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Answer Series 3
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Answers

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Series 3

Part 1

Weight
Principle of Moments
Archimedes Principle

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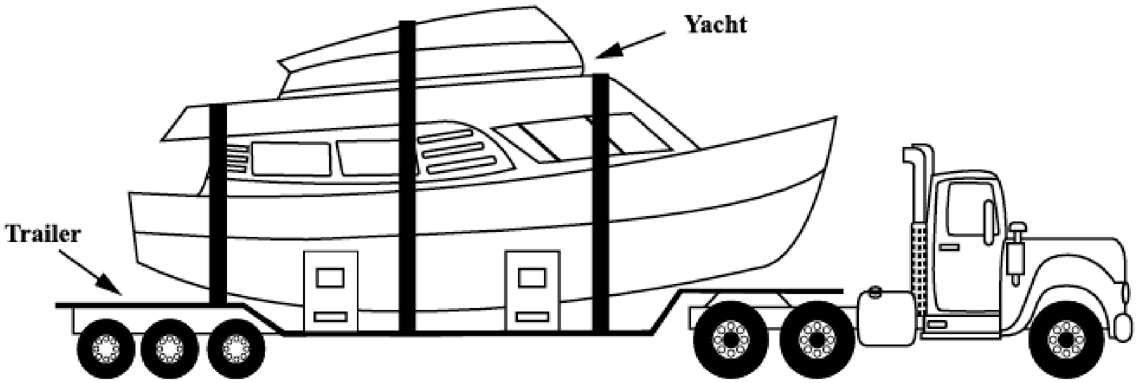
(a) The yacht shown in the image below has a mass of 9500 kg.



What is its weight in air?

Use acceleration due to gravity as $g = 10 \text{ N kg}^{-1}$

W = mg

m = 9500 kg

$g = 10 \text{ Nkg}^{-1}$

$W = 9500 \text{ kg} \times 10 \text{ Nkg}^{-1}$

W = 95000 N

(2 marks)

(b) To transport the yacht on land, it is placed on a trailer. Each tyre of the trailer can support a maximum of 7000 N. Work out the least number of tyres the trailer should have to safely support the yacht.

The weight of 95000 N must be distributed evenly over each tyre.

$$No.\,of\ tyres = \frac{95000\,N}{7000\,N}$$

$$No.\,of\ tyres = 13.57$$

Since there is no such thing as 0.57 of a tyre, the minimum number if tyres needed is 14.

(c)

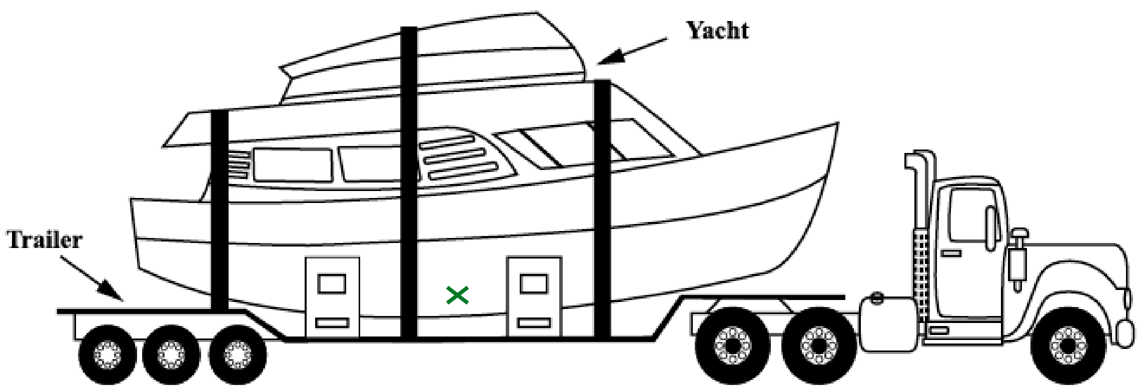
(i) State two conditions that must be true in order for the yacht to remain in equilibrium.

The sum of the forces in one direction must equal the sum of the forces in the opposite direction

The sum of the anti-clockwise moments must equal the sum of the clockwise moments

(2 marks)

(ii) Place an x on the yacht that is an ideal location for the center of gravity



Ideally the center of gravity should be somewhere in the middle and close to the bottom of the boat to prevent it from toppling easily.

