

Answers

Semester 2 Examination 2011

Question/Answer Booklet

PHYSICS
YEAR 12
Stage 3

Name: _____

Teacher: _____

TIME ALLOWED FOR THIS PAPER

Reading time before commencing work: Ten minutes

Working time for the paper: Three hours

MATERIALS REQUIRED/RECOMMENDED FOR THIS PAPER

To be provided by the supervisor:

This Question/Answer Booklet

Formula and Constants sheet

To be provided by the candidate:

Standard items: pens, pencils, eraser or correction fluid, ruler, highlighter.

Special items: non-programmable calculators satisfying the conditions set by the Curriculum Council for this course, drawing templates, drawing compass and a protractor.

IMPORTANT NOTE TO CANDIDATES

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Short answer	13	13	50	54	30
Section Two: Extended answer	7	7	90	90	50
Section Three: Comprehension and data analysis	2	2	40	36	20
Total				180	100

Instructions to candidates

- The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2010*. Sitting this examination implies that you agree to abide by these rules.
- Write answers in this Question/Answer Booklet.
- Working or reasoning should be clearly shown when calculating or estimating answers.
- You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.
- Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
 - Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
 - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

No separate marks for direction unless specified
(no deduction if missing)

1 mark off for missing or incorrect units
each time

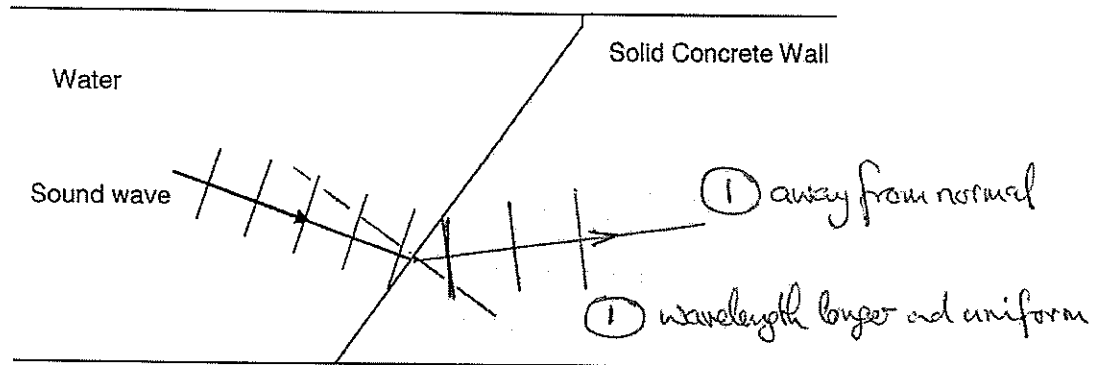
Section One: Short response

30% (54 Marks)

This section has **13** questions. Answer **all** questions. Write your answers in the space provided. Suggested working time for this section is 50 minutes.

Question 1

A sound wave travels through water to meet a boundary with a solid concrete wall of a dam where the sound travels faster in the concrete than in the water.



a) Draw a wave front diagram for a possible path of the sound wave as it refracts into the concrete. (2)

b) Is it possible for total internal reflection to occur at this boundary? Explain briefly. (2)

Yes (1)

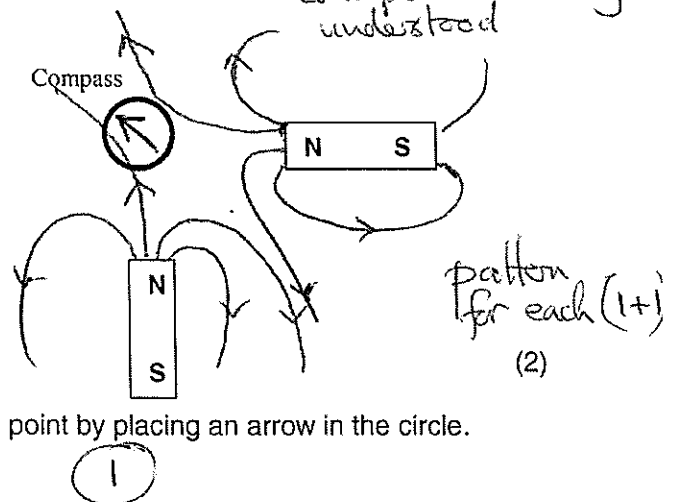
Critical angle will be reached for incident wave where refracted angle = 90° . Beyond this total internal reflection will occur. (1)

Be flexible if concept is obviously understood

Question 2

Two identical magnets are fixed in position on a flat bench. A compass is placed near the magnets.

