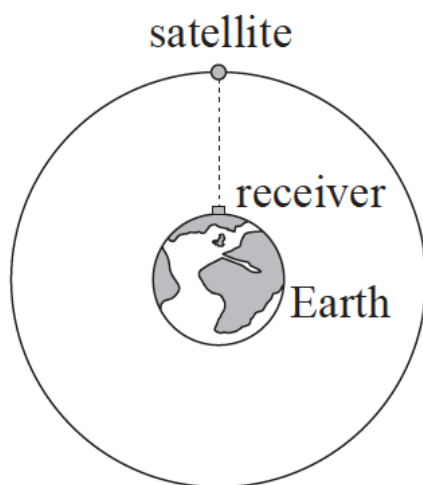


Doppler Effect [25 marks]

Part 2 Satellite

- 1a. State, in words, Newton's universal law of gravitation. [2 marks]
- 1b. The diagram shows a satellite orbiting the Earth. The satellite is part of the network of global-positioning satellites (GPS) that transmit radio signals used to locate the position of receivers that are located on the Earth. [3 marks]

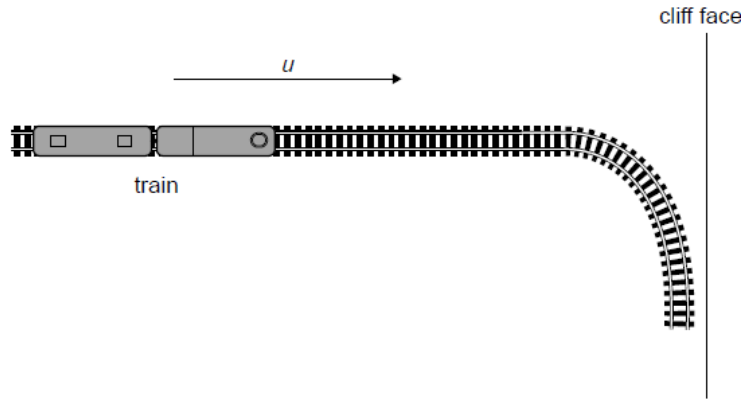


(not to scale)

- When the satellite is directly overhead, the microwave signal reaches the receiver 67ms after it leaves the satellite.
- (i) State the order of magnitude of the wavelength of microwaves.
- (ii) Calculate the height of the satellite above the surface of the Earth
2. A stationary sound source emits waves of wavelength λ and speed v . The source now moves away from a stationary observer. [1 mark]
What are the wavelength and speed of the sound as measured by the observer?

	Wavelength	Speed
A.	longer than λ	equal to v
B.	longer than λ	less than v
C.	shorter than λ	equal to v
D.	shorter than λ	less than v

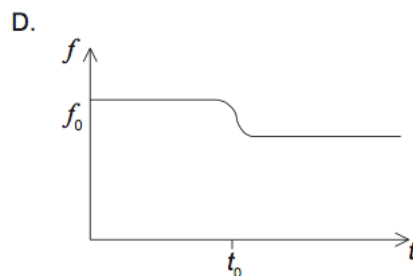
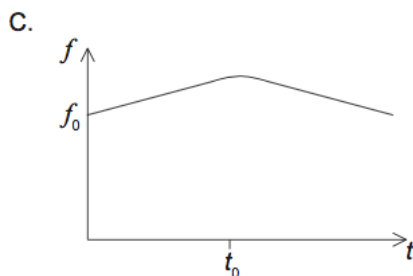
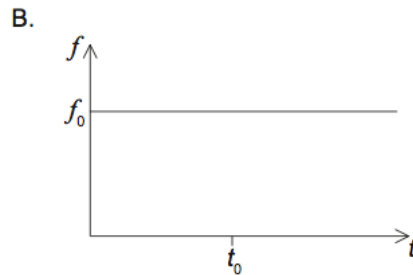
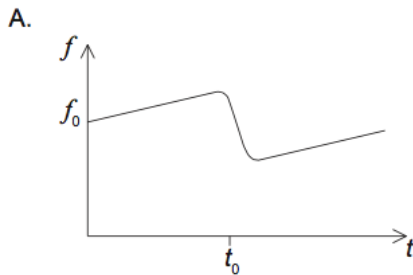
3. A train moving at speed u relative to the ground, sounds a whistle of constant frequency f as it moves towards a vertical cliff face. [1 mark]



The sound from the whistle reaches the cliff face and is reflected back to the train. The speed of sound in stationary air is c .

What whistle frequency is observed on the train after the reflection?

