Section One: Short response

Question 1 **(4 marks)**

The intensity of an earthquake wave 120 km from its focus (origin) is measured to be 1.25×10^6 Wm^{-2}. Calculate the intensity of the same wave 480 km from its focus.

$$I \propto \frac{1}{r^2},\ and\ d_2\ is\ 4\ d_1 \quad \textbf{(1m)}$$

$$I_2 = \frac{1}{16} I_1 \quad \textbf{(1m)}$$

$$= \frac{1.25 \text{ x } 10^6}{16} \quad \textbf{(1m)}$$

$$= 7.81\ x\ 10^4\ Wm^{-2} \quad \textbf{(1m)}$$

Question 2 **(4 marks)**

100 g of ice is taken from a freezer where it is kept at -6°C. It is heated until it becomes steam at 110°C. Calculate how much energy it has absorbed.

$$Q = 0.1\,[\,2.1 \times 10^3 \times 6) + (\,3.34x10^5) + (4180 \times 100) + 2.26 \times 10^{\,6} + (2.0 \times 10^3 \times 10)]$$ **(3m)**

$$\underline{= 2.71\ x\ 10^{\,5} J} \quad \textbf{(1m)}$$

Question 3 **(4 marks)**

A 0.10 kg hockey puck is at rest. A force of 20.0 N acts on it for 0.2 s, which sets it in motion. Over the next 2.0s it encounters an average of 0.4N frictional force. Lastly, a force of 24.0N acts for 0.05s in the direction of motion. Calculate the puck's final speed.

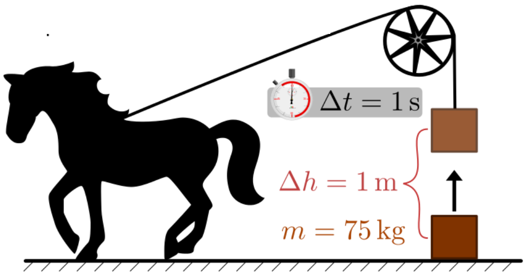
- $In\ first\ 0.2\ sec: a = {}^{F}/_{m} = \frac{20}{0.1} = 200ms^{-2}$
  $v = u + at = 200\ x\ 0.2 = 40\ ms^{-1}$ (**1m**)

- $In\ next\ 2.0s: \ a = -4ms^{-2}$
  $v = u + at = 40 - 8 = 32ms^{-1}$ (**1m**)

- $\text{Lastly}, a = {}^{F}/_{m} = \frac{24}{0.1} = 240ms^{-2}$
  $v = u + at = 32 + 240\ x\ 0.05 = \mathbf{44.0\ ms^{-1}}$ **(2m)**

Question 4 **(4 marks)**

The Horsepower (hp) is an old unit to measure Power, the rate at which work is done. The diagram below shows that that 1.00 hp is needed to lift a 75 kg mass by 1 metre in 1 second.



a) Show by calculation that 1.0 hp = 735.0 W. (2 marks)

$$P = \frac{\Delta PE}{t} = \frac{75 \times 9.8 \times 1}{1} \quad (\mathbf{1m})$$
$$= \mathbf{735.0\ W} \quad (\mathbf{1m})$$

b) If a 12.50 hp air conditioner is working for 2 minutes 15 seconds, calculate how much work has been done. (2 marks)

$$work\ done = P \times t$$
$$12.50\ x\ (735\ x\ 2.25x\ 60) \quad \text{(1m)}$$
$$= \mathbf{1.24 \times 10^6\ J} \quad \textbf{(1m)}$$

Question 5 **(4 marks)**

A stone is dropped into a still pool of water. It generates 20 waves that spread out a distance of 10.0 m from where it entered the water. The outer wave covers the 10.0 m in a time of 5.00 s and the average height of the waves is 10.0 mm (crest to trough).

a) Determine the wavelength and velocity of the waves. (2 marks)

- $\lambda = \frac{10}{20} = \mathbf{0.5\ m}$ $\quad v = d/t = 10/5 = \mathbf{2ms^{-1}}$

(1m each)

b) Calculate the period of the water waves. (2 marks)

$$T = \frac{\lambda}{v} = \frac{0.5}{2} \quad (\mathbf{1m})$$
$$= \mathbf{0.25\ sec} \quad (\mathbf{1m})$$

Question 6 **(5 marks)**

Jack took 8 minutes to dry his hair with a hair dryer. During this period the hair dryer drew a current of 5.5 A from a 240 V supply.

a) Calculate much charge passed through the hair dryer in this time. (2 marks)

$$Q = I.T$$
$$= 5.5 \times 8 \times 60 \ \ (\mathbf{1m})$$
$$= \mathbf{2640\ C} \ \ (\mathbf{1m})$$

b) What is the resistance of the heating coil of the hair dryer? (1 mark)

$$R = \frac{V}{I} = \frac{240}{5.5}$$
$$= \mathbf{43.64\ \Omega} \qquad (\mathbf{1m})$$

c) What is the power rating of the hair dryer? (2 marks)

$$P = I.V = 5.5 \times 240 \qquad (\mathbf{1m})$$
$$= \mathbf{1320\ W} \qquad (1m)$$