(d)

(i) State Archimedes' principle

The principle states that for a body that is wholly or partially submerged in a fluid, the upthrust on the body is equal to the weight of the fluid that the body displaces.

(2 marks)

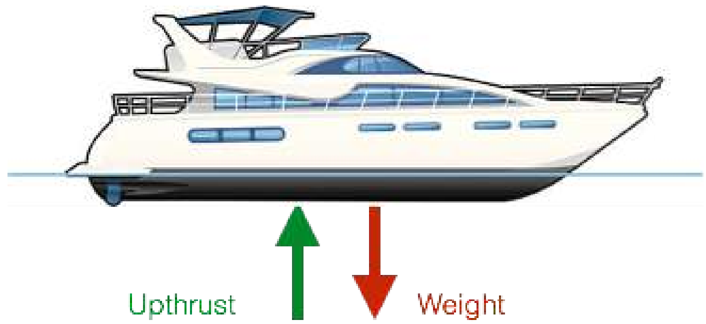
(ii) The yacht's hull is made of steel of density 7850 kgm^{-3}. Explain how the yacht is able to float in sea water of density 1025 kgm^{-3}.

The yacht will float in sea water if its weight (acting downwards) is equal to the upthrust on it. The upthrust is determined by the weight of the sea water displaced. The hull of the yacht is shaped so that it displaces a small amount of sea water therefore minimizing the upthrust on the yacht.

(2 marks)

(iii) Calculate the volume of sea water displaced by the yacht as it floats

When the yacht floats the upthrust (upward force) is equal to the weight of the yacht (downward force)



$W_{yacht} = 95000$ N

$\therefore$Upthrust = 95000 N

From archimedes' principle the weight of the displaced sea water is the upthrust

$\therefore W_{sea\ water} = 95000$ N

We can determine the volume of sea water using its density and the mass displaced

$$m_{sea\ water} = \frac{W_{sea\ water}}{g} = \frac{95000\ N}{10\ Nkg^{-1}} = 9500\ kg$$

(Note how this is the same as the mass of the yacht)

$m_{sea\ water} = 9500$ kg

$\rho = 1025$ kgm^{-3}

$$\rho = \frac{m}{v} \quad \rightarrow \quad v = \frac{m}{\rho}$$

$$v = \frac{9500\ kg}{1025\ kgm^{-3}}$$

$$v = 9.27\ m^{-3}$$

(4 marks)

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Part 2

Gas Law
Kinetic Theory
Pressure Law
Charles Law

Adaptation from
Jun 2014 Paper 2 Question 3

(a)

i. Write down the equation for the general gas law for an ideal gas. Use only symbols.

$$\frac{PV}{T}=n$$

(1 mark)

ii. State the meaning of each symbol stated in the equation above.

P – pressure of the gas

V – volume of the gas

T – absolute temperature of the gas in Kelvin

n - a constant value

(4 marks)

(b)

i. On an early morning when the temperature was 15 ^{o}C, a car tyre was pumped to a pressure of 1.90 x 10 $^{-5}$ Nm^{-2}. The temperature rose, over the course of the day, to 26 ^{o}C. Assuming that the volume of air in the tyre is kept constant, calculate the new pressure in the tyre at a temperature of 26 ^{o}C.

Since volume is constant we need to apply the Pressure law. Remember that you must use absolute temperatures when working with the gas laws, so we must convert ^{o}C to K.

$$\frac{P_1}{T_1}=\frac{P_2}{T_2}$$

P_1 = 1.90 x 10 $^{-5}$ Nm^{-2}

T_1 = 15 ^{o}C = 15 +273 = 288 K

T_2 = 26 ^{o}C = 26 + 273 = 299 K

P_2 = ?

$$\frac{1.90\times10^{-5}\ \ Nm^{-2}}{288\ \ K} = \frac{P_2}{299\ \ K}$$ (The next line drops units for simplicity)

$$299\times\frac{1.90\times10^{-5}}{288} = P_2$$

$P_2 = 1.97 \times 10^{-5} Nm^{-2}$

(5 marks)

ii. Using the Kinetic Theory of matter, explain why the increase in pressure occurred.