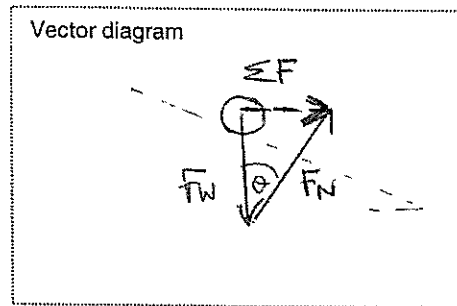
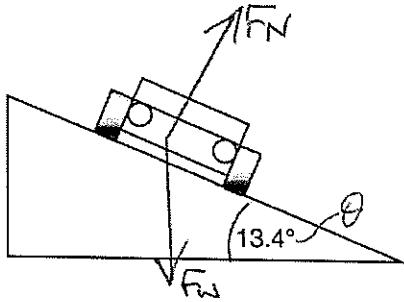
a) Sketch the magnetic field in the region around the magnets. Draw at least 4 field lines for each magnet. (2)



b) Indicate the direction that the compass needle will point by placing an arrow in the circle. (1)

Question 3

By banking the curves of racetracks it is possible for vehicles to turn in a horizontal circle without relying on friction. For a car of mass 1700 kg the angle of banking is set at 13.4° above the horizontal. The curve has a radius of 171 m and the car drives at a speed to maintain its height.



- a) Draw a vector diagram showing the forces acting on the car and the sum of those forces in the space indicated above.

Must show F_w , F_N AND ΣF

- b) Calculate the centripetal force acting on the car.

$$\tan \theta = \frac{\Sigma F}{F_w} = \frac{mv^2/r}{mg} = \frac{v^2}{rg}$$

OR

$$\frac{v^2}{r} = g \tan \theta$$

$$= 9.8 \tan \theta$$

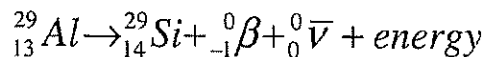
$$= 2.33$$

$$F_c = m \cdot \frac{v^2}{r} = 3970 \text{ N towards centre of arc}$$

① for formula
①
①
①

Question 4

Aluminium-29 decays to Silicon-29 by beta emission as described in the nuclear equation:



- a. Identify the particle with the symbol ${}^0_0\bar{\nu}$ antineutrino (1)
- b. The beta particle is an electron that has come from the nucleus. Explain what happens in the nucleus that has given rise to the beta particle and the ${}^0_0\bar{\nu}$ particle.

① A neutron decays to a proton + β + $\bar{\nu}$ (3)

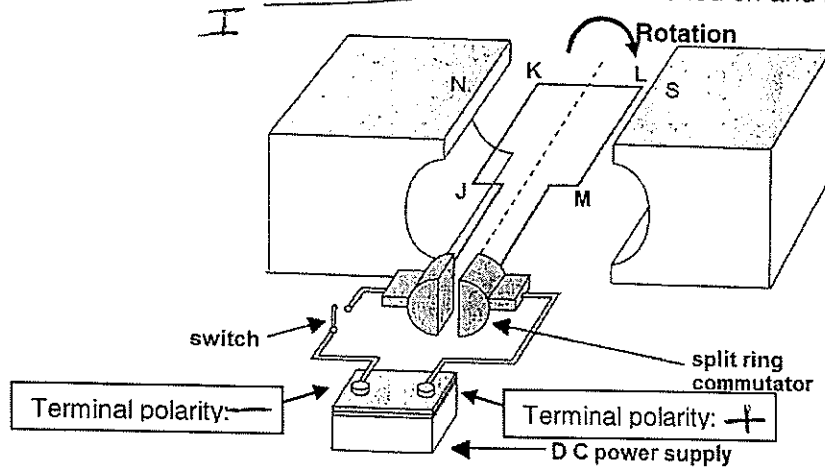
Down quark decays to an up quark + β + $\bar{\nu}$

① ①

Question 5

The figure below represents a DC motor whose coil is initially stationary.

- JK = LM = 16.0 cm KL = JM = 12.0 cm
- The coil has 120 turns of wire
- The uniform magnetic flux density between the poles = 95.0 mT
- The current in the coil is 6.30 A when the motor is switched on and it turns clockwise.



- a) Indicate the positive and negative terminals on the DC power supply for this direction of rotation. (1)

- b) Calculate the force acting on side LM of the coil when the switch is closed. (2)

$$\begin{aligned}
 N &= 120 \\
 B &= 95 \times 10^{-3} \text{ T} \\
 I &= 6.3 \text{ A} \\
 L &= 16 \times 10^{-2} \text{ m}
 \end{aligned}$$

$$\begin{aligned}
 F &= BIL \\
 &= 95 \times 10^{-3} \times 6.3 \times 120 \times 0.16 \quad (1) \\
 &= 11.5 \text{ N} \quad (1) \quad (\text{down})
 \end{aligned}$$

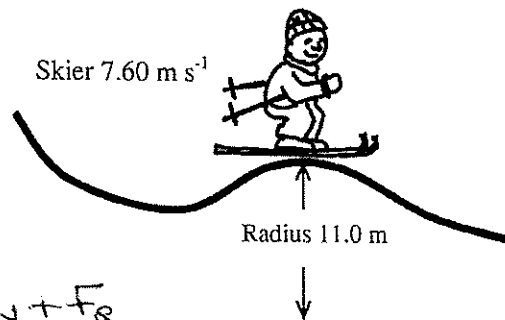
- c) Calculate the maximum torque that this motor can produce. (2)

$$\begin{aligned}
 r &= 6 \text{ cm} \\
 \tau &= 2 \times F \cdot r \\
 &= 2 \times 11.5 \times 6 \times 10^{-2} \quad (1) \\
 &= 1.38 \text{ Nm} \quad (1) \quad (\text{clockwise})
 \end{aligned}$$

Question 6

A 70 kg skier is on a frictionless slope. He follows a circular path of radius 11.0 m as he goes over a mound and has a speed of 7.60 m s^{-1} at the top of the circle.