Question 7 **(5 marks)**

In an experiment to measure your reaction time, a partner drops a ruler through your open hand and you try to catch the ruler. The length from the start of the ruler to where you catch it can then be used to find your reaction time.

a) Assuming the ruler starts at rest, derive a formula to show how you could calculate the reaction time as a function of length. (2 marks)

$$s = ut + \frac{1}{2}at^2 \qquad (\mathbf{1m})$$

$$then\ t = \sqrt{\frac{2s}{g}} \qquad (\mathbf{1m})$$

$$\boldsymbol{or \quad t = \sqrt{\frac{s}{4.9}}}$$

$$\boldsymbol{where\ s = length\ the\ ruler\ fell}$$

b) A group of students collected the following data:

Trial	Distance ruler fell (mm)
1	46
2	44
3	38

4	32
Average:	40

Complete the table by calculating the average distance the ruler fell. (1 mark)

40 mm or (0.04 m)

c) Calculate the average reaction time as shown by the data above. (2 marks)

$$t = \sqrt{\frac{2s}{g}}$$

$$= \sqrt{\frac{2 \times 0.04}{9.8}} \quad \mathbf{(1m)}$$

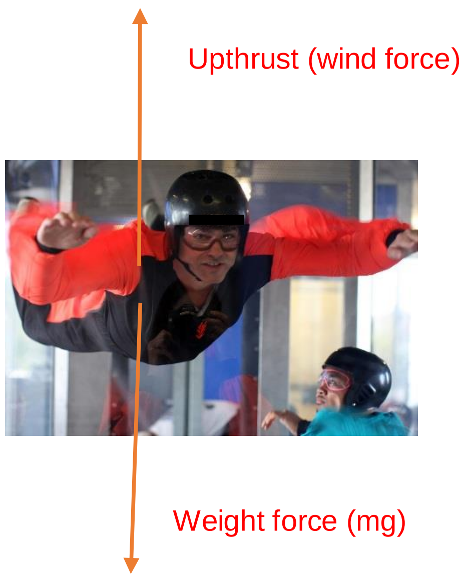
$$= \mathbf{0.09\ sec} \quad \mathbf{(1m)}$$

Question 8 **(4 marks)**

A person has decided to try Indoor skydiving. A large aeroplane engine bolted to the ground provides a very high wind, on which participants can "fly".

a) Draw and clearly label two forces that act on a person whilst in "flight" (2 marks)

Relative magnitude doesn't matter at this stage



b) If a 70.0 kg person wishes to remain at a constant height, calculate the force that the wind needs to apply to them. Be sure to show your working. (2 marks)

$$\text{Vertically,} \quad \Sigma F = 0$$

$$hence\ F = -mg \quad \mathbf{(1m)}$$

$$= 70 \times 9.8$$

$$= \mathbf{686\ N\ \ Upwards} \quad \mathbf{(1m)}$$

Question 9 **(7 marks)**

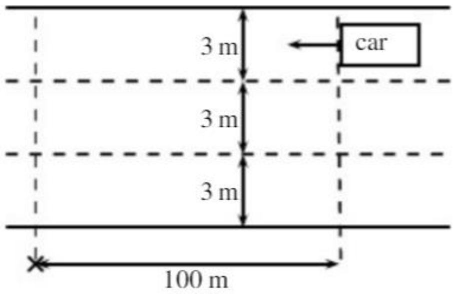
On the way to school, a student decides not to use the pedestrian bridge to cross a busy road, and decides instead to run across the road. He sees a car 100 m away travelling towards him, and is confident that he can cross in time.

a) The car is travelling at 105 kmh^{-1} and the student can run at 10 kmh^{-1}, calculate their respective speeds in ms^{-1}. (2 marks)

Divide kmh^{-1} by 3.6 to get ms^{-1}….

Car 29.17 ms^{-1} Student 2.78 ms^{-1}

b) If the road has 3 lanes, and each lane is 3 m wide, how long will it take for the student to cross all three lanes, from kerb to kerb? (2 marks)



$$time = \frac{s}{v} = \frac{9}{2.78}$$
$$= \mathbf{3.24\ seconds}$$

c) If the car is travelling in the furthermost lane from the student, will he be able to cross all 3 lanes of the road safely? Provide a calculation as part of your reason. (3 marks)

Answer:

YES $(\mathbf{1m})$

Reason: $Car\ will\ take\ \frac{100}{29.17} = 3.429\ sec\ to\ reach\ where\ the\ student\ is\ crossing.$

$In\ that\ time, student\ travels\ 2.78\ x\ 3.429 = 9.53\ m, crossing\ to\ the\ other\ side\ of\ the\ road.$

$Or\ similar.\ (\mathbf{2m})$

Question 10 **(5 marks)**

A 240 V electric kettle is used to heat 280 mL of water initially at 22 ^{0}C. The heating element draws a current of 1.8 A, and is left on for 3 minutes. Determine the final temperature of the water, assuming 85% efficiency.

