Wave Basics QP1

1 Traffic police sometimes use ‘speed guns’ to check the speed of cars.

(a) Radar speed guns use the Doppler effect to determine the speed of cars travelling towards or away from the radar speed gun.
A radar speed gun emits a continuous microwave signal at a frequency of 40 GHz and detects the signal reflected from a moving car.

Explain how the frequency of the microwave signal detected is affected by the speed of the car and whether the car is travelling towards or away from the radar speed gun.

(4)

RevisionMadeSimple.com

(b) Lidar speed guns use infrared radiation instead of microwaves to measure the speed of a car. Lidar speed guns emit a series of short pulses of infrared radiation. The time taken for the pulses to return after being reflected from the moving car is measured.

A pulse is detected 3.333×10^{-7} s after it is emitted.
The next pulse is detected 3.315×10^{-7} s after it is emitted.
The time interval between the two reflections was 0.0091 s.

Calculate the speed of the car.

(4)

Speed of the car = ...

(c) A speed gun needs to be able to measure a vehicle's speed even when other vehicles are nearby. By considering the wavelengths of the radiations used by the two different speed guns, explain why the lidar gun is more suitable for this.

(3)

(Total for Question = 11 marks)

RevisionMadeSimple.com

2 Over 40 years ago, the Apollo astronauts placed reflectors on the surface of the Moon. These are still used by a number of observatories on Earth to monitor the distance to the Moon by reflecting pulses of laser light from them and detecting the reflected signal.

Scientists have determined that the Moon is at a distance of 363 104 km at its closest and 405 696 km at its furthest. It has also been determined that the Moon is getting about 3.8 cm further away from the Earth each year.

(a) Describe how the reflected pulses can be used to determine the distance to the Moon.

(2)

.....

.....

.....

.....

(b) An observatory sends out pulses of laser light of duration 2.0×10^{-10} s when it is determining the distance to the Moon.

(i) Calculate the pulse length.

(2)

.....

.....

.....

.....

Pulse length = ...

(ii) Discuss whether the levels of precision quoted for the distance to the Moon and its rate of increasing distance from the Earth are justified.

(2)

.....

.....

.....

.....

.....

RevisionMadeSimple.com

(iii) The round trip for the light pulses takes about 2.5 seconds. As many as 10 pulses per second may be used.

State why pulses are used rather than a continuous beam.

(1)

.....

.....

(c) Another observatory uses a higher power laser.

(i) This laser produces a pulse of duration 1.0×10^{-10} s. The energy of the pulse is 115 mJ.

Calculate the power of this laser.

(2)

.....

.....

.....

Power = ...

(ii) The wavelength of light produced by this laser is 5.32×10^{-7} m. The light is emitted from an aperture of diameter 75 cm.

Suggest, using the concept of diffraction, why such a large aperture is necessary.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

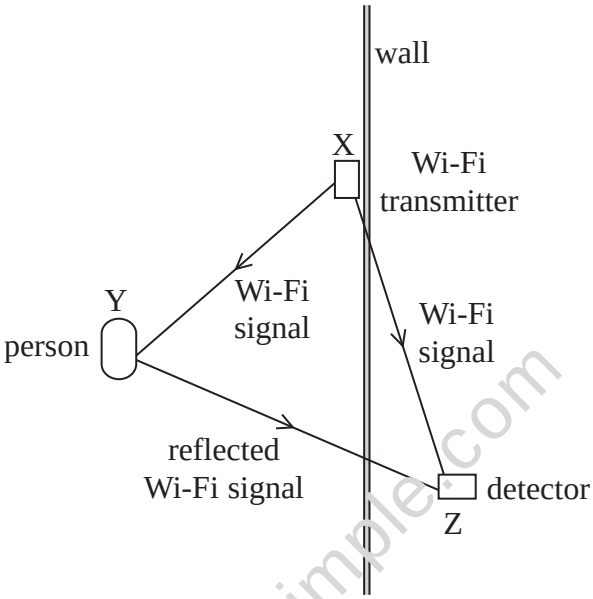
(Total for Question = 12 marks)

RevisionMadeSimple.com

3 Engineers are developing a system, using the Doppler effect, which will detect the movement of people in a room during a hostage situation.

The system makes use of the Wi-Fi transmitter already in a building, rather than needing a separate transmitter.

The system is shown in the diagram.



A detector placed outside the room receives signals directly from the Wi-Fi transmitter, along path XZ. It also receives signals reflected by the person in the room, which have travelled along path XYZ.

(a) Explain how the system uses the Doppler effect to detect the motion of the person.

(3)

.....

.....

.....

.....

.....

.....

(b) Suggest an advantage of a pulse-echo technique over this system.

