Section One: Short response

Question 1 **[6 marks]**

Complete the rows in the following table by writing the missing values (name of measurement or SI unit) for each measurement, and stating whether it is a scalar or vector quantity. For SI units you may enter the name and/or the symbol for the missing value. The first row has been completed for you as an example.

Measurement	SI unit	Scalar or vector
Length	metre (m)	Scalar
Time	seconds (s)	Scalar
Acceleration	$m\ s^{-2}$	Vector
(Electric) Current	Ampere (A)	Scalar
Momentum	$kg\ m\ s^{-1}$	Vector
Force	newtons (N) [or $kg\ m\ s^{-2}$]	Vector
Temperature	kelvin (K)	Scalar

Question 2 **(4 marks)**

A worker on a building site accidently dropped a 4.00 kg hammer and it fell 12.0 m to the ground.

(a) Calculate the speed of the hammer when it hit the ground. (2 marks)

$v^2 = u^2 + 2as$

$v^2 = 0^2 + 2 \times (9.8 \times 12)$

$v^2 = 235.2$

$v = 15.3\ m\ s^{-1}$

(b) If the impact time of the hammer hitting the ground was 0.300 seconds, calculate the magnitude of the average force exerted on the ground during the impact. (2 marks)

$F t = mv - mu$

$Ft = m(v – u)$

$F \times 0.300 = 4.0 \times (15.34 – 0)$

$F = [4 (15.34 – 0)] / 0.300$

$F = 205\ N$

Question 3 **[3 marks]**

Neil Armstrong became the first person to walk on the moon in 1969 after descending from the lunar module (right). The acceleration due to gravity on the moon is $1.62\ m\ s^{-2}$. If Armstrong had a mass of 90.0 kg, what is the difference between his weight on the moon and his weight on Earth?

