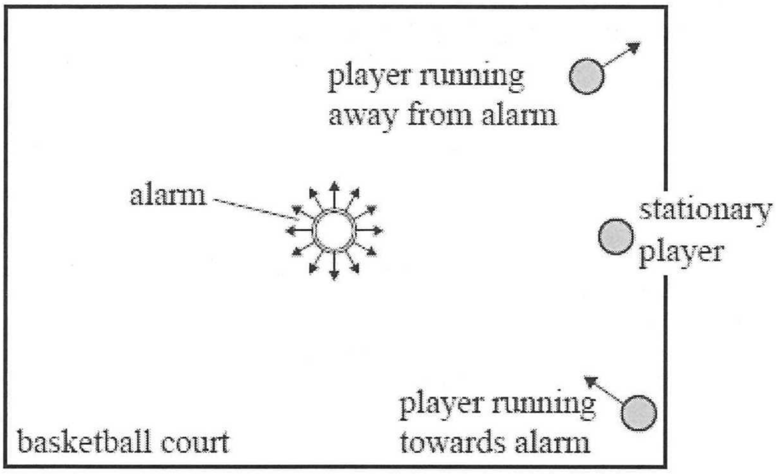
Name ANSWERS Total Marks: /55

Answer all questions to 3 significant figures.

Question 1

An alarm is sounding in the centre of a large indoor basketball court. A stationary player measures the speed of sound as 335 ms^{-1}. A player runs directly towards the alarm (at 5 ms^{-1}) and another runs directly away from the alarm (also at 5 ms^{-1}). As they run they both measure the speed of sound using a small portable device. The situation is shown in the diagram below.



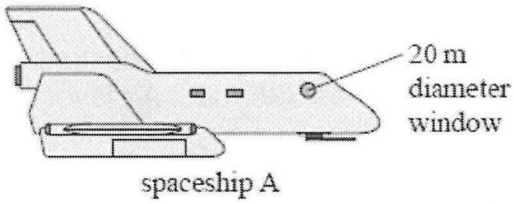
What is the speed of sound as measured by **(2 marks)**

The player running towards the alarm	The player running away from the alarm
$340 ms^{-1}$	$330 ms^{-1}$

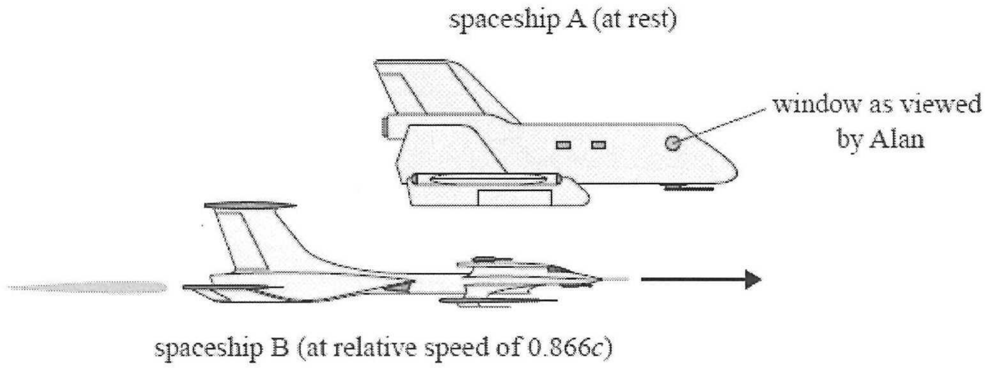
1 1

Question 2

Spaceship **A** has a circular window in its side. Alan, a crew member of spaceship **A**, measures the diameter of the window as 20 m. The diagram below shows spaceship **A** at rest.



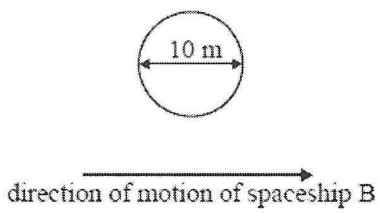
Ivy is a crew member of spaceship **B**. She measures the dimensions of the window as spaceship **B** moves past spaceship **A** at a speed of 0.866 c.