Calculate the normal reaction force he experiences from the mound at the top of the circle.



$$M = 70 \text{ kg}$$

$$r = 11 \text{ m}$$

$$v = 7.6 \text{ m s}^{-1}$$

$$F_w = mg$$

$$F_R$$

$$\Sigma F = F_c = F_w + F_R$$

Down is +ve

$$\frac{mv^2}{r} = mg + F_R$$

$$F_R = \frac{mv^2}{r} - mg$$

$$= \frac{70 \times 7.6^2}{11} - 70 \times 9.8$$

$$= 367.56 - 686$$

$$= -318$$

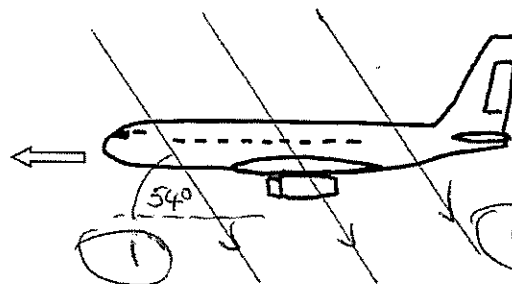
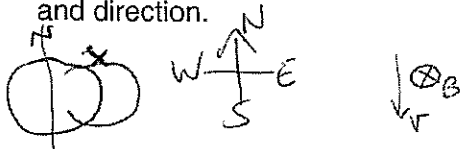
$$F_R = 318 \text{ N up}$$

(4)

Question 7

A jet airliner is flying due South in the Northern geographical hemisphere where the Earth's magnetic field has a flux density of $5.20 \times 10^{-5} \text{ T}$ at an angle of dip of 54°

- a) Sketch the alignment of the Earth's magnetic field lines relative to the jet airliner on the diagram, indicating any angles and direction.



(2)

direction
(back and down)

- b) Calculate the emf induced across the 60.0 m wingspan if the jet has a speed of 140 m s^{-1} .

$$B = 5.2 \times 10^{-5}$$

$$\theta = 54^\circ$$

$$l = 60 \text{ m}$$

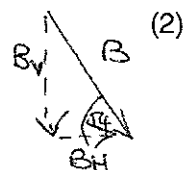
$$v = 140 \text{ m s}^{-1}$$

$$V_{\text{emf}} = Blv$$

$$B_v = B \sin 54$$

$$= 5.2 \times 10^{-5} \sin 54 \times 60 \times 140$$

$$= 0.353 \text{ V}$$



(2)

- c) Circle the best response. There would be a build-up of electrons at the:

A. West wing tip

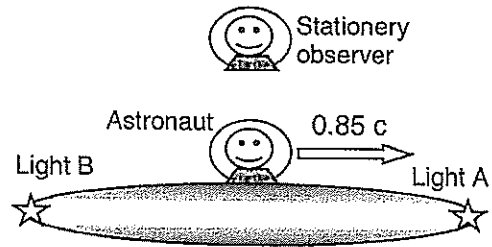
B. East wing tip

C. Middle of the wings

(1)

Question 8

An astronaut flies past a stationary observer at a constant 85% of the speed of light. His spacecraft has light A at the front and light B at the rear. The Astronaut sees the two lights A and B illuminate simultaneously. The Stationary observer sees one light illuminate before the other one.



- a) From the frame of reference of the Stationary observer **explain** the order of the lights going on. (2)

Light B will illuminate first (1)
 Speed of light A and light B will both be observed as 3×10^8 by observer but light B will have further to travel as spaceship moves to right. (1)

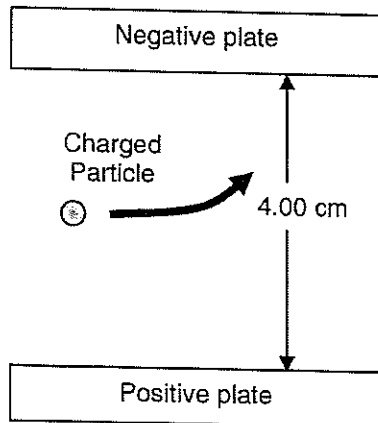
- b) The astronaut and the observer both have identical stopwatches set to countdown from one minute. As the astronaut passes the observer both stopwatches commence their countdown. The astronaut states that his stopwatch will finish the countdown first but the observer states the opposite. Explain who is correct and why. (2)

Both. (1)
 In each time-frame the time observed will appear correct for the observer on their own instrument. (1)

- c) The stationary observer has previously seen the spacecraft from the same distance when it was at rest. He remarks that it seems smaller when it flies past him at 85% the speed of light. Explain in which way the spacecraft seems smaller and also in which way it has retained the same dimensions. (1)

Spacecraft seems shorter in direction of motion but same dimensions of width and height (1)
 Need both statements