F_W(Earth) = 90.0 x 9.80

= 882 N down **(1 mark)**

F_W(moon) = 90.0 x 1.62

= 145.8 N down **(1 mark)**

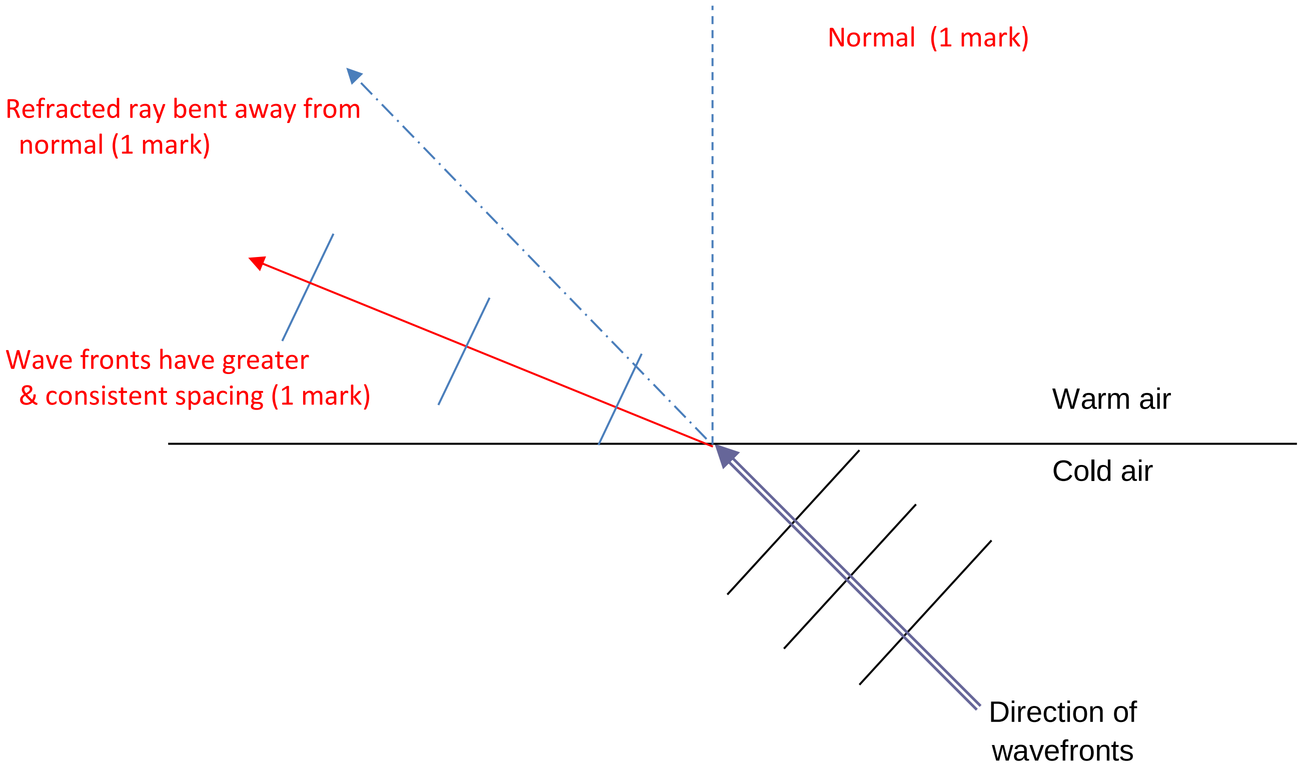
Difference = 882 – 145.8

= 736.2 N

= 736 N **(1 mark)**

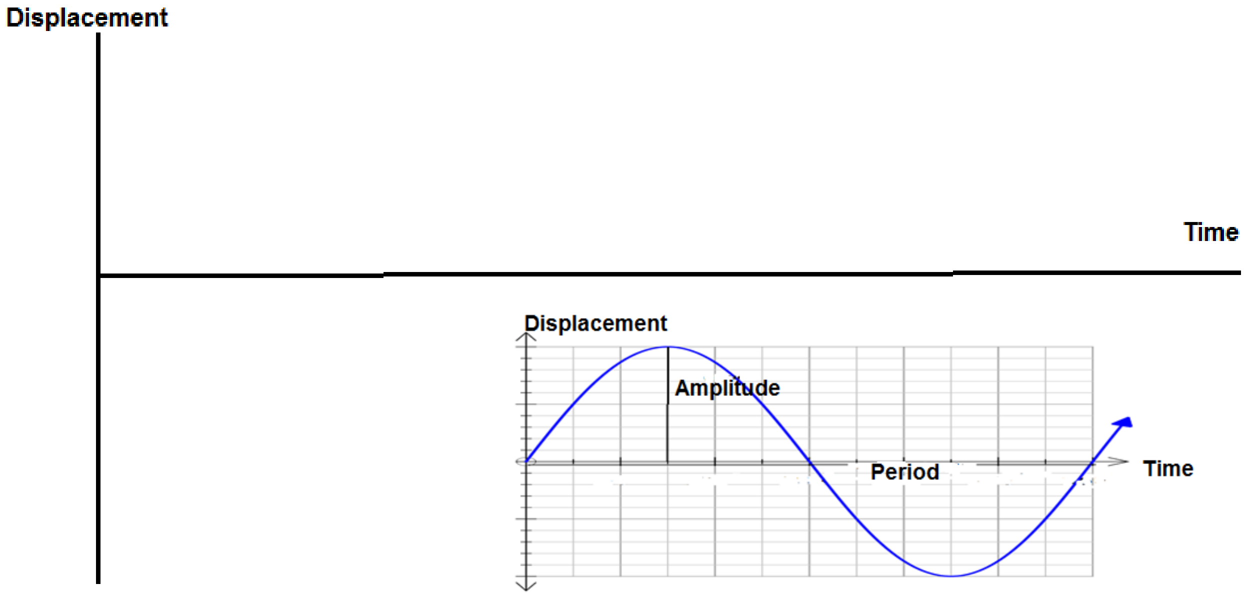
Question 4 **(3 marks)**

Sound travels faster in warm air than in cold air. The following diagram represents a temperature inversion, where a layer of warm air rests above cold air. A beam of sound is directed upward at an angle. Complete the diagram to show the direction of the wavefronts and the new wavelength of the sound refracted in the warm layer. Include a labelled normal, refracted wave and wave fronts.

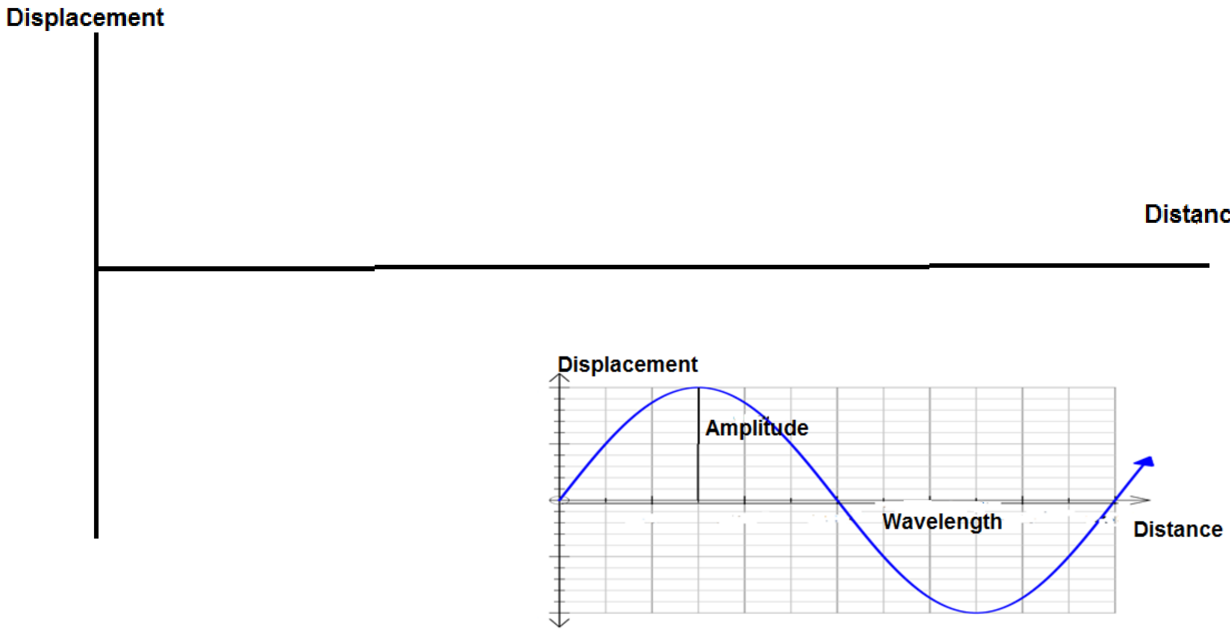


Question 5 **(3 marks)**
Draw two graphs (displacement/time and displacement/distance) to represent a wave.