- A. $\frac{(c+u)}{(c-u)}f$
- B. $(c + u)f$
- C. $(c - u)f$
- D. $\frac{(c-u)}{(c+u)}f$
4. A train travelling in a straight line emits a sound of constant frequency f . An observer at rest very close to the path of the train detects a sound of continuously decreasing frequency. The train is [1 mark]
- A. approaching the observer at constant speed.
- B. approaching the observer at increasing speed.
- C. moving away from the observer at constant speed.
- D. moving away from the observer at increasing speed.
5. A train moves at constant speed whilst emitting a sound wave of frequency f_0 . At $t=t_0$ the train passes through a station. Which graph shows the variation with time t of the frequency f of the sound wave as measured by an observer standing on the station platform? [1 mark]



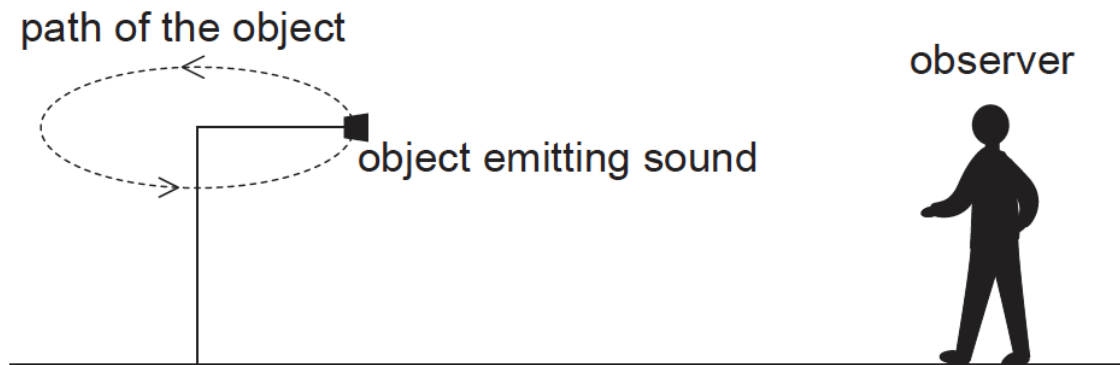
6. A source emits sound of wavelength λ_0 and wave speed v_0 . A stationary observer hears the sound as the source moves away. What are the wavelength of the sound and the wave speed of the sound as measured by the stationary observer? [1 mark]

	Wavelength	Wave speed
A.	less than λ_0	equal to v_0
B.	greater than λ_0	equal to v_0
C.	less than λ_0	less than v_0
D.	greater than λ_0	less than v_0

7. A car horn emits sound of frequency f . While the horn is sounding, the car moves in a straight line towards a stationary observer. The speed of the car is $0.10v$ where v is the speed of sound. What is the frequency of the sound of the horn heard by the observer? [1 mark]

1. $\frac{f}{0.90}$
2. $1.1 f$
3. $\frac{f}{1.1}$
4. $0.90 f$

8. An object emitting a sound of frequency 100 Hz orbits in a horizontal circle at a rate of two revolutions per second. [1 mark]



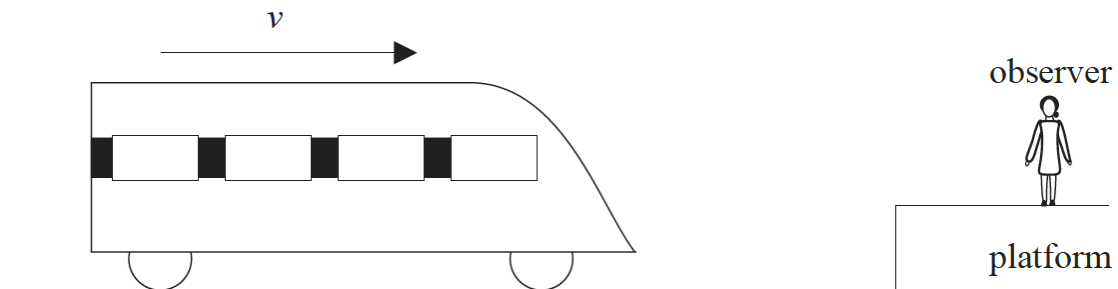
An observer standing a short distance away from the object is able to hear the sound. Which of the following describes the sound the observer is able to hear?