Question 9



A charged particle enters a region between 2 parallel charged plates. The plates are separated by 4.00 cm. The electric field strength in the region between the charged plates is $8.75 \times 10^4 \text{ V m}^{-1}$.

a. Calculate the potential difference between the plates.

$$E = 8.75 \times 10^4 \text{ V m}^{-1}$$

$$d = 4 \text{ cm}$$

$$0.04 \text{ m}$$

$$E = \frac{V}{d}$$

$$V = Ed$$

$$= 8.75 \times 10^4 \times 0.04$$

$$= 3500 \text{ V}$$

(2)

(1)

(1)

b. The charged particle experiences a force of magnitude $2.80 \times 10^{-14} \text{ N}$ that causes it to deflect towards the negative plate. Determine the magnitude and nature of the charge of the particle.

$$F = 2.8 \times 10^{-14} \text{ N}$$

$$E = 8.75 \times 10^4$$

$$E = \frac{F}{q}$$

$$q = \frac{F}{E} = \frac{2.8 \times 10^{-14}}{8.75 \times 10^4} = 3.20 \times 10^{-19} \text{ C}$$

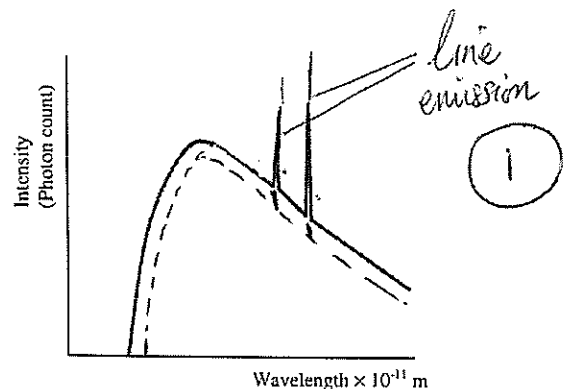
(2)

(1)

Positive charge (1)

Question 10

The graph shows the X-ray spectrum from a target metal bombarded by electrons with a supply voltage of 33.0 kV



a) Show on the X-ray spectrum diagram the line emission portion of the spectrum and explain briefly how it is formed.

Bombarding electrons interact with electrons in the target metal raising them to higher energy levels.

As these excited electrons return to lower energy levels they emit photons corresponding to the energy drops with frequencies

(3)

(1)

b) Sketch on the graph, the general shape of the X-ray spectrum if the supply voltage is decreased to 31.0 kV.

Same shape (including spikes)

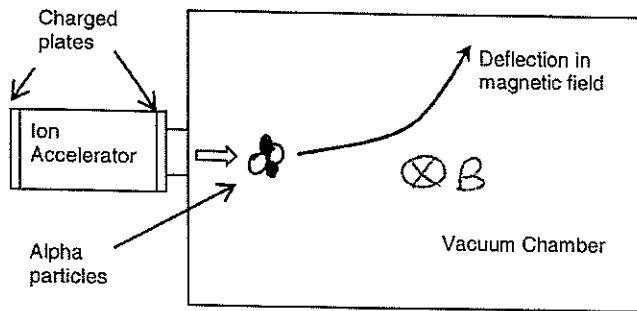
Lower wavelength starting position

(2)

(1)

Question 11

Alpha particles (He^{2+}) are doubly charged positive ions. They are accelerated through an electric field between charged parallel plates before entering a vacuum chamber where they are deflected by a magnetic field.



- a. Calculate the potential difference between the charged plates in the Ion Accelerator that will give the alpha particles a maximum velocity of $3.40 \times 10^5 \text{ m s}^{-1}$ ✓ (2)

$$V = 3.4 \times 10^5$$

$$q = 2 \times 1.6 \times 10^{-19}$$

$$m = 6.65 \times 10^{-27}$$

$$Vq = \frac{1}{2}mv^2$$

$$V = \frac{mv^2}{2q}$$

$$= \frac{6.65 \times 10^{-27} \times (3.4 \times 10^5)^2}{2 \times 2 \times 1.6 \times 10^{-19}}$$

$$= 1.20 \times 10^3 \text{ V}$$

- b. Indicate on the diagram, the direction of the magnetic field within the vacuum chamber that will cause the deflection shown. (1)

Into page (as shown) (1)

- c. The magnetic flux density within the chamber is set to 72.5 mT. Calculate the magnitude of force experienced by an alpha particle travelling at $3.40 \times 10^5 \text{ m s}^{-1}$. (2)

$$B = 72.5 \times 10^{-3} \text{ T}$$

$$F =$$

$$v = 3.4 \times 10^5 \text{ m s}^{-1}$$

$$F = qvB$$

$$= 2 \times 1.6 \times 10^{-19} \times 3.4 \times 10^5 \times 72.5 \times 10^{-3}$$

$$= 7.89 \times 10^{-15} \text{ N}$$

Question 12

The left-hand table shows the charge on a variety of Quarks. The right-hand table shows the composition of a number of Hadrons.