On these graphs label the period, amplitude and wavelength.
Displacement/time



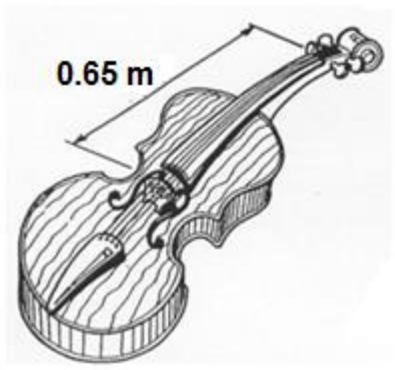
Displacement/distance



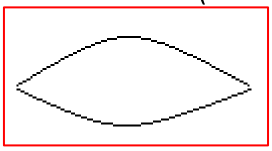
(1 mark each for showing wavelength, period, and amplitude)

Question 6 **(6 marks)**

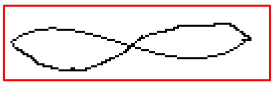
A violin string is 0.650 m in length. Sketch the standing waves produced for the 1^{st} and 2^{nd} harmonics and determine their wavelengths. (4 marks)



1^{st} **Sketch** (1 mark) **Wavelength =** ________1.30 m (1 mark)



2^{nd} **Sketch** (1 mark) **Wavelength =** ________0.650 m (1 mark)



b) If the wave speed in the string is 4.00×10^2 m s^{-1}, calculate the frequencies of the first two harmonics (2 marks)

$f = \frac{v}{\lambda}$

1^{st} $f = \frac{400}{1.3} = 308\ Hz$ 1 mark

2^{nd} f = 2 x 308 = 615 Hz 1 mark

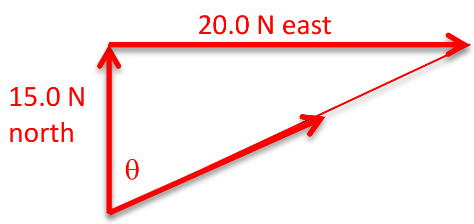
Question 7 **[3 marks]**

A 150 g hockey puck is struck simultaneously by two hockey sticks. One stick strikes with a force of 15.0 N north and the other strikes with a force of 20.0 N at east. Calculate the acceleration of the puck, and the direction in which it will travel.

$F_{net} = \sqrt{(F_1^2 + F_2^2)}$

$= \sqrt{(15^2 + 20_2^2)}$

= 25.0 N **(1 mark)**



tan(θ) = 20/15

$\theta = \tan^{-1}(20/15)$

= N 53.1° E **(1 mark)**

F = ma

a = F/m

= 25.0/0.150

= 167 m s^{-2} **(1 mark)**

The puck will have an acceleration of 167 m s^{-2} and travel at an angle of N 53.1° E.

Question 8 **[12 marks]**

Meso-man is not quite as powerful as Superman, but tries his best. He stands 1.55 m high and has a mass of 90.0 kg. Air resistance is to be ignored for all the following questions.

a) In his effort to run faster than a speeding bullet he opts to race against a shotgun pellet which has a speed of 3.35×10^2 m s^{-1}. Meso-man starts running from resting position and covers 9.50 k min a straight line in 0.500 min. What was his average speed, and would he beat the shotgun pellet over this distance? (3 marks)

$s = 9.50 \times 10^3$ m; $t = 30.0$ s

$v = s/t$ **(1 mark)**

$= 9.50 \times 10^3/30.0$

$= 3.17 \times 10^2$ m s^{-1} **(1 mark)**

No, he would not beat the speeding bullet. **(1 mark)**

b) Meso-man wants to prove that he is more powerful than a locomotive. He goes to the Castledare Model Railway and races with a velocity of 80.0 km h^{-1} east towards a model engine which is travelling at 20.0 km h^{-1} west. After the collision, the engine is travelling 1.50 km h^{-1} east and Meso-man has a velocity of 1.00 km h^{1} east. What is the mass of the engine? How many times more massive is the engine than Meso-man? (4 marks)

Let east be positive

Let the mass of Meso-man be m_1 and that of the engine, m_2:

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$ **(1 mark)**

$(90.0 \times 22.2) + (m_2 \times -5.55) = (90.0 \times 0.278) + (m_2 \times 0.417)$ **(1 mark)**

$2000 - 5.55m_2 = 25.0 + 0.417m_2$

$2000 – 25.0 = 5.55m_2 + 0.417m_2$

$5.972m_2 = 1975$

$m_2 = 1975/5.14$

$= 331$ kg **(1 mark)**

The train is 384/90 = 3.67 times more massive than Meso-man. **(1 mark)**

c) Meso-man wants to find out how high he can leap. Since Superman is 2.00 m tall, Meso-man stands on a stool which is 0.450 m high in order to make up for the difference. He leaps vertically upwards and uses 3.75×10^3 J of energy. Calculate the maximum height he reaches above the ground? Assume 100% efficiency of conversion of energy. (4 marks)

$m = 90.0$ kg; $g = -9.80$ m s^{-1}; $h = x + 0.450$ m

$E_P = 3.75 \times 10^3 = mgh$ **(1 mark)**

$h = E/mg$

$= 3.75 \times 10^3/(90.0 \times -9.80)$ **(1 mark)**

$= -4.25$ m down

$= 4.25$ m up **(1 mark)**

Maximum height = 4.25 m + 0.450 m

$= 4.70$ m **(1 mark)**

d) Meso man claims he can jump over a building of the height calculated in part (c) of this question. Is Meso-man cheating? Explain briefly (just 'yes' or 'no' will not get the mark). (1 mark)

Yes he is cheating since the height in part (c) is the height of his centre of mass. He would not be able to clear this height with the lower part of his body.