- A. A sound of constant frequency but varying in amplitude
 - B. A sound of constantly varying frequency
 - C. A sound with a frequency of 50 Hz
 - D. A sound with a frequency of 200 Hz
9. A source of sound moves away from an observer. The observed frequency of the sound differs from the frequency emitted by the source because the [1 mark]
- A. observed wavelength of the sound is less than the emitted wavelength.
 - B. observed wavelength of the sound is greater than the emitted wavelength.
 - C. speed of sound relative to the observer has decreased.
 - D. speed of sound relative to the observer has increased.

10. Light of wavelength λ_0 is emitted from a nearby galaxy. The light is received on Earth and the wavelength is measured to be λ where $\lambda < \lambda_0$. Which of the following correctly describes the speed and direction of motion of the galaxy? [1 mark]

	Speed	Direction
A.	$\frac{\lambda_0 - \lambda}{\lambda_0} c$	towards earth
B.	$\frac{\lambda_0 - \lambda}{\lambda} c$	towards earth
C.	$\frac{\lambda_0 - \lambda}{\lambda_0} c$	away from earth
D.	$\frac{\lambda_0 - \lambda}{\lambda} c$	away from earth

11. The diagram shows a train travelling in a straight line at constant speed v , as it approaches the platform of a station. [1 mark]

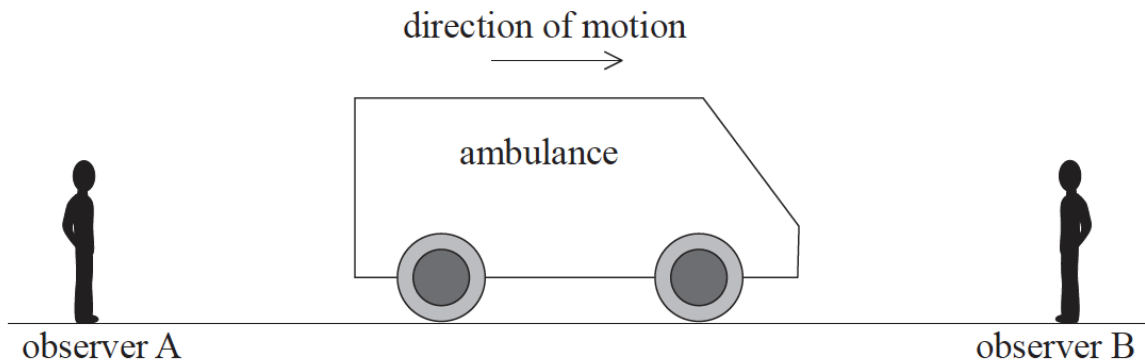


The whistle of the engine is emitting a sound of constant frequency. Which of the following is **not** true for the sound of the whistle heard by an observer on the platform?

- A. A sudden change in frequency of the sound as the train passes the observer.
- B. A sound of constant frequency as the train approaches the observer.
- C. A sound of increasing frequency as the train approaches the observer and of decreasing frequency after the train has passed the observer.
- D. A sound of constant frequency after the train has passed the observer.

12. An ambulance emits a sound of frequency f as it travels along a straight road between stationary observers A and B.

[1 mark]



Which of the following shows how the frequency of the sound heard by each observer compares with f ?

	Observer A	Observer B
A.	greater than f	greater than f
B.	greater than f	less than f
C.	less than f	greater than f
D.	less than f	less than f

13. A sample of hydrogen on Earth emits a spectral line that is measured by an Earth observer to have wavelength 500 nm. The same spectral line is emitted by a galactic source that is moving away from Earth at speed of $0.1c$. What is the wavelength of the galactic spectral line that will be measured by the Earth observer? [1 mark]

- A. 50 nm
- B. 450 nm
- C. 550 nm
- D. 5000 nm

14. A stationary source of sound emits sound of frequency f . A moving observer measures the sound as having the frequency f' . The observer is moving directly away from the source at a speed that is 30% of the speed of sound in air. [1 mark]