Quark	Charge
Up (u)	$+\frac{2}{3}e$
Down (d)	$-\frac{1}{3}e$
Charmed (c)	$+\frac{2}{3}e$
Strange (s)	$-\frac{1}{3}e$
Top (t)	$+\frac{2}{3}e$
Bottom (b)	$-\frac{1}{3}e$

Hadron	Quarks
Proton	uud
Neutron	udd
Kaon-minus	$\bar{s}u$
Pi-plus (π^+)	$u\bar{d}$
Sigma-plus	uus
Lambda-zero	uds
Charmed Omega	ssc

(1)
(1)

a) Determine the charge of the Lambda-zero: zero

(1)

b) The compositions of the proton and neutron have been omitted from the table. Complete the table for these 2 particles.

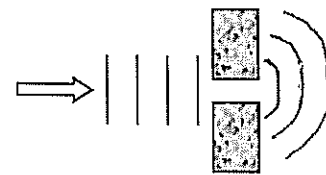
on table above

(2)

Question 13

A source of sound waves can be directed through air at 25°C towards an 8.65 cm gap between two wooden blocks.

a) Complete the wave front diagram for the waves through the gap.



spread and same λ
(1)

b) The wave source can emit sound waves at frequencies of either 5.00 kHz or 500 kHz. Explain briefly which wave will diffract more and why.

(3)

$$\lambda_5 = \frac{v}{f_5} = \frac{346}{5000} = 0.0692 \text{ (6.92cm)}$$

(1)

$$\lambda_{500} = \frac{v}{f_{500}} = \frac{346}{500000} = 6.92 \times 10^{-5} \text{ m}$$

(1)

Will diffract more as gap is too large to diffract other, much smaller λ 's.

(1)

$$v = 346$$

$$f_5 = 5000 \text{ Hz}$$

$$f_{500} = 500000 \text{ Hz}$$

End of Section One

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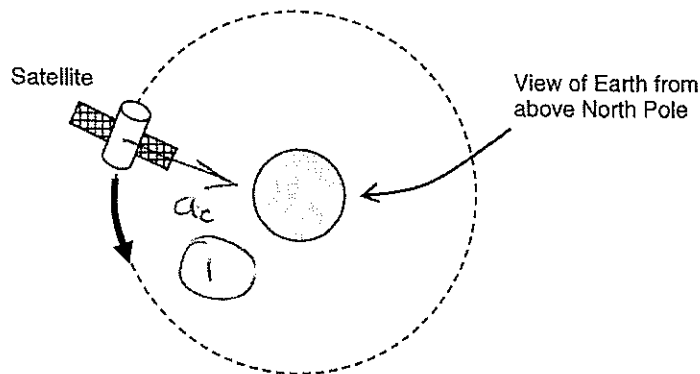
Section Two: Problem-solving

50% (90 Marks)

This section has **eight (8)** questions. You must answer **all** questions. Write your answers in the space provided. Suggested working time for this section is 90 minutes.

Question 14 (13 marks)

A satellite is in orbit around the equator of the Earth. It has a mass of 1490 kg and is at an altitude of 1.91×10^4 km above the Earth's surface.



- a) Calculate the **period** of this satellite and state your answer in hours.

$$\begin{aligned}
 M &= 1490 \text{ kg} \\
 h &= 1.91 \times 10^7 \text{ m} \\
 r &= R_E + h \\
 &= (6.37 \times 10^6 + 1.91 \times 10^7) \text{ m} \\
 &= 2.547 \times 10^7 \text{ m} \quad (1)
 \end{aligned}$$

$$\begin{aligned}
 \frac{GM_E M}{r^2} &= \frac{Mv^2}{r} = \frac{4\pi^2 r^2}{T^2} \quad (1) \\
 T^2 &= \frac{4\pi^2 r^3}{GM_E} = \frac{4\pi^2 \times (2.547 \times 10^7)^3}{6.67 \times 10^{-11} \times 5.98 \times 10^{24}} \\
 &= 1.635 \times 10^9 \\
 T &= 4.04 \times 10^4 \text{ s} \\
 &= 11.2 \text{ hours.}
 \end{aligned}$$

- b) Explain whether or not a satellite can be geostationary at this altitude.

Not possible as period needs to 24 hours
 (1) (1)

(2)

- c) Place **labelled** arrow(s) on the diagram to show the direction of the **net acceleration** of the satellite.

On diagram

(1)

- d) Give two examples of the uses of artificial satellites in everyday life.

Communications

(2)

Global positioning devices

Weather predicting

The Earth is a natural satellite that orbits the Sun. (Assume a circular orbit for this question)

- e) Calculate the orbital speed of the Earth as it goes around the Sun.