As the temperature of the gas increases, the molecules of the gas gain kinetic energy and as a result hit the container walls harder and bounce off the walls more frequently. Since a pressure is exerted when the molecules bounce off the walls this causes an increase in pressure.

(2 marks)

iii. Calculate the ratio of new volume to old volume $\left(\frac{V_2}{V_1}\right)$ for the tyre, if the pressure is held constant while the temperature raises from 15 ºC to 26 ºC?

Since the pressure is held constant while the volume and temperature change we can apply Charles' Law.

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$ Rearrange this equation to create the ratio $\left(\frac{V_2}{V_1}\right)$

$$\frac{T_2}{T_1} = \frac{V_2}{V_1}$$

The ratio $\left(\frac{V_2}{V_1}\right)$ is given by the ratio of the temperatures $\left(\frac{T_2}{T_1}\right)$

$$\left(\frac{V_2}{V_1}\right) = \left(\frac{299}{288}\right)$$

$\left(\frac{V_2}{V_1}\right)$ = 1.04 correct to 3 significant figures

(2 marks)

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Part 3

Waves
Sound Waves
Electromagnetic Waves

Adaptation from
Jun 2012 Paper 2 Question 6

(a)

i. Outline three ways in which ‘light waves’ and ‘sound waves’ are different.

Light waves travel at a speed of 3.0×10^8 ms^{-1} while sound waves travel at 330 ms^{-1}.

Light waves are transverse waves while sound waves are longitudinal waves.

Light waves form a part of the electromagnetic spectrum while sound waves do not.

(3 mark)

ii. Describe at least three more properties of electromagnetic waves that you did not mention in part (i).

All electromagnetic waves exhibit reflection, refraction and interference. They are regarded as a combination of traveling magnetic fields and electric fields at right angles to each other.

The frequency of any electromagnetic wave is given by the equation $f = \frac{v}{\lambda}$ where v is the speed and λ is the wavelength.

(3 marks)

(b) Petah and Paul were doing a School Based Assessment on estimating the speed of sound in air using an echo method.

Petah stood 150 m from a wall and clapped two wooden blocks to produce an echo. He listened for the echo and clapped the wooden blocks again so that it coincided with the echo. He repeated the clapping of the block so that it continued to coincide with successive echoes. When he had a good rhythm going, Paul, who stood beside him, started his watch in one instance when the blocks clapped together and then counted 15 claps. The time for 15 claps was calculated to be 13.1 s.

Use these results to calculate the speed of the sound generated.

Use equation for speed $v = \frac{s}{t}$ where s is the distance the echo travelled and t is the time for the echo to travel the distance

Time was recorded for 15 claps. This is the time essentially for 15 echoes. The time for the sound to go from the block, to the wall and back to them….15 times.

Therefore time for one echo = $\frac{13.1}{15} = 0.87\,s$

Because the echo must travel to the wall and back, this is double the distance

s = 150 m x 2

s = 300 m

$$v = \frac{300\,m}{0.87\,s}$$

$$v = 344.82\,ms^{-1}$$

(5 marks)

(c) A popular radio station broadcasts with a frequency of 105 x 10^6 Hz.

Calculate in centimeters the wavelength of the sound generated.

Speed of radio waves = 3.0 x 10^8 ms^{-1} .

Using the wave equation

$v = f \times \lambda$ rearranging to make λ the subject we get

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

v = 3.0 x 10^8 ms^{-1}

f = 105 x 10^6 Hz

$$\lambda = \frac{3.0\,x\,10^8}{105\,x\,10^6}$$

$\lambda = \frac{3.0\,x\,10^8}{1.05\,x\,10^8}$ re-write the denominator in the same form as the numerator to ease calculation

λ = 2.86 m

To convert m to cm we must multiply by 100

λ = 2.86 m x 100

λ = 286 cm

(4 marks)

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Part 4

Magnetic Field
Electromagnetic Induction
Transformers

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Adaptation from
Jun 2005 Paper 2 Question 4