$$Q = mc\Delta T = V.I.T \quad (\mathbf{1m})$$

$$\therefore \Delta T = \frac{V.I.T}{m.c} \quad (\mathbf{1m})$$

$$= \frac{1.8 \times 180 \times 240 \times 0.85}{0.28 \times 4180} \quad (\mathbf{1m})$$

$$= \mathbf{56.473}℃ \quad (\mathbf{1m})$$

$$Hence\ Final\ temp = \mathbf{78.46}\ ℃ \quad (\mathbf{1m})$$

Question 11 **(4 marks)**

In a game of 10-pin bowling, a person bowls a 10.5 kg bowling ball so that it hits the last remaining 1.0kg bowling pin at 2.4 ms^{-1} and continues after the collision at 1.94 ms^{-1}. The collision is head-on, so that all motion is in one dimension and 10.0% of the initial energy is lost in the collision. Calculate the speed of the pin immediately after the collision.

$$(0.9)\Sigma KE_{initial} = \Sigma KE_{final} \quad (\mathbf{1m})$$

$$so, \quad (0.9)\ 5.25 \times 2.4^2 + 0 = 5.25 \times 1.94^2 + 0.5v^2 \quad (\mathbf{1m})$$

$$27.216 = 19.75 + 0.5\ v^2 \quad (\mathbf{1m})$$

$$14.932 = v^2$$

$$v = \mathbf{3.86}\ \boldsymbol{ms^{-1}} \quad (\mathbf{1m})$$

Question 12 **(4 marks)**

A resistor within a circuit has a voltage that has twice the magnitude of the current through it when measured in volts and amperes respectively. The resistor converts 273 J of electrical energy into heat energy over 1 minute of operation. Find the voltage and current of the resistor.

$P = \frac{E}{t} = \frac{273}{60} = 4.55\ W$ (1)

$P = VI\ \ and\ \ V = 2I$ (1)

$P = 2I * I = 2I^2$

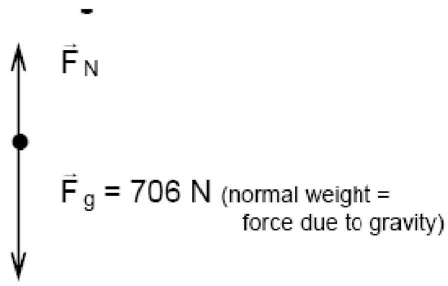
$I = \sqrt{\frac{P}{2}} = \sqrt{\frac{4.55}{2}} = 1.22\ A$ (1)

$V = 2I = 2 * 1.22 = 2.44\ V$ (1)

Question 13

If you normally weigh 706 N, what is your apparent weight if you are in a lift that is slowing down at the rate of 1.65 m/s^2 ?

First, draw a free body diagram and determine the direction of acceleration:



Acceleration is downward as the direction of motion is up but the object is slowing down and coming to a rest, therefore there is an acceleration downward.

Second, determine the mass of the object using the F_g:

$F_g = mg$
$m = F_g/g = 706/9.81 = 71.9674$ kg

Third, determine an equation that represents the forces acting on you:

$F_{net} = F_g - F_N$
$71.9674*(1.65) = 706 – F_N$
$F_N = 706 - 118.7462 = 587$ N, up

.

Section Two: Problem-solving

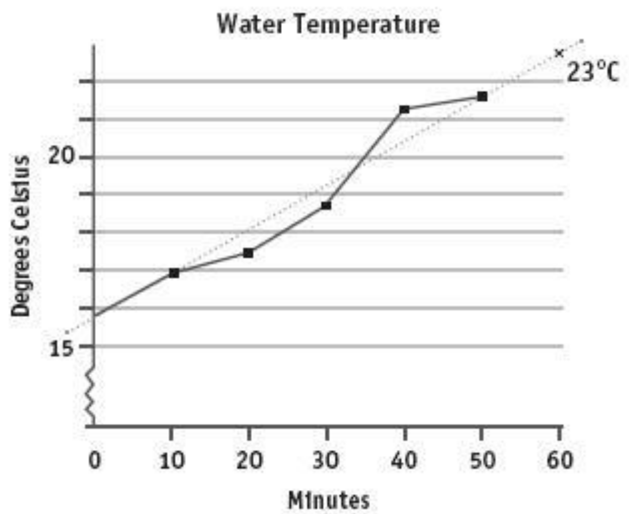
Question 13 **(16 marks)**

A solar camp shower is a device to heat water for a shower when other sources of energy are unavailable. The bag is simply hung in a sunny spot for a period of time. A typical camp shower would hold 20.0 litres of water.

a) Explain why the bag is black in colour. (1 mark)

To absorb maximum amount of solar radiation

b) Examine the graph to the right, which shows how on a certain day, the temperature of water changes with time.



i. State and briefly explain one reason why the temperature of the water is not increasing at a constant rate. (2 marks)

- Cloud cover will vary or Sun may have been obscured for a time meaning amount of solar radiation hitting the bag will also vary
- Wind may affect the temp of the bag by evaporative cooling
- Or similar, reasonable **answer** with short **explanation** (1m each)

ii. Use the graph's line of best fit to calculate the average rate at which the water is heated. Express your answer in $^oC\ min^{-1}$. (2 marks)

$$\frac{\Delta T}{\Delta t} = \frac{23 - 15.8}{60} \quad (\mathbf{1}\boldsymbol{m})$$
$$= \mathbf{0.12}\ ℃\ \boldsymbol{min}^{-1} \quad (\mathbf{1}\boldsymbol{m})$$

iii. How long would it take to heat the water to 30°C ? (2 marks)

$$\Delta T = 14.2\ ^\circ\text{C}$$
$$hence\ time = \frac{14.2}{0.12} = \mathbf{118.33\ min} \qquad (\mathbf{2m})$$
$$(or\ 7099\ \text{sec}\,,\quad or\quad 1\ hr, 58\ \text{min}\ 32\ \text{sec})$$

c) Calculate the amount of energy 20.0 litres of water needs to absorb to be heated from 15.8°C to 30.0°C.