(3)

$$M_E = 5.98 \times 10^{24} \text{ kg}$$

$$M_S = 1.99 \times 10^{30} \text{ kg}$$

$$r = 1.50 \times 10^{11} \text{ m}$$

$$\frac{Mv^2}{r} = G \frac{M_S M_E}{r^2} \quad (1)$$

$$v^2 = \frac{6.67 \times 10^{-11} \times 1.99 \times 10^{30}}{1.50 \times 10^{11}} \quad (1)$$

$$= 8.8488 \times 10^8$$

$$v = 2.97 \times 10^4 \text{ ms}^{-1} \quad (1)$$

$$v = \frac{2\pi r}{T}$$

- f) If the Sun was 90% of its current mass, describe how the orbital speed of the Earth would be affected if it remained at the same distance from Sun. (A calculation is not required)

(1)

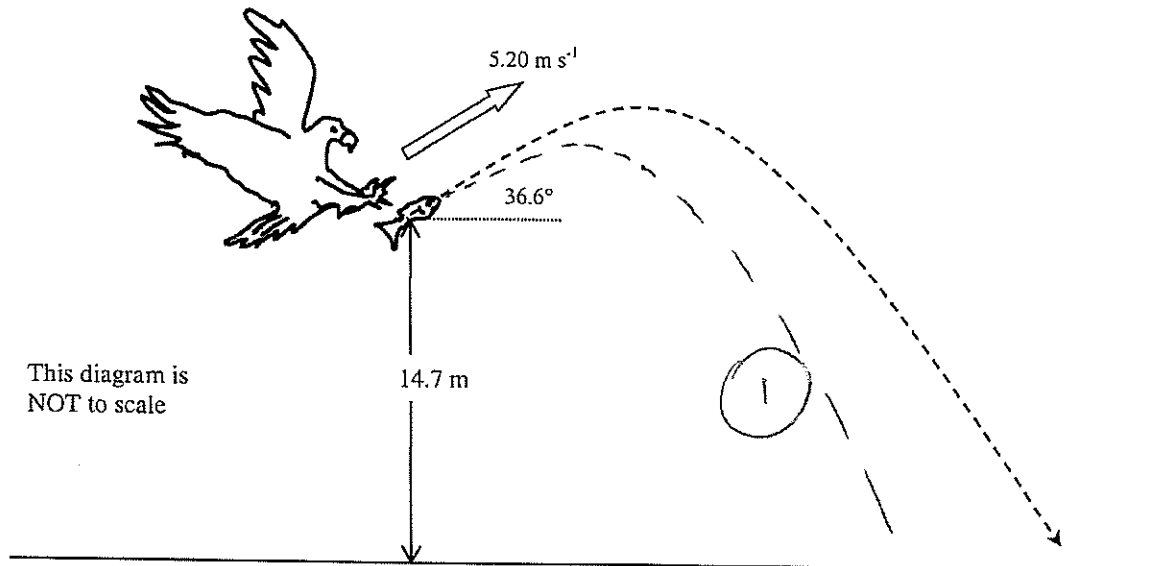
$$v \propto \sqrt{M_S}$$

If M_S decreases v decreases

(1)

Question 15 (13 marks)

An eagle has captured a fish and is 14.7 m directly above the water when it releases the fish. The eagle is moving with a velocity of 5.20 m s^{-1} at an angle of 36.6° above the horizontal when the fish is released. Ignore air resistance for calculations.



a) Calculate the time taken for the fish to reach the water. (4)

Vertical motion

$$u = 5.2 \sin 36.6 \uparrow$$

$$t = ?$$

$$a = 9.8 \text{ m s}^{-2} \downarrow$$

$$s = 14.7 \text{ m} \downarrow \quad (1)$$

Down is +ve

$$s = ut + \frac{1}{2}at^2$$

$$14.7 = -5.2 \sin 36.6 t + 4.9 t^2 \quad (1)$$

$$4.9 t^2 - 3.1 t - 14.7 = 0$$

$$t = \frac{3.1 \pm \sqrt{-3.1^2 - 4 \times 4.9 \times -14.7}}{9.8}$$

$$= \frac{3.1 \pm 17.25}{9.8} \quad (1)$$

$$= 2.08 \text{ s} \quad (1)$$

(take + value)

- b) Calculate the horizontal distance that the fish travels during its flight to the water.

$$\begin{aligned}
 s_H &= v_H \cdot t && \textcircled{1} \\
 &= 5.2 \cos 36.6 \times 2.08 && \textcircled{1} \\
 &= 8.67 \text{ m} && \textcircled{1} \text{ (right)}
 \end{aligned}$$

follow through mark if incorrect time

- c) Calculate the maximum height above the water that the fish reaches during its flight.

↑ Vert.

$$v = 0$$

$$u = 5.2 \sin 36.6 \uparrow$$

$$a = 9.8 \downarrow \textcircled{1}$$

$$s = ?$$

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

$$0 = (5.2 \sin 36.6)^2 - 19.6s$$

$$s = 0.490 \text{ m} \quad \textcircled{1}$$

$$\begin{aligned}
 \text{Height} &= 14.7 + 0.49 \\
 &= \underline{15.2 \text{ m}} \quad \textcircled{1}
 \end{aligned}$$

If air resistance is taken into account then the flight path is altered.