Question 9 **(5 marks)**

A bullet is discharged accidentally from a rifle and travels due east with a velocity of 3.70×10^2 m s^{-1}. It strikes a rock and ricochets off due north at 1.80×10^2 m s^{-1}. The bullet has a mass of 1.90 g. You may ignore any effects due to gravity and assume that the collision is completely elastic.

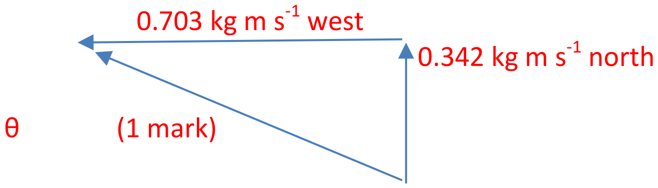
Calculate the change in momentum of the bullet, including a vector diagram.

$P_{initial} = mv = 1.90 \times 10^{-3}$ kg x 3.70×10^2 m s^{-1}

= 0.703 kg m s^{-1} east

$P_{final} = mv = 1.90 \times 10^{-3}$ kg x 1.80×10^2 m s^{-1}

= 0.342 kg m s^{-1} north (1 mark)



$\Delta P = P_{final} - P_{initial}$

= 0.342 kg m s^{-1} north - 0.703 kg m s^{-1} east

= 0.342 kg m s^{-1} north + 0.703 kg m s^{-1} west

= $\sqrt{(0.342^2 + 0.703^2)}$

= √(0.611

= 0.781 kg m s^{-1} (1 mark)

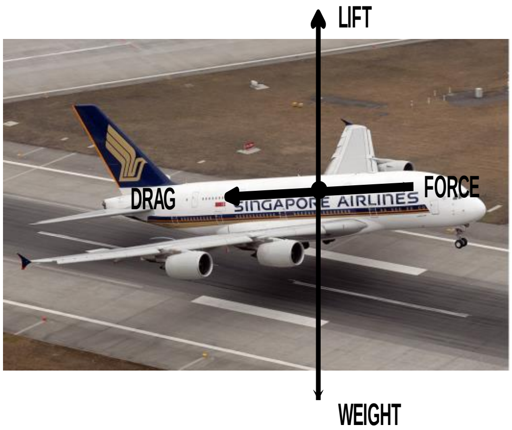
$\theta = \tan^{-1}(0.703/0.342)$

Question 10 **(4 marks)**

A fully loaded A380 Airbus having a mass of 5.60×10^5 kg takes off at an angle of 20° to the runway and is propelled forward by its four engines.

(a) On the photo opposite draw arrows to show the forces that are acting on the aircraft as it takes off. (2 marks)

The arrows should show relative magnitudes. Lift is greater than weight and force is greater than drag



(b) Calculate the minimum vertical force that the engines need to produce to just lift the Airbus off the runway. (2 marks)

F = m g

F = $(5.60 \times 10^5) \times 9.8$ (1 mark)

F = 5.49×10^6 N (1 mark)

Question 11 **(3 marks)**

A 161.0 g cricket ball moving at 25.0 m s^{-1} hit the edge of a stationary bat transferring 18.1 J of energy to the bat. Calculate the speed of the ball after the collision.

Energy before collision = $\frac{1}{2}mv^2$ = $0.5 \times 0.161 \times 25^2$ = 50.3125 J (1 mark)
Energy of ball after collision = 50.3125 – 18.1 = 32.2125 J (1 mark)
$E = \frac{1}{2}mv^2$
$32.2125 = 0.5 \times 0.161 \times v^2$
$v^2 = 32.2125 / (0.5 \times 0.161) = 400.155$
$v = 20.0$ m s^{-1} (1 mark)

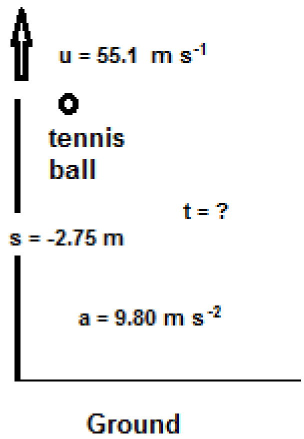
Section Two: Problem-solving
Question 12 **(13 marks)**

Vanessa Williams celebrates a victory by climbing into the crowd and smashing a tennis ball vertically upwards.The ball is hit from a position 2.75 m above the ground with an initial velocity of 55.1 m s^{-1} upwards.The ball has a mass of 57.3 g.