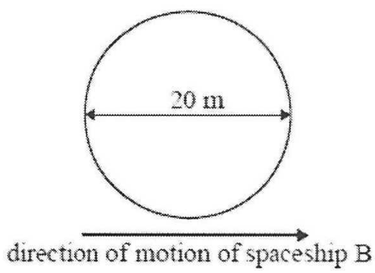
a) Which of the following diagrams best shows the dimensions of the circular window on spaceship **A** as measured by Ivy on spaceship **B**?

(2 marks)

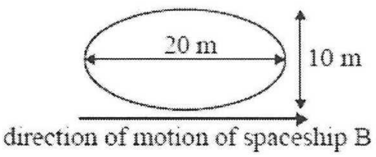
A.



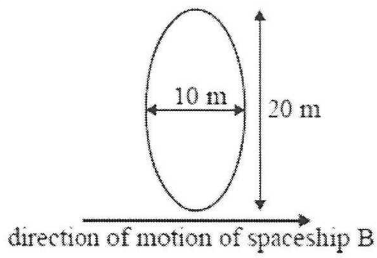
B.



C.



D.



2

b) Calculate the actual length of the window as seen by Ivy. **(3 marks)**

$\ell = \ell_0\sqrt{\left(1-\frac{v^2}{c^2}\right)} = 20\sqrt{(1-0.866^2)}$ ① ①

$= 10m$

①

c) Both Alan and Ivy observe a quasar (distant star). When it is observed, it is at a distance of 2.5 x 1025 km from them and is travelling away from Alan at a speed of 0.16 c.

Both Alan and Ivy measure the speed of the light emitted from the quasar. What value would each expect to measure for the speed of light? Explain the reason for your answer. **(2 marks)**

- Both will measure the speed of light to be C. ①
- The 2nd postulate states that all observers will measure the speed of light as "c" regardless of frame of reference. ①

Question 3

A metre rule is thrown like a spear at a speed of 0.72 c. How long does the rule appear to be when seen by a person at rest? **(3 marks)**

①

$L = L_0\sqrt{1-\frac{v^2}{c^2}} = 1\sqrt{1-0.72^2} = 0.694m$ ①

①

Length contraction will occur

Question 4

An astronaut moving in a spaceship at 0.95 c relative to the Earth measures the time taken for a ball to bounce from the floor to the ceiling of her spacecraft as 0.66 seconds. An observer (at rest) watches the spaceship pass by her. According to this observer, how long will it take for the ball to bounce from the floor to the ceiling?

(3 marks)

$$t = \frac{t_0}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}} = \frac{0.66}{\sqrt{1 - 0.95^2}} = 2.11 s$$

(1) (1) (1)

Question 5

Suppose that a proton was able to move at 99.5 % of the speed of light. What **relativistic mass** will this proton appear to have when observed by a stationary observer?

(4 marks)

$$m = \frac{m_0}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}} = \frac{1.67 \times 10^{-27}}{\sqrt{\left(1 - 0.995^2\right)}} = 1.67 \times 10^{-26} kg$$

(1) (1) (1) (1)

Question 6

Use the information in your Formulae and Data Sheet to answer the following:

a) If a π-meson has a charge of +1, what combination of quarks could make up a π-meson? **(1 mark)**

$u\bar{d}$

① for any

b) What combination of quarks could make up the baryon known as an anti-neutron? **(1 mark)**

$\bar{u}\bar{d}\bar{d}$

①

c) Complete the following table: **(3 marks)**

Combination of Quarks	Overall Charge	Meson or Baryon
Up, down, strange	0	Baryon ①
Down, anti-up	-1	Meson ①
Up, anti-strange	1	Meson ①

Question 7

When a muon meets an anti-muon, both are annihilated and a photon of energy 3.45 x 10^{-11} J is formed.

What is the mass of a single muon? **(3 marks)**

$$\frac{3.45 \times 10^{-11}}{2} = 1.73 \times 10^{-11}\text{ J per muon}$$ ①

$$E = mc^2$$ ①

$$m = \frac{E}{c^2} = \frac{1.73 \times 10^{-11}}{(3 \times 10^8)^2} = 1.92 \times 10^{-28}\text{ kg}$$ ①

or

1.91×10^{-20} kg.

Question 8

a) Which one of the following l particles is not classified as a **lepton**? Circle your answer. **(1 mark)**

A: neutrino
B: neutron
C: electron
D: anti-neutrino

1

b) Why are leptons described as being "fundamental particles" whereas hadrons are not? **(2 marks)**

· leptons can not be broken down into smaller parts. 1
· hadrons can be broken into quarks 1

Question 9

In the **STANDARD MODEL of MATTER**, it is assumed that there are 4 fundamental forces found in nature.