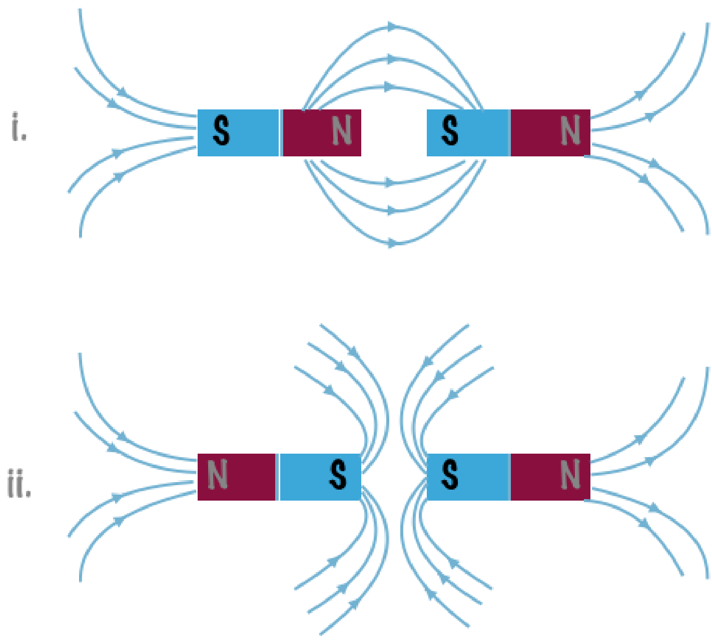
(a)

i. Write a definition for the term "magnetic field"

Any region around a magnet where a magnetic force is felt. The direction is given by the direction on a north pole test magnet.

(2 mark)

ii. Two bar magnets are placed close to each other so that their fields interact. Sketch the field patterns for the two magnetic arrangements below.



(4 marks)

(b)

i. The image below shows a transformer. The primary coil of the transformer is connected to a battery and a switch while the secondary coil is connected to a center-zero galvanometer.

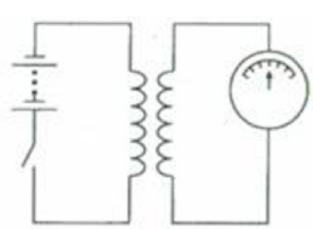


Figure 1

A user closes the switch in the primary coil. Describe what you would see on the galvanometer when this happens.

When the switch is closed there will be a temporary deflection in the needle on the galvanometer. The needle would immediately return to the zero centre point.

(2 marks)

ii. Explain in your own words why this happens.

This happens because a current flowing in the primary coil sets up a magnetic field in the primary coil, as the magnetic field grows, it cuts the coils of the second circuit and by Faraday's Law, an emf is induced in the second coil. This causes the deflection in the needle as a small amount of current flows. It only lasts for as long as the time that the current is being turned on.

(3 marks)

iii. Deduce what would be observed on the galvanometer if the battery was replaced with an alternating current.

The galvanometer would continually deflect to the right and then to the left of the center point of the galvanometer.

(1 mark)

iv. Describe one way of increasing the amount of current that is generated in the secondary coil.

Increasing the number of turns in the secondary coil would greatly increase the amount of current generated in it.

(1 marks)

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Part 5

Rutherford's Experiment
Isotopes

Bonus
Cloud Chamber Experiment
Energy in nuclear Reaction ($E=mc^2$)

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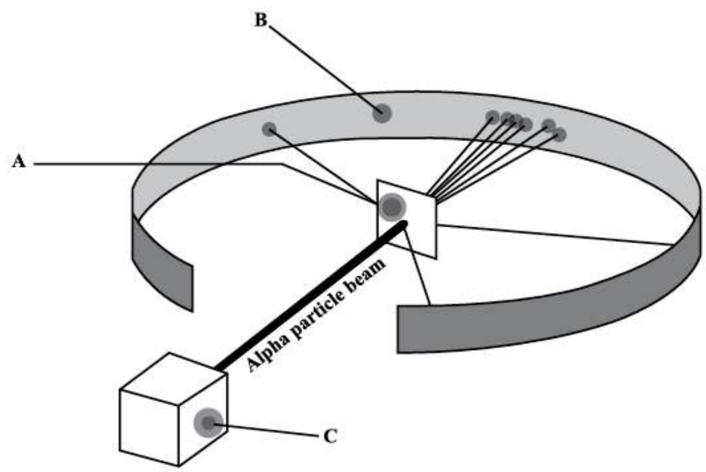
1)

(a) The figure shows a typical layout of Rutherford's experiment used to determine the composition of the atom.



i. State the names of the components labelled A, B and C

A Gold foil

B detecting screen

C alpha source such as uranium

ii. Using your knowledge from Rutherford's experiment, explain why it was critically important for him to use the substance or element for the component labelled A.
The aim of the experiment was to understand the structure of the atom. By using very thin sheets, Rutherford was able to conduct the experiment with the alpha particles interacting with a very small number of atoms (about 1000). Gold is very malleable and was the most suitable material at the time that could be hammered out to a thickness that was suitable for the experiment.