a) Calculate the time the ball takes to reach the ground. (3 marks)

up is +ve

$s = ut + ½at^2$
$-2.75 = 55.1 t -4.90 t^2$
t = 11.3 s



b) Calculate the velocity of the ball after 5.10 s. (2 marks)

t = 5.10 s
v = u + at
= 55.1 + (-9.80 x 5.10) (1 mark)
= 5.12 m s^{-1} up (1 mark)

c) Calculate the distance that the ball travels to reach the ground. (3 marks)

Highest point v = 0
$v^2 = u^2 + 2as$
$0 = 55.1^2 -19.6 s$ (1 mark)
s = 1.55 x 10^2 m (1 mark)
Total distance = (2 x 1.55 x 10^2) + (2.75)
= 3.13 x 10^2 m (1 mark)

d) Calculate the mechanical energy of the ball whilst in flight. (3 marks)

$E_M = E_K + E_P$ (1 mark)
= $0.5 mv^2 + mgh$
= 0.5 x 0.0573x 55.1^2 + 0.0573 x 9.8 x 2.75 (1 mark)
= 8.85 x 10^1 J (1 mark)

e) The tennis racquet is in contact with the ball for 0.312 s. Calculate the impulsive force on the ball. (2 marks)

F = (mv – mu)/t
= 0.0573 (55.1 -0)/0.312 (1 mark)
= 1.01 x 10^1 N (1 mark)

Question 13 **(12 marks)**

In a 50.0 km long distance race involving an able -bodied runner and a wheelchair athlete, the able-bodied runner maintained an average speed of 17.0 km h^{-1} for the race. The wheelchair athlete set off 30.0 minutes after the able-bodied runner and travelled at an average of 21.0 km h^{-1} for the race.

(a) Calculate how long it took for the able-bodied runner to finish the race. (2 marks)

t = s/v
= 50.0 km/17.0 km h^{-1} (1 mark)
= 2.94 h
= 1.06 x 10^4 s (1 mark)

(b) Calculate how long it took for the wheelchair athlete to finish the race. (2 marks)

t = s/v
= 50.0 km/21.0 km h^{-1} (1 mark)
= 2.38 h
= 8.57 x 10^3 s (1 mark)

(c) Who won the race? Support your answer with calculations and clear reasoning. (2 marks)

Since the wheelchair athlete started 30.0 mins after the able-bodied athlete, they crossed the finish line 2.38 + 0.5 = 2.88 h after the start of the race. (1 mark)
Since 2.88 < 2.94, the wheelchair athlete crossed the finish line first. (1 mark)

(d) By how many minutes did the winner beat the loser? (2 marks)

2.94 – 2.88 = 0.06 h (1 mark)
0.06 h x 60 min h^{-1} = 3.60 min (1 mark)
(Or 3 min 36 s)

(e) When the winner crossed the finish line how much further did the loser have to travel before they finished? (2 marks)

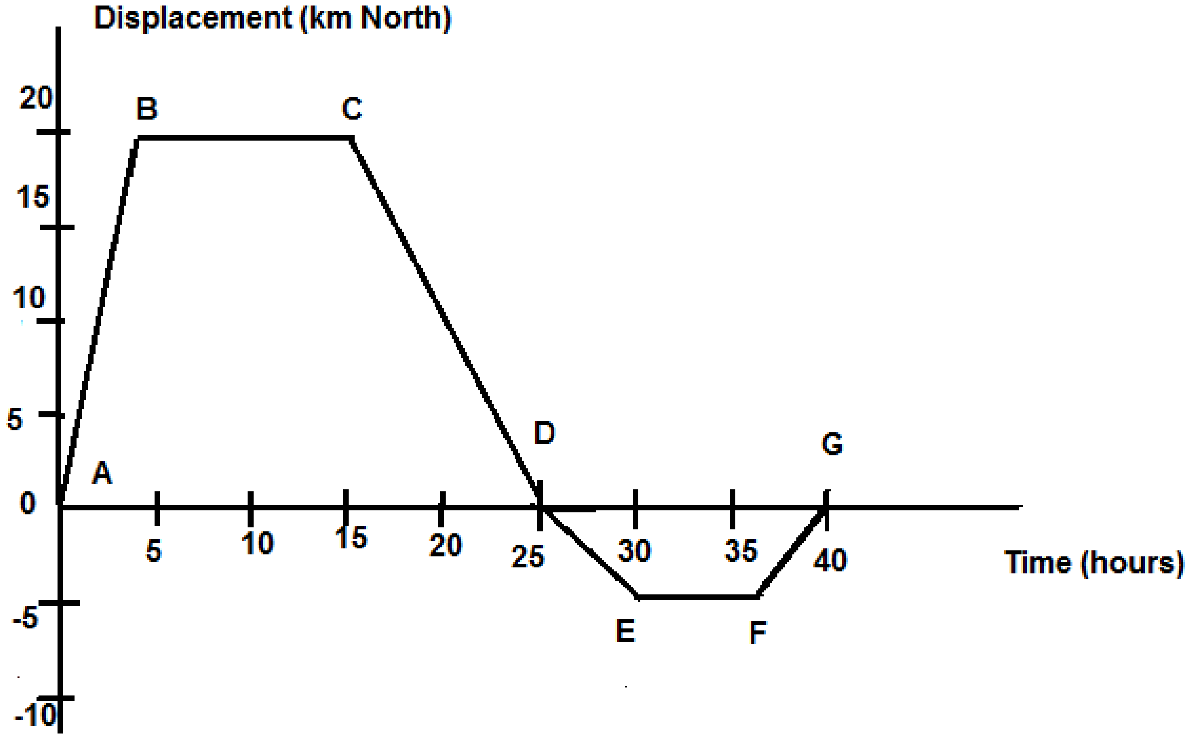
The loser still had 0.06 h remaining before they crossed the finish line (1 mark)
0.06 h x 17.0 km h^{-1} = 1.02 km remaining (or 1.02 x 10^3 m) (1 mark)