- d) Sketch the altered flight path onto the diagram.

lower and earlier apex / parabolic shape (1)

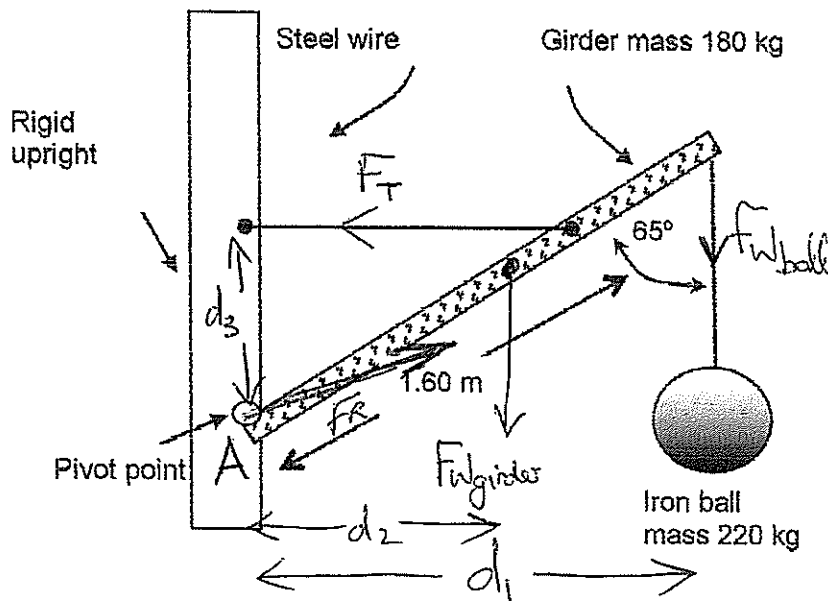
- e) Will the time of flight be longer or shorter when air resistance is taken into account? Discuss the factors that affect this.

Longer (1) (2)

Air resistance reduces acceleration (deceleration on way up)
 Most affect on falling from apex so it is not accelerated down as quickly. (1)

Question 16 (13 marks)

Diagram is not drawn to scale.



An iron ball of mass 220 kg is suspended from the end of a rigid steel girder.

The girder has a mass of 180 kg and a length of 2.40 m and is pivoted to a rigid upright.

A steel wire is attached 1.60 m along the girder. The wire runs horizontally to the upright, as shown in the diagram, and holds the girder in equilibrium.

- a) Identify all the forces acting on the girder by drawing them on the diagram.

$$\begin{array}{l} F_{W_{\text{ball}}}, F_{W_{\text{girder}}} \quad (1) \\ F_T, F_R \quad (1) \end{array} \quad (2)$$

- b) Demonstrate by calculation that the tension in the steel wire is $9.77 \times 10^3\text{ N}$.

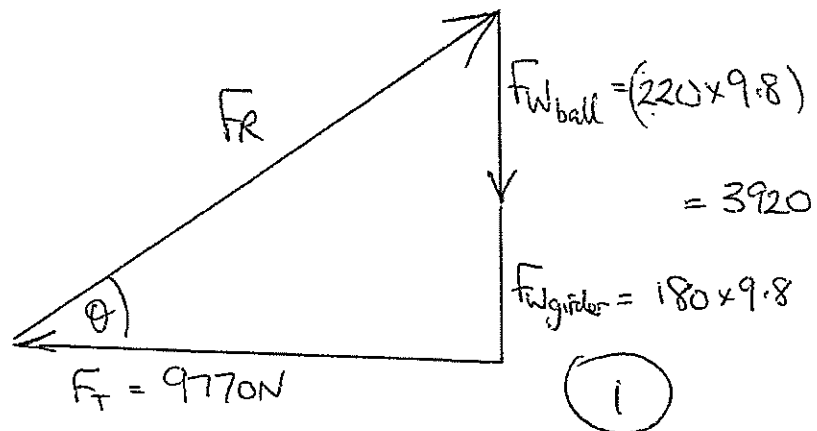
direction needs to be outwards from wall (6)

Moments about pivot, A $\Sigma \tau = 0$

$$\begin{aligned} \Sigma \text{CM} &= \Sigma \text{ACM} \quad (1) \\ (F_{W_{\text{ball}}} \times d_1) + (F_{W_{\text{girder}}} \times d_2) &= F_T \times d_3 \quad (1) \\ (220 \times 9.8 \times 2.4 \cos 25) + (180 \times 9.8 \times 1.2 \cos 25) &= F_T \times 1.6 \cos 65 \quad (1) \\ 4689.6 + 1918.47 &= F_T \times 0.67619 \quad (1) \\ F_T &= 9770\text{ N} \quad (1) \end{aligned}$$

- c) If the tension in the steel wire is $9.77 \times 10^3 \text{ N}$ calculate the magnitude and direction of the reaction force from the pivot acting on the steel girder.