(1 mark)

$$Q = mc\Delta T = 20 \times 4180 \times 14.2$$
$$= \mathbf{1.187\ \times 10^6\ J} \qquad (\mathbf{1m})$$

d) The average amount of solar radiation received at the Earth's surface is 1.37×10^3 Wm^{-2}. The camp shower bag has an absorbing area of 0.40 m^2.

i. Calculate the rate at which solar energy falls on the bag (2 marks)

$$Power = 1370 \times 0.4 \quad (\mathbf{1m})$$
$$= \mathbf{548\ Js^{-1}} \quad (\mathbf{1m})$$

ii. If 100% of this energy was to go into heating water, how long would it take to heat 20.0 litres of water from 15.8°C to 30.0°C (3 marks)

$$time = \frac{work}{power} = \frac{1.187\ \times 10^6}{548} \qquad (\mathbf{2m})$$
$$= 2166.05\ \text{sec}\ (\ or\ 36\ \text{min}) \quad (\mathbf{1m})$$

e) Calculate the efficiency of the camp shower at converting the solar energy it receives into thermal energy in the water. (3 marks)

$\mathbf{Note}$: *can calculate this any of three ways.* $(\mathbf{2m\ for\ working})$ *Answer is* $\mathbf{30.5\%}$ $(\mathbf{1m})$

$$Efficiency = \frac{energy\ abosrbed\ by\ water\ to\ get\ to\ 30^\circ\text{C}}{energy\ recieved\ in\ 7099\ sec} = \frac{1.187\ \times 10^6}{3890252} = \mathbf{30.5\%}$$

$$\mathbf{Or}: \frac{Rate\ at\ which\ energy\ is\ actually\ absorbed\ by\ water}{rate\ at\ which\ solar\ energy\ falls\ on\ bag} = \frac{167.20}{548} = \mathbf{30.5\%}$$

$$\mathbf{Or}: \frac{Answer\ from\ part\ d)\ ii}{actual\ time\ taken} = \frac{2166.05}{7099} = \mathbf{30.5\%}$$

Of Question 14 **(13 marks)**

Panpipes, or pan flutes, can be traced back to Greek, Mayan, Native American, and many other ancient cultures. Although the sizes and styles differ across cultures, the basic design is a series of closed-end tubes of varying length, fixed together.
The sound is produced by blowing into the pipes and setting the column of air inside into motion. Once the wave pattern is stabilized it is known as a standing wave.

a) Will the closed end of the tube always serve as a displacement node or a displacement antinode? Briefly explain your answer in terms of interference of waves.
(2 marks)

As a **node**. **(1m)**
Oncoming and reflected wave are 180° out of phase and hence **destructively interfere**, creating a node. **(1m)**

b) Determine the relationship between the wavelength of the **fundamental** frequency and the length of the tube. (1 mark)

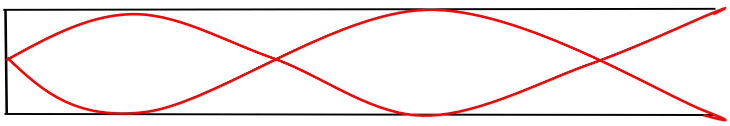
$$\lambda = 4l$$

c) If a pipe of length 30.4 cm was made to resonate at its fundamental frequency, calculate the frequency of sound produced. (2 marks)

$$f_1 = \frac{v}{4l} = \frac{346}{4 \times 0.304} \quad (\mathbf{1m})$$

$$= \mathbf{26.30\ Hz} \quad (\mathbf{1m})$$

d) The tube is now vibrating with a standing wave pattern of three antinodes and three nodes. State which overtone this represents. Draw a particle displacement diagram below to aid your answer. (2 marks)



Overtone: 1st (3rd harmonic) **(1m)**

Sketch (1m)

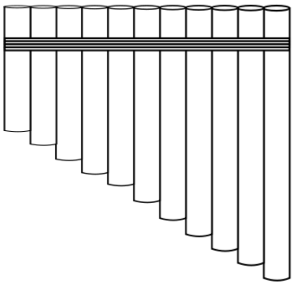
e) A student wishes to make another pipe that produces sounds 1 octave above this (i.e twice its frequency). What length pipe will she need to make? Justify your answer. (2 marks)

$$recognise\ that\ f \propto \frac{1}{l} \quad (\mathbf{1m})$$

$$hence\ make\ the\ new\ pipe\ HALF\ as\ long.\ (or\ 15.2\ cm) \quad (\mathbf{1m})$$

f) An internet guide to making your own panpipe suggests that each pipe is 9/8 the length of the previous. One of the pipes resonates at its 3rd harmonic, producing an A note of 440 Hz.