Complete the following table. **(3 marks)**

Name of force	What does it act upon?	Name of mediating particle
Strong Force	quarks, baryons, mesons 1	gluon
Electromagnetic Force	between any charged matter 1	photon
Weak Force	between leptons and/or quarks 1	W & Z bosons
Gravitational Force	between any objects with mass	Graviton

Question 10

Why is it not possible (under the assumptions of Einstein's Theory) for a particle with mass to reach the speed of light? **(4 marks)**

$m = \frac{m_0}{\sqrt{(1 - \frac{v^2}{c^2})}}$

- As velocity approaches c, mass increases significantly to the point of being infinite. (1)
- Infinite mass would require infinite force to accelerate (1) - Newton's 2nd Law. Infinite force is impossible. (1)

∴ particle travelling at c is impossible. (1)

Question 11

Use conservation of charge, lepton number and baryon number to prove or disprove the possibility of the following interactions. **Show your reasoning.**

a) A neutron transmutates into a proton, an electron and an electron-neutrino

$n \rightarrow p + e^- + v_e$ **(3 marks)**

B $1 \rightarrow 1 + 0 + 0$ ✓ (1) possible (1)

L $0 \rightarrow 0 + 1 + (-1)$ ✓

C $0 \rightarrow (1+) + (1-) + 0$ ✓ (1)

b) A tau lepton decays into an electron, an electron-anti-neutrino and a tau neutrino.

(3 marks)

$\tau^- \rightarrow e^- + \bar{v}_e + v_\tau$

B $0 \rightarrow 0 + 0 + 0$ ✓ (1) possible (1)

L $1 \rightarrow 1 + (-1) + 1$ ✓

C $-1 \rightarrow -1 + 0 + 0$ ✓ (1)

c) State for the above interactions, which of the fundamental forces was involved. **(2 marks)**

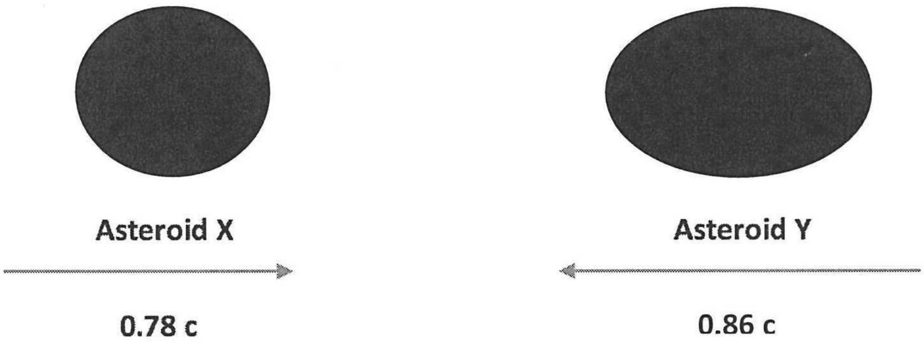
a) weak force (1)

b) weak force (1)

Question 12

Two asteroids are on a course to narrowly miss, but fly by one another. Asteroid **X** is travelling at 0.78 c and Asteroid **Y** is travelling at 0.86 c.

Marvin is catching a ride on Asteroid **X.** How fast will Marvin observe Asteroid **Y** travelling as it passes him? **(3 marks)**



$$u' = \frac{u - v}{1 - \frac{vu}{c^2}} = \frac{-0.86c - 0.78c}{1 - \frac{(0.78 \times -0.86)}{c}}$$ 1 1

$$= -0.982c$$ 1

$2.95 \times 10^8 \, ms^{-1}$

Question 13

For the following statements, state which fundamental force is responsible for the interaction: **(3 marks)**

Friction	electromagnetic
Nuclear bonding	strong
Planetary orbits	gravity

Question 14

Explain, giving reasons, which of the fundamental forces act on the protons within your body.

(4 marks)

• Electromagnetic - protons have a like charge therefore electromagnetic repulsion occurs.

(1)

• Strong - protons are held together in the nucleus by the strong force

(1)

• Gravitational - protons have mass, therefore the strong force is acting.

(1)

• Weak - does act on all but the smallest quarks and leptons, which cannot decay any further.

(1)

END OF TEST