

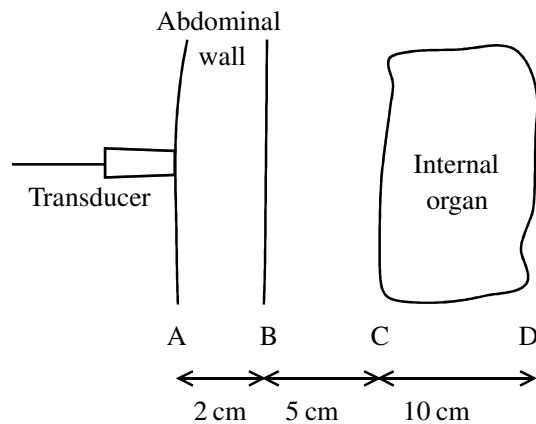
# HW Four

## The Doppler Effect

45 min  
45 marks

1. (a) Ultrasound images of the body are a useful diagnostic tool for doctors. A single transducer can be used both to send and receive pulses of ultrasound.

The diagram shows a lateral cross-section through part of the abdomen. The diagram is not to scale.



- (i) Calculate the time interval between sending out a single pulse and receiving its echo from interface B. The speed of ultrasound in the abdominal wall is  $1500 \text{ m s}^{-1}$ .

Time interval = .....

(3)

- (ii) The time between pulses being emitted by the transducer is  $200 \mu\text{s}$ . At what frequency are the pulses emitted?

Frequency = .....

(2)

- (iii) The time interval before the echo returns from interface D is  $250 \mu\text{s}$ . Suggest why this time interval will make reflections from D difficult to interpret and what could be done to overcome this problem.

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(3)

- (iv) State **one** reason why ultrasound rather than X-rays is now used to scan expectant mothers.

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(1)

- (b) Ultrasound is also used to measure blood flow in the body. It uses the Doppler shift of the reflected pulse to measure the speed of blood through the arteries of the body.

Describe the principle of this method and how it can be used to determine the speed of blood.

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(4)  
(Total 13 marks)

2. Radar is the use of radio waves to detect the position and speed of an object. Air traffic control uses radar in this way to track the position of aircraft.

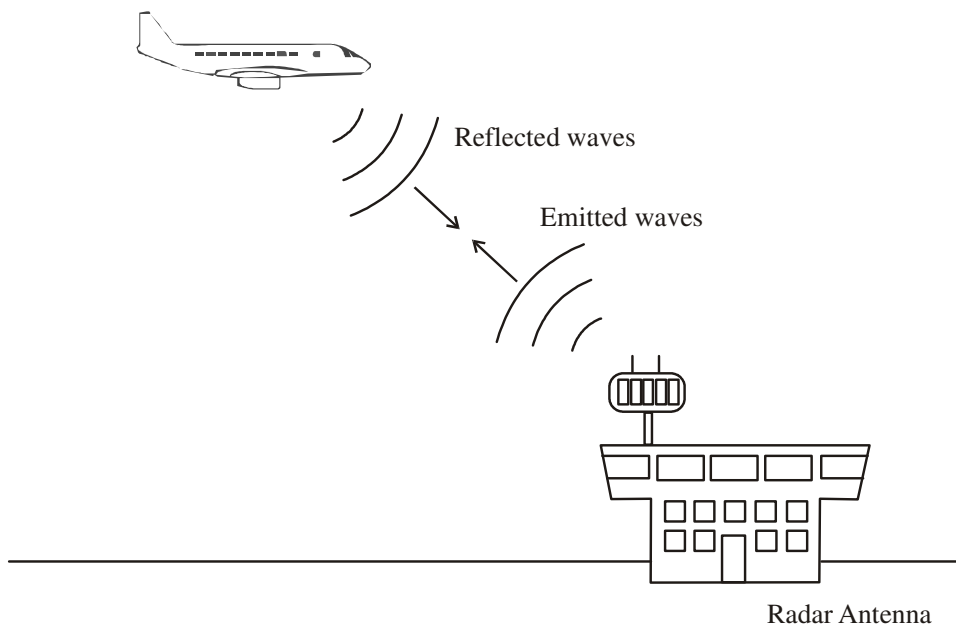


Diagram from: <http://electronics.howstuffworks.com/radar.htm>

A short pulse of high frequency radio waves is transmitted from the control tower and is reflected back from an aircraft. There is an interval of  $48 \mu\text{s}$  between the transmitted pulse and the detected echo. Show that the distance of the aircraft from the control tower is about 7 km.

[ $1 \mu\text{s} = 1 \times 10^{-6} \text{ s}$ ]

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Distance = ..... (2)

Give two reasons why **pulses** of radio waves are needed.

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(2)

The 'Doppler shift' of the reflected radar signal can be used to measure the speed of the moving aircraft. Describe the principle of this method and how it can be used to determine the aircraft's speed.