(2 marks)

iii. State two conclusions from Rutherford's experiment about the model of the atom.

Rutherford concluded that i) the atom consists of mostly empty space with the nucleus at the center ii) the nucleus is positively charged and contains most of the mass of the atom.

(2 mark)

(b) The symbol $^{28}_{14}Si$ represents an atom of the metal silicon.

i. Determine the number of neutrons found in ONE atom of silicon

Since there are 14 protons in this atom and the mass number is 28, there are also 14 neutrons in this atom.

number of neutrons = mass number - number of protons

(1 mark)

ii. Using the same standard notation, state a possible isotope of $^{28}_{14}Si$

An isotope will have the same number of protons but different number of neutrons.

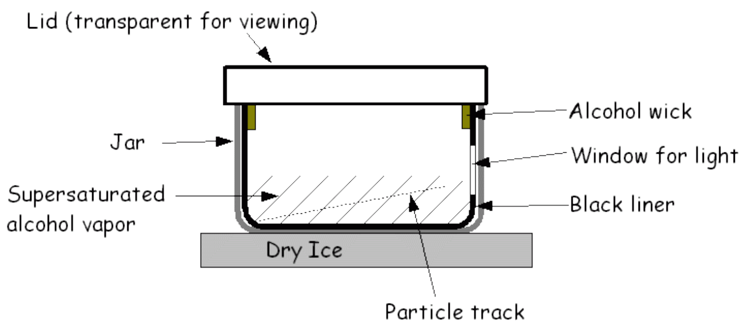
One such isotope is $^{32}_{14}Si$

(1 mark)

2.

(a) It is suspected that a certain radioactive source emits alpha, beta and gamma radiations. With the aid of a diagram, describe how the presence of any TWO of the three types of radiation in such sample could be confirmed.

A cloud chamber can be used to identify the types of radiation emitted by the source.



(6 marks)

Darken the inside of a container, leave a little room for light to enter it.

Place a cotton soaked with alcohol on the inside of the container, affixing it to the sides of the container

Place the container on a block of dry ice

Place the source of radiation on the inside of the container.

As the alcohol cools and condenses on the ions that are formed by the radiation, it forms tracks that can help identify the radiation present. (Cooling occurs due to the dry ice)

α-tracks: An α-particle has a mass of more than 7000 times that of a β-particle. They are strongly ionising on collision with other particles and, therefore, produce thick tracks. The tracks are straight since α-particles are not easily deviated by collision with other particles.

β-particles are only weakly ionising due to their relatively small mass and therefore, produce weak tracks. Slow moving particles form tracks that are short and twisted. They can be randomly directed since these particles deviate readily on collision with other particles.

(b) Radioactive carbon $\left({}^{14}_{6}C\right)$ loses a beta particle to become nitrogen (N).

Write a nuclear equation to represent this nuclear reaction.

$^{14}_{6}C \rightarrow ^{14}_{7}N + ^{0}_{-1}\beta$

(3 marks)

(c) Calculate the energy released in the solar fusion of deuterium represented by

$^{2}_{1}H + ^{2}_{1}H \rightarrow ^{4}_{2}H + energy$

Assume u = 1.66 x 10 $^{-27}$ kg

$^{2}_{1}H$ has atomic mass of 2.0140 u

$^{4}_{2}H$ has atomic mass of 4.0026 u

E = Δmc^2

mass of reactants = 2 x 2.0140 = 4.0280 u

mass of product = 4.0026 u

mass deficit = 4.0280 u - 4.0026 u

mass deficit = 0.0254

mass deficit = 0.0254 x 1.66 x 10 $^{-27}$ kg

= 4.2164 x 10 $^{-29}$ kg

E = 4.2164 x 10 $^{-29}$ kg x (3.0 x 10 ^{8})^{2} ms^{-1}

E = 3.79 x 10 $^{-12}$ J

(6 marks)