Calculate the frequency of the fundamental note produced by the pipe 3 "steps" longer than this. (4 marks)



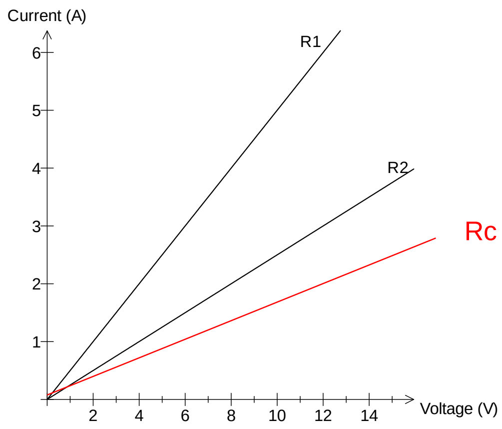
$$l_1 = \frac{3v}{4f} = \frac{1038}{1760} = 0.590\ m \quad (\mathbf{1m})$$

$$l_3 = 0.590 \times \frac{9^3}{8} \quad (\mathbf{1m})$$
$$= 0.84\ m \quad (\mathbf{1m})$$

$$f_1 = \frac{v}{4l} = \frac{346}{4 \times 0.84} = \mathbf{102.97\ Hz} \quad (\mathbf{1m})$$

Question 15 **(14 marks)**

In an experiment, the current that passes through two separate resistors is measured as the voltage across them is changed. The results are shown in the graph below:



a) State whether *either, both or none* of the tested resistors are ohmic. Explain your answer. (2 marks)

- Both are ohmic
- Straight line plots above show that $V \propto I \quad (R\ is\ constant)$

b) Using the graph, determine the resistance of each, R1 and R2. Be sure to show your working.

(4 marks)

For each resistor, R = gradient $^{-1}$ **(2m)**

R1= 2Ω R2= 4Ω

c) If the resistors are now joined in series, plot and label their combined resistance (Rc) on the graph above. (3 marks)

Rc= R1 + R2 = **6Ω** **(1m)**

Shown on graph: **(2m)**

d) If the current running through the series circuit is 1.8 A, determine the Potential Difference of the battery powering the circuit. (2 marks)

$$V = IR$$
$$= 1.8 \times 6 \qquad \mathbf{(1m)}$$
$$= \mathbf{10.8\,V} \qquad \mathbf{(1m)}$$

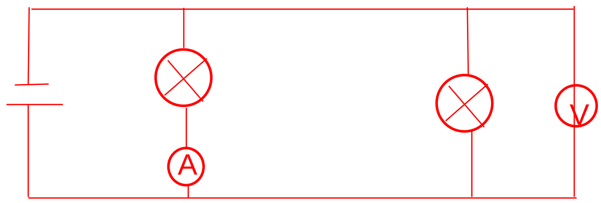
e) The two resistors are now placed in parallel to the battery. An ammeter is placed in position to measure the current passing through R1 and a voltmeter is in position to measure the potential difference across R2. Draw a labelled diagram of the circuit as described

(3 marks)

Ⓥ in // with R2 **(1m)** , Ⓐ in series with R1 **(1m)**

Labelled **(1m)**

Or similar to below:



Question 16 **(12 marks)**

The La Quebrada Cliff Divers® are a group of professional high divers based in Acapulco, Mexico. They regularly dive head first from a height of 36 m into a narrow inlet of ocean water. The water depth varies from 1.8 m – 4.9 m as the ocean waves surge in and out of the inlet. The average depth is 3.6 m.

a) A diver jumped from the cliff with an initial vertical velocity of 3.5 ms^{-1} upwards. Calculate the kinetic energy of a 60 kg diver at the instant he reached the water.

(4 marks)

$$v^2 = u^2 + 2as \quad (\mathbf{1m})$$
$$= 3.5^2 + (2 \times (-9.8) \times 36)$$
$$= 693.35\ m^2s^{-2}$$
$$or\ v = -26.33\ ms^{-1} \quad (\mathbf{1m})$$

$$KE = ½\, mv^2 = 30 \times 693.35 = \mathbf{2.08 \times 10^4 J} \quad (\mathbf{2m})$$

b) If he came to stop at a depth of 3.0 m, what average vertical force must the water exert on him?

(2 marks)

$$W = F \times s$$

$$F = \frac{2.08 \times 10^4}{3.0} \quad (\mathbf{1m})$$
$$= 6933.5\ N\ (upwards) \quad (\mathbf{1m})$$

c) The divers time their dive by observing the waves at the entrance of the inlet, to their right. The aim is to land as the wave passes under them, hence the water is at a maximum depth. Calculate how far away from the landing zone a wave peak travelling at 12 ms^{-1} would need to be for the diver in part a) to hit the water when at its maximum depth.