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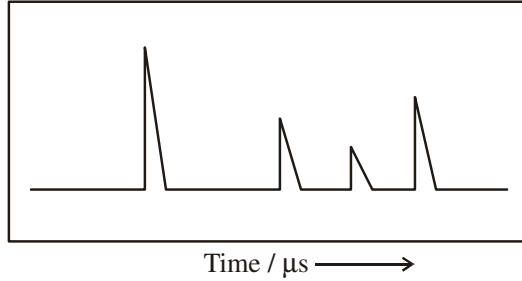
(3)

(Total 7 marks)

3. According to a study carried out by Bell Labs in New Jersey, the signal from a mobile phone could be used to detect your pulse and breathing rate. The phone does not need to be answered and so could be used to locate unconscious survivors of earthquakes.

When the phone rings, microwaves are emitted which then reflect back to the phone from different parts of the owner's body such as the chest, heart and lungs.

The following diagram shows some of these reflected waves being displayed on the screen of a cathode ray oscilloscope.



Explain why the microwaves are reflected off different parts of the body.

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(1)

Give **two** reasons why the amplitudes of the peaks vary.

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.....

(2)

Give one reason why the time between the peaks varies.

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(1)

If the microwaves are reflected from a moving object, such as a beating heart, a Doppler shift is observed.

Explain what is meant by the term **Doppler shift** and how it occurs.

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(2)

Describe and explain the observed changes in the **wavelength** and the **frequency** of the detected microwave signal when the heart is contracting (moving away from the microwave source).

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(3)

(Total 9 marks)

4. There are concerns among fishermen that dwindling fish stocks in the world's oceans are result a of modern fishing, techniques. Fishing trawlers can detect shoals of fish using ultrasound.

Describe the movement of water molecules when an ultrasound wave passes.

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(2)

Ultrasound pulses can be transmitted into the sea and the reflected waves can be detected and used to find the position of a shoal of fish.

Explain why **pulses** of ultrasound are used.

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(1)

A shoal of fish is at a depth of 300 m. Calculate the time interval between transmitting the pulse and receiving its echo.

(The speed of ultrasound in water =  $1500 \text{ m s}^{-1}$ .)

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Time interval = .....

(2)

A **continuous** ultrasound signal can be used to determine the speed of the shoal of fish.

Name the effect used in this method.

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Briefly explain the physics principles of this effect.

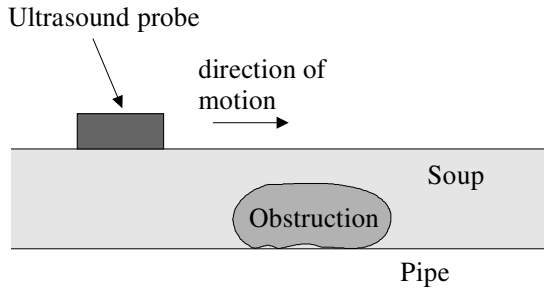
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(3)

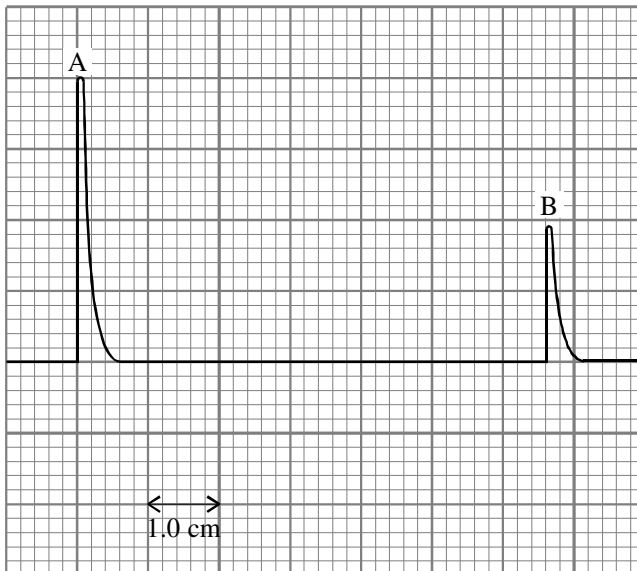
(Total 8 marks)

5. A food packaging factory is moving soup through a 0.075 m diameter pipe when an obstruction occurs in the pipe. An ultrasound probe, connected to an oscilloscope, is moved along the pipe to find the obstruction (figure 1). The oscilloscope trace is shown below (figure 2).

**Figure 1**



**Figure 2**



Oscilloscope time base =  $20 \times 10^{-6} \text{ s cm}^{-1}$ .

On figure 2, pulse A is the outgoing signal from the probe and pulse B is the reflected signal from the other side of the pipe

Calculate the speed of the ultrasound in the liquid in the pipe.

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Speed = .....

(2)

State one way in which the oscilloscope trace will change when the ultrasound probe is above the obstruction.

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(1)

After the obstruction has been cleared, a “Doppler” ultrasound probe is used to measure the speed of the soup in the pipe. Describe the principle of this method.

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(3)

What must be measured to determine the speed of the soup?

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**(1)**

Someone says that this would be easier if the soup contained lumps like vegetables. Comment on this suggestion.

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**(1)**

**(Total 8 marks)**