(f) What average speed would the loser of the race have had to maintain, just to finish at the same time (that is, draw the race), as the winner? (2 marks)

They would have to cover the 50.0 km distance in 2.38 + 0.5 = 2.88 h (1 mark)
Average speed would need to be 50.0 km/2.88 h = 17.4 km h^{-1} (=4.82 m s^{-1}) (1 mark)

Question 14 **(9 marks)**

A keen bushwalker went for an extended hike as shown by the following graph.



Use the graph to determine the following information:

How far did the hiker walk? (1 mark)

50 km (1 mark)

Calculate the velocity (km h^{-1}) in the following segments:

AB (1 mark)

20 km/4 h = 5 km h^{-1} N

EF (1 mark)

0.0 km h^{-1} (stationary)

AG (1 mark)

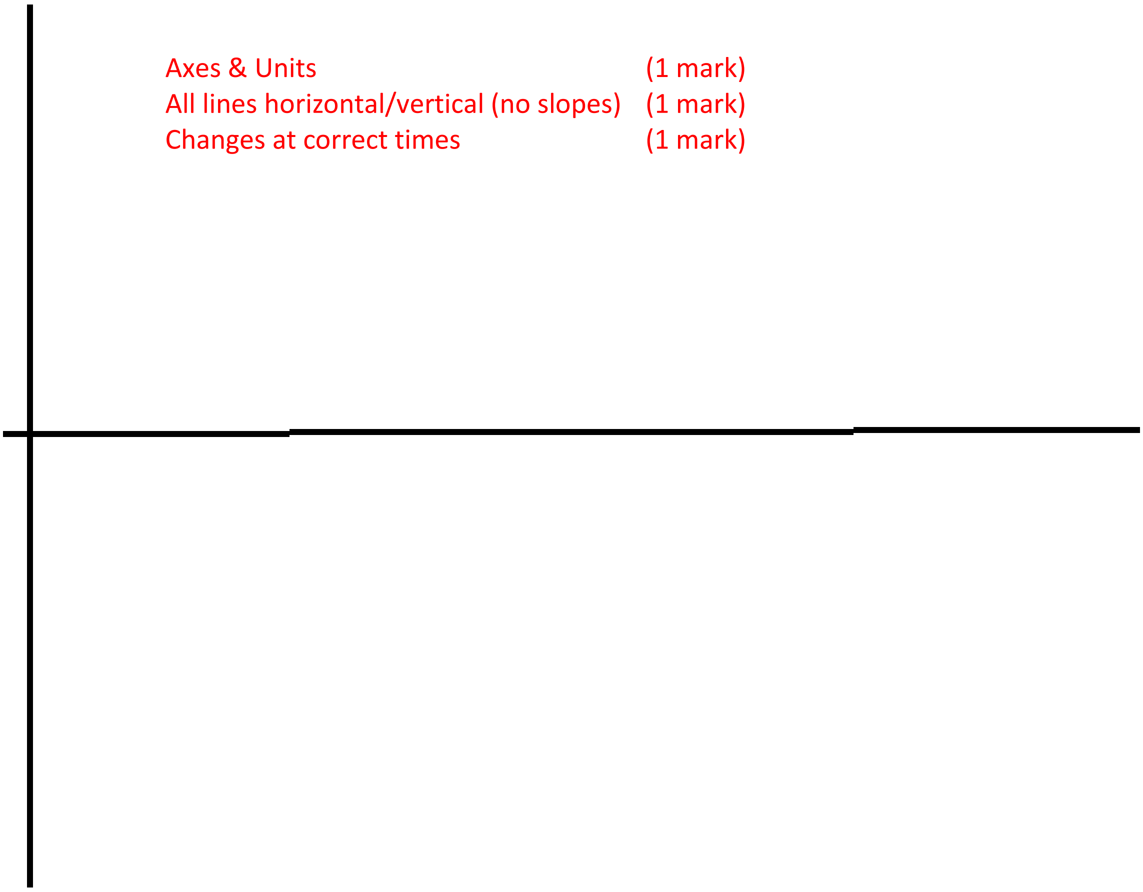
0.0 km h^{-1} (stationary)

DE (1 mark)

km/5 h = 1 km h^{-1} S

Question 14 (cont.)