(4 marks)

$$time\ to\ dive = \frac{v-u}{a} = \frac{-26.33 - 3.5}{-9.8} = 3.04\ \text{sec} \quad (\mathbf{2m})$$

$$for\ wave: s = v \times t = 12 \times 3.04 = \mathbf{36.5\ m}\ away. \ (\mathbf{2m})$$

d) The rocks at the base of the cliff protrude up to 4m into the water from where the divers jump. Explain, in terms of forces, why a diver would be killed if they hit these rocks. (2 marks)

Need to state that a **very large force** will be exerted on the diver. **(1m)**
Explain either in terms of rate of change of momentum, or using newton's second law. **(1m)**

Question 17 **(11 marks)**

Nuclear Fusion is the process that powers our Sun and stars as smaller nuclei fuse together to form larger ones, and matter is converted into energy. When Hydrogen is heated to very high temperatures, its electrons are separated from the nuclei and the gas changes to a plasma. These high temperatures are also needed to overcome strong repulsive forces.

a) Describe the origin of the "strong repulsive forces" mentioned above. (2 marks)

Electrostatic repulsion from like charges (protons) in the nucleus. **(2m)**

b) As the temperature of the plasma rises, describe two things that happen to the particles within it. (2 marks)

Any two:

- Speed (hence KE) increases
- PE decreases
- Rate of collisions with other particles also increases

c) Write a nuclear equation for the fusion of a Deuterium $({}_{1}^{2}H)$ nucleus and a Tritium $({}_{1}^{3}H)$ nucleus to form a ${}_{2}^{4}He$ nucleus, one other particle and energy. (2 marks)

$${}_{1}^{2}H + {}_{1}^{3}H \rightarrow {}_{2}^{4}He + {}_{0}^{1}\boldsymbol{n} + E \quad \textbf{(2m)}$$

d) Given the data below, determine the amount of energy (in J) released by each such reaction. (5 marks)

m$({}_{1}^{2}H)$ = 2.01410178 u
m $({}_{1}^{3}H)$ = 3.01604927 u
m $({}_{2}^{4}He)$ = 4.00260325 u

Note: Mass of ${}_{0}^{1}n$ is given in kg on F +D sheet. stds will need to convert to u for following:

$$\Delta m = (2.01410178 + 3.01604927) - (4.00260325 + 1.00866492) \quad (\mathbf{1m})$$
$$= 0.01888288\ u \quad (\mathbf{1m})$$
$$= 3.13455808 \times 10^{-29} kg \quad (\mathbf{1m})$$

$$E = mc^2 \quad (\mathbf{1m})$$
$$= 3.13455808 \times 10^{-29} \times 9 \times 10^{16}$$
$$= \mathbf{2.8211 \times 10^{-12} J}\ per\ fusion\ reaction. \quad (\mathbf{1m})$$

Question 18 **(8 marks)**

Fuses provide a way of protecting people against electrocution. They are generally a short length of wire which is designed to melt when the current in the circuit exceeds a certain amount.

a) Describe why the wire will melt when a high current passes through it. (2 marks)

Electrical energy is converted to HEAT in the wire. May mention friction, etc.

b) Explain what would have to happen to the resistance of a circuit for the current to increase, and what might cause this to happen. (2 marks)

- R would need to **decrease** **(1m)**
- May be caused by a **short circuit** or faulty wiring **(1m)**

c) In a house, a lighting circuit might use a 20A fuse, whilst an oven would use 40A. State which of these circuits would use a fuse with a thicker wire. (1 mark)

Answer The oven (40A) No reason needed.

d) State one disadvantage of fuses, compared to a residual current device (RCD). (1 mark)

- Will not prevent electrocution, only overheating/fire **(1m)**
- Not easy to re-set
- Slower to respond to faults.
- Any other reasonable answer.

e) List two other electrical safety devices or features commonly used in a home. (2 marks)

- Double insulation of appliances
- Earthing wires
- Circuit breakers

Any two **(1m) each**

Section Three: Comprehension

Question 20 **(18 marks)**

The Great Eastern Japan Earthquake and Tsunami

On March 11, 2011 at 2:45 pm a massive earthquake occurred off the North-East Coast of Japan. The hypocentre was at an underwater depth of approximately 29 km.

Less than an hour after the earthquake, the first of many tsunami waves hit Japan's eastern coastline. It is estimated that the Tsunami waves were travelling at about 340 kmh^{-1} with wavelengths averaging 280 km when they encountered the coastline. The tsunami waves reached run-up heights (how far the wave surges above sea level as it hits the land) of up to 39 metres at Miyako city and travelled inland as far as 10 km in some places.

The tsunami waves also travelled across the Pacific, reaching Alaska, Hawaii and Chile. In Chile, some 17,000 km distant, the tsunami waves were 2 metres high when they reached the shore. The earthquake produced a low-frequency rumble called infrasound, which travelled into space and was detected by the Goce satellite.

As well as the devastation from the Tsunami, several nuclear power stations were damaged, releasing significant amounts of radioactive material into the atmosphere. Some 55,000 households were displaced and evacuation zones of up to 100km from the reactors were established.