(1)

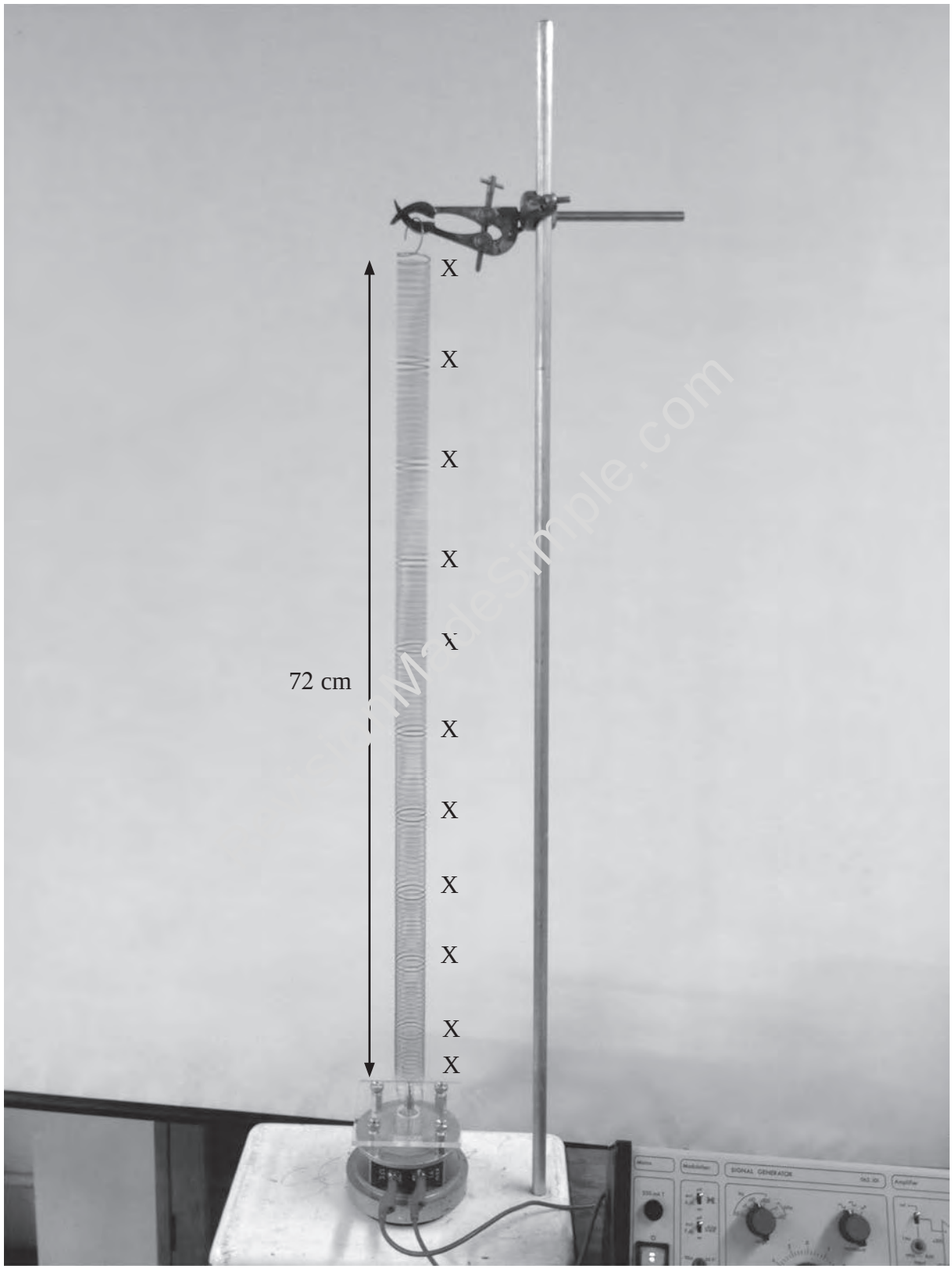
.....

.....

(Total for Question = 4 marks)

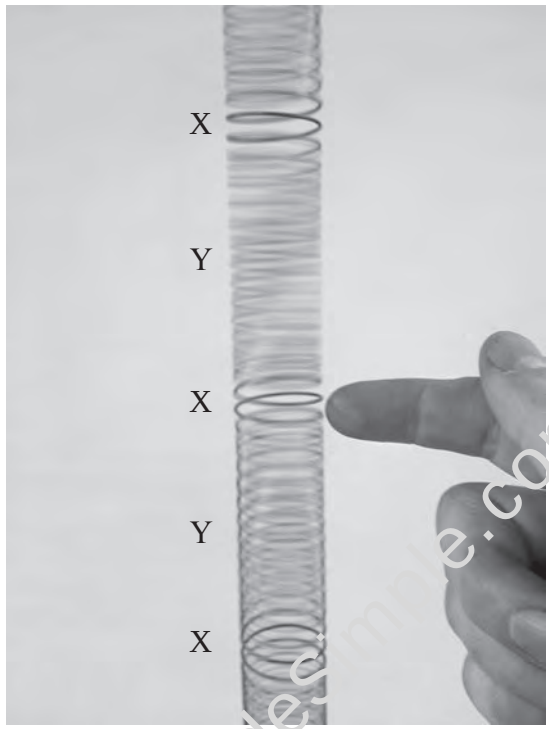
RevisionMateSimple.com

4 A vibration generator vibrates vertically to create a standing wave in a spring as shown in Photograph 1. The positions marked X show where the coils are stationary.