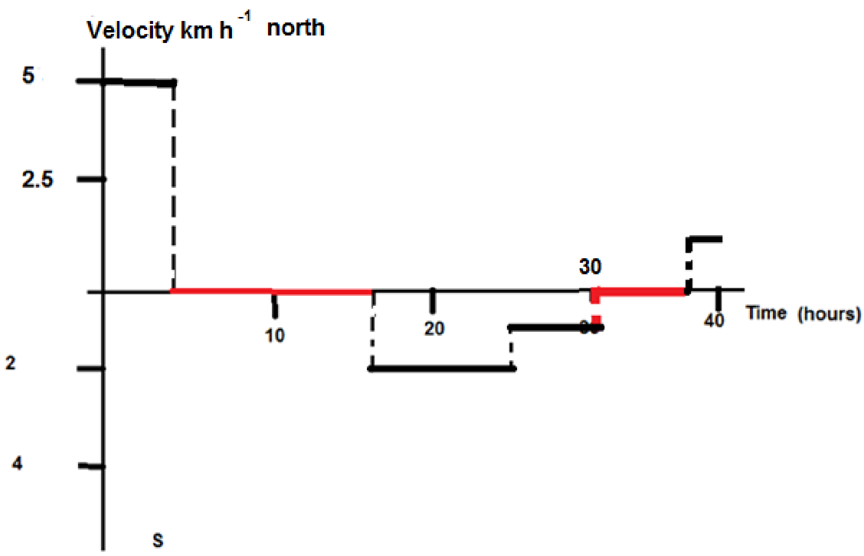
Draw a graph of velocity versus time. (3 marks)



Axes & Units	(1 mark)
All lines horizontal/vertical (no slopes)	(1 mark)
Changes at correct times	(1 mark)

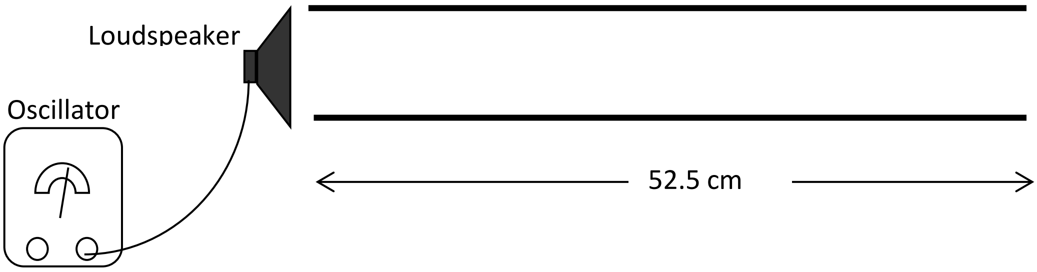
For how long was the walker stationary? (1 mark)

17 +/- 2 hours



Question 15 **(10 marks)**

In an experiment a student sets up the following apparatus. A loudspeaker is placed at one end of an open pipe. The loudspeaker is connected to an oscillator which allows vibrations with variable frequencies to be produced.



The student gradually increases the frequency of sound from zero and notices that at a frequency of 333 Hz the pipe makes a loud sound.

(a) Why is the sound loud at this frequency? (2 marks)

333 Hz is the natural (fundamental) frequency of the air column in the pipe (1 mark)
Since the forcing frequency matches the natural frequency, the sound is amplified (1 mark)

(b) On the above diagram draw a wave pattern (wave envelope) for the displacement of air particles at this fundamental frequency. (1 mark)

Sketch should show antinodes at each end with a node in the centre

(c) At what position inside the pipe could a small burning candle be placed so that the flame remained steady (not being blown from side to side)? Explain briefly. (2 marks)

Candle should be placed in the centre of the pipe (1 mark)
Since this is a displacement node, the air particles will not be displaced by the sound wave energy and the candle's flame will be steady. (1 mark)

Question 15 (cont.)

(d) The pipe is 52.5 cm long.

(i) What is the wavelength of the sound? (2 marks)

$L = ½\lambda$

$\lambda = 2L$ (1 mark)

$= 2 \times 0.525$ m

$= 1.05$ m (1 mark)

(ii) What is the speed of sound in the tube? (1 mark)

$v = \lambda f$

$= 1.05 \times 333$

$= 350$ m s^{-1}

(e) The student now increases the frequency until another loud sound can be heard.

(i) Draw the wave patterns for the displacement of particles for this harmonic (1 mark)

Sketch should show antinodes at both ends and in the centre, with 2 nodes evenly spaced

(ii) What is the frequency of this overtone? (1 mark)

$\lambda = L = 0.525$ m (1 mark)

$v = \lambda f$

$f = v/\lambda$

$= 350/0.525$

$= 666$ Hz (1 mark)

OR $f_2 = 2 \times f_1 = 2 \times 333$ Hz $= 666$ Hz

Section Three: Comprehension **20% (36 Marks)**

Question 15 **(16 marks)**

How Safe is Your Car?

Crash Protection Features

Crash protection features provide greater levels of injury protection to drivers and passengers in car crashes. They include:

Crumple zones

Modern cars protect drivers and passengers in frontal, rear and offset crashes by using crumple zones to absorb crash energy. This means that the car absorbs the impact of the crash, not the driver or passengers.

Strong occupant compartment

The cabin of the car should keep its shape in frontal crashes to protect the driver and passengers' space. The steering column, dashboard, roof pillars, pedals and floor panels should not be pushed excessively inwards, where they are more likely to injure drivers and passengers. Doors should remain closed during a crash and should be able to be opened afterwards to assist in quick rescue, while strong roof pillars can provide extra protection in rollover crashes.

Side impact protection

Increased side door strength, internal padding and better seats can improve protection in side impact crashes. Most new cars have side intrusion beams or other protection within the door structure. Some cars also have padding on the inside door panels.
Increasingly, car manufacturers are installing side airbags that provide protection from severe injury. Head-protecting side airbags, such as curtain airbags, are highly effective in side impact and rollover crashes.