The following table is from reports released by Japan's Atomic Energy Commission a year after the disaster, estimating the amount of various isotopes released into the atmosphere and the ocean:

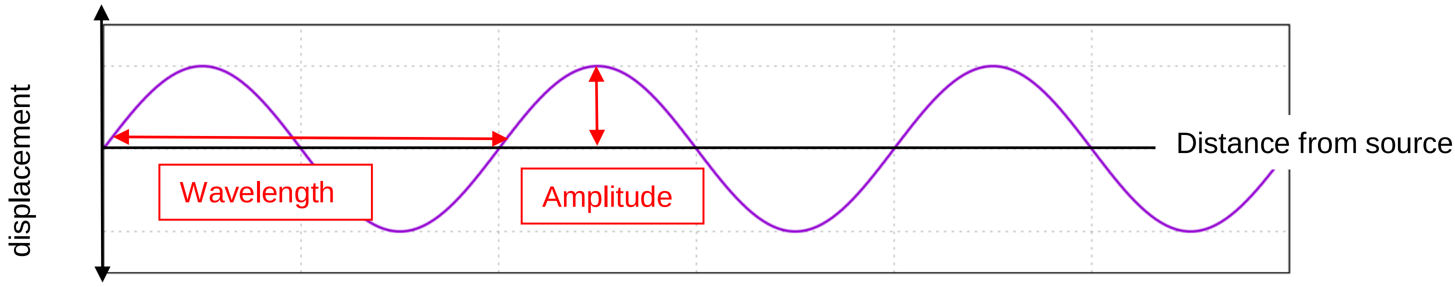
Isotope	Estimated amount released (TBq)
iodine-131	511,000
caesium-134	13,500
caesium-137	13,600
strontium-90	8,300

- Iodine-131 is easily absorbed by the thyroid, so persons exposed to releases of I-131 have a higher risk of developing thyroid disease. Children are more vulnerable to I-131 than adults. I-131 decays by beta minus and gamma emissions with a short half-life at 8.02 days.
- Caesium-137 has a long, 30-year half-life. Internal exposure to Cs-137, through ingestion or inhalation, allows the radioactive material to be distributed in the soft tissues, especially muscle and lung tissue, exposing these tissues to the beta particles and gamma radiation.
- Strontium-90 behaves like calcium (20–30% of ingested Sr-90 is absorbed and deposited in the bone and bone marrow). It undergoes β^- decay into Yttrium-90, with a half-life of 28.8y.

On 22 March, World Nuclear News reported that 6 workers had received over 100 mSv, and one of over 150 mSv. On 24 March, three workers required hospital treatment after radioactive water seeped through their protective clothes. The injuries indicated exposure of 2000 to 6000 mSv around their ankles, with whole body doses of about 170 mSv. They were not wearing protective boots, as their employing firm's safety manuals "did not assume a scenario in which its employees would carry out work standing in water at a nuclear power plant".

Questions:

a) As the Tsunami waves travel in deep water, they can be approximated as a sine wave. On the diagram below, clearly indicate the amplitude and wavelength of the wave. 1m each (2 marks)



b) Calculate the time between two successive waves hitting Japanese the coastline. (1 mark)

$$T = \frac{\lambda}{c} = \frac{280}{340} = 0.8235\ hrs\ or\ 49.4\ min \quad \textbf{(1m)}$$

c) As a result of their long wavelengths, tsunamis act as shallow-water waves. A wave becomes a shallow-water wave when the wavelength is very large compared to the water depth. Shallow-water waves move at a speed, *c*, that is dependent upon the water depth and is given by the formula:

$$c = \sqrt{gH}$$

where *g* is the acceleration due to gravity and *H* is the depth of water, in metres.

i. Refer to the equation above to state what would happen to the speed of the tsunami wave as it approached the shore. (1 mark)

As $\propto \sqrt{H},\ c\ would\ \mathbf{decrease}\ as\ depth\ gets\ shallower.\ (\mathbf{1m})$

ii. Calculate how long after the earthquake the Tsunami wave would reach the shore of Chile if the average ocean depth is 3.00 km. (3 marks)

$$t = \frac{d}{\sqrt{gH}} \quad (\mathbf{1m})$$

$$= \frac{17 \times 10^6}{\sqrt{9.8 \times 3 \times 10^3}} \quad (\mathbf{1m})$$

$$= \mathbf{99146\ sec} \quad \boldsymbol{or\ 27.5\ hrs} \quad (\mathbf{1m})$$

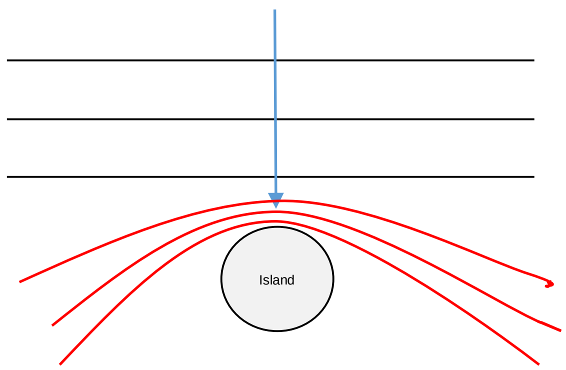
iii. Explain why the wave height would only be around 2m when it reached Chile.(2 marks)

- Wave attenuates due to friction, etc.
- $I \propto \frac{1}{r^2}, so\ Intensity\ falls\ with\ distance\ away.$
- $Or\ similar\ resonable\ explanation$

d) Complete the diagram below to show how the Tsunami waves behave around and beyond a large island.