Photograph 1

Photograph 2 shows a section of the spring. The coils at the positions marked Y look blurred because the coils are in motion.



Photograph 2

(a) Explain why the waves shown in Photograph 2 must be longitudinal.

(2)

.....

.....

.....

.....

(b) The positions marked X are nodes.

State what is meant by a node.

(1)

.....

.....

RevisionMadeSimple.com

(c) Explain how the standing wave is produced.

(3)

(d) The frequency of the standing wave in Photograph 1 is 34 Hz.

Show that the velocity of longitudinal waves in the spring is about 5 m s^{-1}.

(3)

(e) The velocity of longitudinal waves in the spring is also determined by finding the time for a pulse to travel along the length of the spring.

The spring is filmed while a pulse is created at the bottom and allowed to reflect from the top. The pulse travels up and back down the spring 21 times.

Show that the velocity of longitudinal waves in the spring determined by this method is also about 5 m s^{-1}.

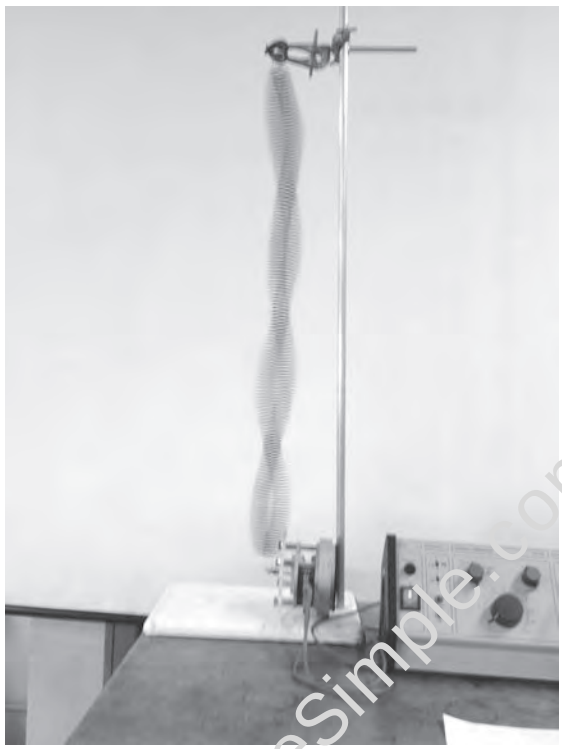
time taken = 6.17 s

length of spring = 72 cm

(3)

RevisionMadeSimple.com

(f) The vibration generator is then turned sideways so that it vibrates horizontally. Photograph 3 was taken when the frequency was set to 14 Hz. The length of the spring is still 72 cm.



Photograph 3

Compare the patterns shown in Photograph 1 and Photograph 3.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

(Total for Question = 15 marks)

RevisionMadeSimple.com

5 In the diagram, line X represents the equilibrium positions of a line of molecules in a solid.

A sound wave of wavelength λ and frequency f passes through the solid from left to right.

Line Y represents the positions of the same molecules at a time t.

RevisionMadeSimple.com

(a) Explain how the diagram shows that the wave is longitudinal.

(1)

.....

.....

(b) On line Y

(i) identify **two** compressions and label them C;

(ii) identify **two** rarefactions and label them R;

(iii) label the wavelength λ of the wave.

(3)

(c) The period of the wave is T.

On the line Z mark the positions of two compressions at a time $t+\frac{3}{4}T$ and label them P.

(2)

(Total for Question = 6 marks)

6 (a) Ultrasound scanning can be used by doctors to obtain information about the internal structures of the human body without the need for surgery. Pulses of ultrasound are sent into the body from a transmitter placed on the skin.

(i) The ultrasound used has a frequency of 4.5 MHz.

State why waves of this frequency are called ultrasound.

(1)

.....

.....

(ii) A pulse of ultrasound enters the body and its reflection returns to the transmitter after a total time of 1.6×10^{-4} s.

Calculate how far the reflecting surface is below the skin.

average speed of ultrasound in the body = 1500 m s^{-1}

(3)

.....

.....

.....

Distance = ...

(iii) State why the ultrasound is transmitted in pulses.

(1)

.....

.....

RevisionMadeSimple.com