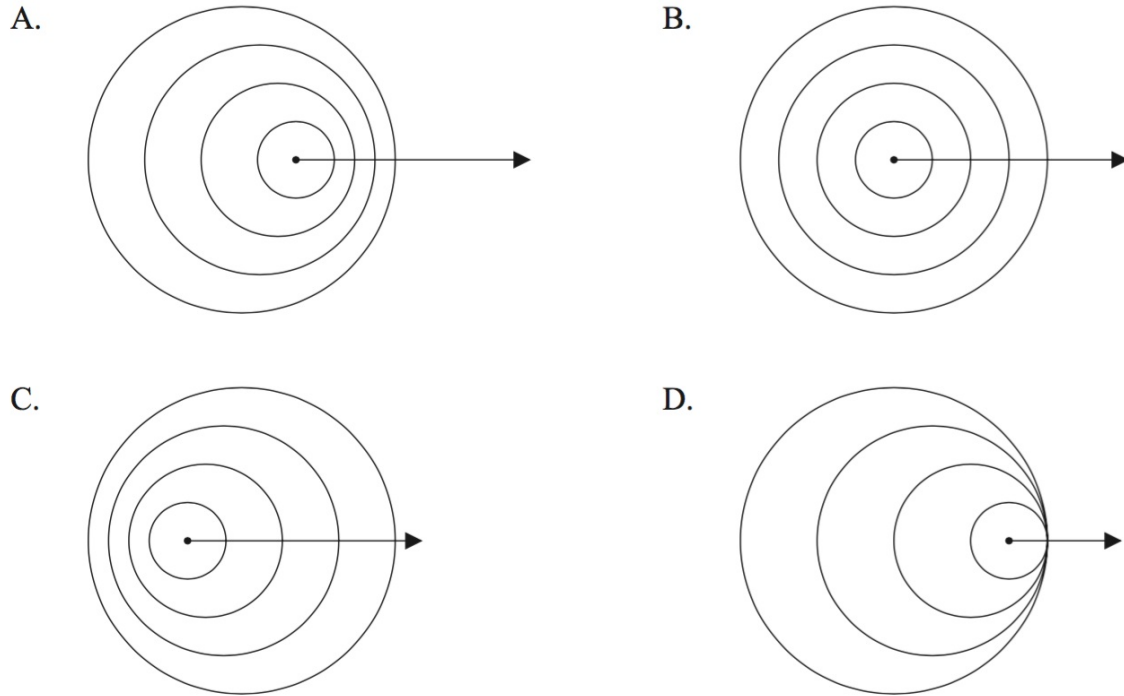
Which of the following gives the correct value for $\frac{f'}{f}$?

- A. $\frac{7}{10}$
- B. $\frac{10}{13}$
- C. $\frac{13}{10}$
- D. $\frac{10}{7}$

15. A siren on an ambulance emits sound of frequency f . The speed of sound in still air is v . What is the frequency of the sound observed when the ambulance travels at speed $\frac{v}{10}$ towards a stationary observer? [1 mark]

- A. $\frac{f}{10}$
 B. f
 C. $\frac{11}{10}f$
 D. $\frac{10}{9}f$

16. A point source of sound is moving to the right at constant speed. The source emits sound waves of constant frequency. The speed of the source is less than the speed of sound. Which diagram correctly shows the wavefronts of the sound? [1 mark]



17. A fire engine with its siren sounding approaches and passes a stationary observer. The frequency of the sound emitted by the siren is f_s . The frequency of the sound measured by the observer is f_o . Which of the following describes the relationship between f_o and f_s ? [1 mark]

	Fire engine approaching observer	Fire engine moving away from observer
A.	$f_o > f_s$	$f_o < f_s$
B.	$f_o < f_s$	$f_o < f_s$
C.	$f_o > f_s$	$f_o > f_s$
D.	$f_o < f_s$	$f_o > f_s$

18. A radar speed gun is used to measure the speed of a car. The car is moving with speed v away from the gun.

[1 mark]



The radar emits microwaves of frequency f and speed c . Which of the following is the frequency of the microwaves measured at the gun after reflection by the car?

- A. $f + \left(\frac{2v}{c}f\right)$
- B. $f + \left(\frac{v}{c}f\right)$
- C. $f - \left(\frac{2v}{c}f\right)$
- D. $f - \left(\frac{v}{c}f\right)$
19. A source of sound approaches a stationary observer. The speed of the emitted sound and its wavelength, measured at the source, are v and λ respectively. Which of the following is the wave speed and the wavelength, as measured by the stationary observer? [1 mark]

	Wave speed	Wavelength
A.	larger than v	larger than λ
B.	equal to v	larger than λ
C.	equal to v	less than λ
D.	larger than v	less than λ

20. Which of the following wave phenomena is associated with blood flow measurements?

[1 mark]

- A. Polarization
- B. Diffraction
- C. Refraction
- D. Doppler effect

21. During a journey an observer travels at constant speed towards, and then goes beyond, a stationary emitter of sound.

[1 mark]

Path followed by observer



Stationary emitter of sound

The frequency of the sound as measured at the emitter is f . The frequency according to the observer

- A. is always greater than f .
- B. is always equal to f .
- C. is always less than f .
- D. varies during the journey.