Shows **Diffraction** around the island.

(2 marks)



e) Which of the isotopes mentioned would cause the most serious health risks in the first weeks after the incident? Explain your answer. (2 marks)

Iodine 131 **(1m)**
as it has a short half life of 8.02 days. **(1m)**

f) Calculate the percentage of the total fallout was from I-131. (1 mark)

$$\frac{511\ 000}{546\ 400} \times 100 = \mathbf{93.5}\%$$

g) Calculate the amount (in TBq) of Iodine131 that remained 30 days after the accident. (2 marks)

$$\frac{A}{A_o} = \left(\frac{1}{2}\right)^n$$

$$A = 511\ 000 \times \left(\frac{1}{2}\right)^{\frac{30}{8.02}} \qquad (\mathbf{1m})$$

$$= \mathbf{3.82\ x\ 10^4\ TBq} \qquad (\mathbf{1m})$$

h) Calculate how much energy would need to be absorbed by a 75.0 kg person for them to receive a whole body dose of 170 mSv. (2 marks)

$$E = AD \times mass$$
$$= 170 \times 10^{-3} \times 75 \quad (\mathbf{1m})$$
$$= 12.75\,J \qquad (\mathbf{1m})$$

Question 21 **(18 marks)**

The Tesla model S, is an electric vehicle which the manufacturer claims is the third-fastest production car ever, with an acceleration of 0-100 kmh^{-1} in 2.7 seconds. It has a mass of 2108 kg, of which 544 kg is the battery packs.

The 2012 Model S P90D came equipped with an 85 kWh battery pack which is arranged in modules, spread under the floor of the vehicle. The 11 modules each have 9 x 3.6 V “bricks” arranged in series. This model has a stated range of 410 km on a full charge. The Environmental Protection authority measured its average energy consumption at 237.5 watt-hours per kilometre or 23.75 kWh/100 km for a combined fuel economy of 2.64 L/100 km equivalent.

The vehicle is charged by simply plugging it into a source of electricity, not unlike a mobile phone. The standard on-board charger accepts 120 or 240 Volt sources at a rate of up to 10.0 kW. An optional US$2,000 upgrade for a second 10 kW on-board charger supports a total of up to 20 kW charging from an 80 amp Tesla Wall Connector.

Questions:

a) Calculate stated the acceleration of the tesla Model S. (2 marks)

$$a = \frac{\Delta v}{\Delta t}$$

$$= \frac{27.78}{2.7} \quad (\mathbf{1m})$$

$$= \mathbf{10.3\ ms^{-2}} \quad (\mathbf{1m})$$

b) Calculate the average force is produced by the engine to produce this acceleration (2 marks)

$$F = m.a = 2108 \times 10.29 \quad (\mathbf{1m})$$

$$= \mathbf{2.17 \times 10^4 N} \quad (\mathbf{1m})$$

c) Calculate the total EMF of the Model S P90D’s battery pack. (2 marks)

$$In\ series, so\ Total\ V = 11 \times 9 \times 3.6 \quad (\mathbf{1m})$$

$$= \mathbf{356\ V} \quad (\mathbf{1m})$$

d) The kilowatt-hour (kWh) is a unit used to measure energy and is the amount of energy used by a 1.0 kW machine in 1 hour. Calculate the capacity of the Model S P90D's battery pack, in Joules. (3 marks)

$$1kWh = 1000 \times 60 \times 60 = 3.6 \times 10^6 J \quad (\mathbf{1m})$$

$$Capacity = 85 \times 3.6 \times 10^6 J \quad (\mathbf{1m})$$
$$= \mathbf{306\ MJ} \quad (\mathbf{1m})$$

e) Calculate the range of the model S P90D, based upon the EPA's testing? How does this compare to the manufacturer's claims? (4 marks)

- Tesla's claim = **410km** **(1m)**
- Range as calc by EPA= $\frac{85kWh}{23.75kWh/100km} = \mathbf{357.89km}$ $(\mathbf{2m})$
- Manufacturer's claim is (52.1km) **greater than** that calculated by EPA. **(1m)**

f) When charging from a 240V source at 10.0kW, calculate how much current is being drawn by the charger. (2 marks)

$$I = \frac{P}{V}$$
$$= \frac{10 \times 10^3}{240} \quad (\mathbf{1m})$$
$$= 41.7\ A \quad (\mathbf{1m})$$

g) Calculate the minimum time it would take to re-charge a flat battery when using the standard on-board charger. (3 marks)

Min time at max power of 10kW $(\mathbf{1m})$

$$time = \frac{Energy\ total}{power} = \frac{306 \times 10^6}{10 \times 10^3} \quad (\mathbf{1m})$$
$$= \mathbf{30600\,sec}\ \ \boldsymbol{or}\ \ \mathbf{8.50}\ \boldsymbol{hrs}. \quad (\mathbf{1m})$$