Seat belts

A properly worn seat belt provides good protection but does not always prevent injuries. Three point lap/sash seat belts offer superior protection to two point seat belts and should be installed in all seating positions. Recent improvements to seat belt effectiveness include:

- webbing clamps that stop more seat belt reeling out as it tightens on the spool
- pretensioners that pull the seat belt tight before the occupant starts to move
- load limiters that manage the forces applied to the body in a crash
- seat belt warning systems to remind you if seat belts have not been fastened.

Airbags

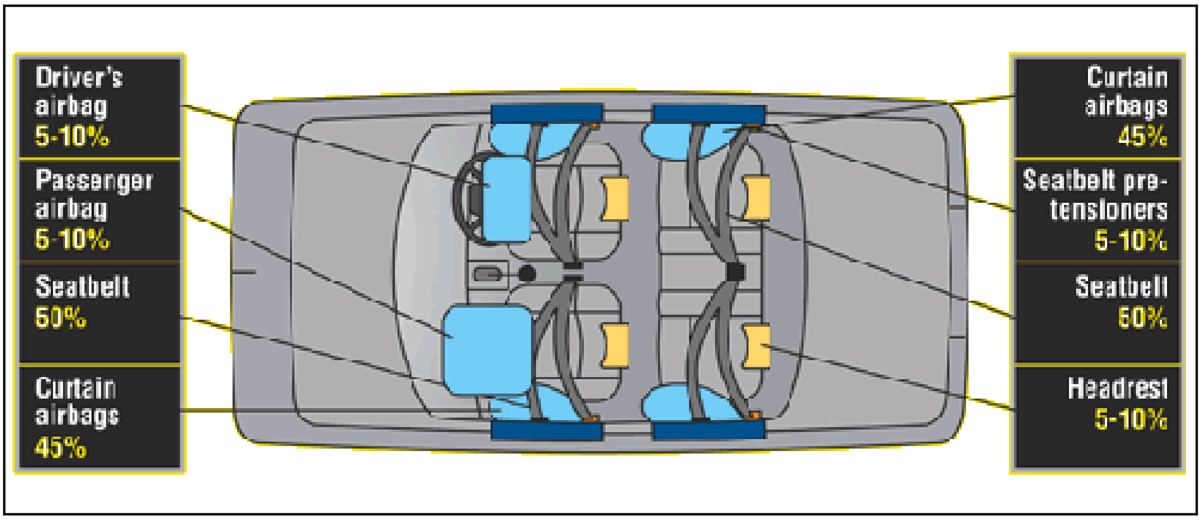
Australian airbags are designed to supplement the protection provided by seat belts - they are not a substitute. The best protection in frontal crashes is achieved using a properly worn seat belt in combination with an airbag.

Head rests

Head rests are important safety features and should be fitted to all seats - front and back. Head rest position is critical for preventing whiplash in rear impact crashes. Whiplash is caused by the head extending backward from the torso in the initial stage of rear impact, then being thrown forward. To prevent whiplash the head rest should be at least as high as the head's centre of gravity (eye level and higher) and as close to the back of the head as possible.

Diagram and Information courtesy of Folksam Research, 2005 (SWEDEN)

Safety features and their capacity for reducing the risk of injury



(a) "Modern cars protect drivers and passengers in frontal, rear and offset crashes by using crumple zones to absorb crash energy." (2 marks)

Explain the energy transformations that occur when a car's crumple zone absorbs energy in a crash.

E_K of car (1 mark) is converted to noise, heat and deforming (1 mark)

(b) Crumple zones also reduce the force experienced when a car crashes. Explain, using Newton's Second Law (momentum), how this acts as an additional safety feature in a car. (4 marks)

Newton's Second Law commonly written as F = ma (1 mark)

Can be rewritten as F = (mv – mu)/t (1 mark)

t increases (1 mark)

F decreases, hence less force on occupants (1 mark)

(c) Two point seat belts are belts that fit across the driver's or passenger's lap. The two points were generally on the floor. Modern car seat belts have a third point about shoulder height when sitting. Why is this advantageous? (2 marks)

Better at keeping occupant in place (1 mark)

Prevents body/head for going forward and hitting something (1 mark)

(d) You are in the passenger seat holding a 3.00 kg parcel on your lap. Your car is involved in a head on crash with a tree. The car speed goes from 72.0 km h^{-1} to zero in 0.100 s. What force is required to hold the parcel? (3 marks)

m = 3.00 kg; v = 0; t = 0.100 s

u = 72.0 km h^{-1} = 72.0/3.6 = 20.0 m s^{-1} (1 mark)

F = (mv- mu)/t

= (3 x 0 – 3 x 20)/0.100 (1 mark)

= 6.00 x 10^2 N (1 mark)

(e) Head rests reduce whiplash injuries in car crashes. Identify and use the appropriate Newton's Law to explain why this is so. (3 marks)

Whiplash is generally caused by crashes where the person is in the vehicle hit from behind

(1 mark)

According to Newton's First Law the unrestrained head continues forward and then body "jerks" it back (1 mark)

The head rest reduces how far back the head can snap back (1 mark)

(f) Airbags inflate and then deflate very quickly. Why? (2 marks)

Inflate quickly to prevent head hitting solid object (1 mark)

Deflate quickly to prevent suffocation (1 mark)