(5)



$$F_R^2 = 3920^2 + 9770^2 \quad (1)$$

$$F_R = 10527$$

$$\tan \theta = \frac{3920}{9770}$$

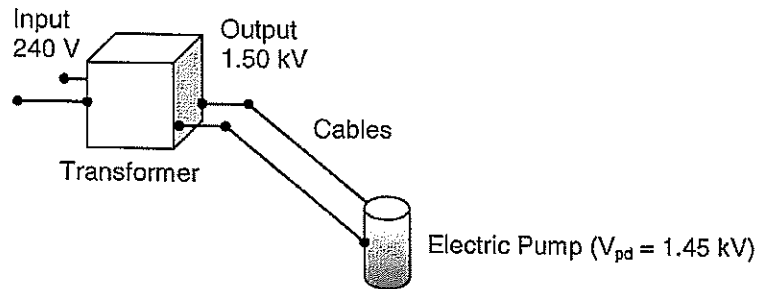
$$\theta = 21.9^\circ \quad (1)$$

$$\text{Reaction force} = 1.05 \times 10^4 \text{ N} \quad (1)$$

@ 21.9° to horiz (1)
out from wall and above horiz

Question 17 (12 marks)

A mining company use an electric pump with an operating voltage in the range 1.25 kV-1.50 kV. There is only a 240 V supply available. A transformer is used to step up the output voltage to 1.50 kV. The secondary winding of the transformer has 2000 turns of wire.



a) Calculate the number of turns required on the primary winding of the transformer. (2)

$$N_p = ?$$

$$N_s = 2000$$

$$V_p = 240V$$

$$V_s = 1500V$$

$$\frac{N_p}{N_s} = \frac{V_p}{V_s}$$

$$N_p = \frac{240}{1500} \times 2000 = 320 \text{ turns}$$

(1)

(1)

The transformer has an electrical power output of 6.45 kW. The underground pump is connected by 1.10 km of cable to the surface. The potential difference across the pump is 1.45 kV.

b) Calculate the total resistance of the cables. (4)

$$P_{\text{out}} = 6450W$$

$$V_{\text{pd pump}} = 1450V$$

$$V_{\text{out}} = 1500V$$

$$P = VI$$

$$V_{\text{pd wires}} = 1500 - 1450$$

$$= 50V \quad (1)$$

$$I = \frac{P_{\text{out}}}{V_{\text{out}}} = \frac{6450}{1500} = 4.30A \quad (1)$$

$$R = \frac{V_{\text{pd wires}}}{I} = \frac{50}{4.3} = 11.6\Omega \quad (1)$$

- c) Calculate how much electrical energy per second is transformed to heat in the cables.

power loss in wires

$$\begin{aligned}
 P_{\text{loss}} &= I^2 R \\
 &= 4.3^2 \times 11.6 \quad (1) \\
 &= 215 \text{ W} \\
 &\quad (1) \text{ (or } \text{J s}^{-1}\text{)}
 \end{aligned}$$

$$\begin{aligned}
 \text{or } V \times I \\
 &= 50 \times 4.3 \\
 &= 215 \text{ W}
 \end{aligned}$$

(2)

- d) Describe two design features of a commercial transformer that increase its efficiency.

Core is laminated to reduce energy loss through production of eddy currents (1)

Larger diameter conducting wires used to carry larger currents (1)

other reasonable answers

Continuous iron core creates max. flux linkage

(2)

- e) Explain why it is more efficient to transfer electricity to the pump at a high voltage of 1.50 kV rather than 240 V.

Current flowing is lower at 1500 V (1)

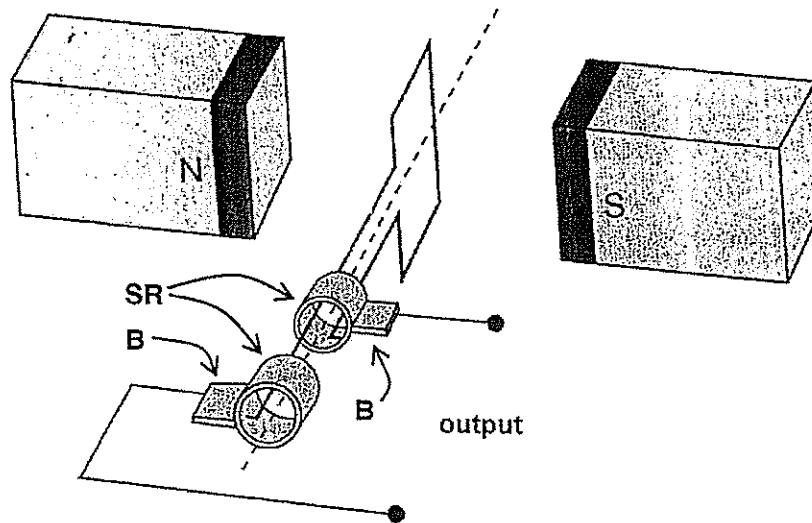
$$\text{and power loss} = I^2 R$$

\therefore smaller current reduces power losses (1)

(2)

Question 18 (13 marks)

The diagram below shows an AC generator consisting of a rectangular coil with dimensions of $14.0\text{ cm} \times 21.0\text{ cm}$, and 800 turns of copper wire. The magnetic flux density between the poles is 9.40 mT . The coil is turned at a uniform rate.



- a) Explain the function of the components labelled SR and B. (2)

Both conduct electric current from coil to external circuit (1)

SR - sliprings. Each is connected permanently to one side of coil so output to external circuit is AC (1)

- b) Referring to Lenz's law, explain how induced emf is achieved from such a generator and why the output is a sine shape rather than being constant. (3)

- As coil is turned conductor moves through magnetic field and induced emf drives a current through coil in a direction to oppose the change (turning of coil). Thus work has to be done to turn the coil and this work done is transferred into electrical energy. (1)
- Rate at which coil cuts magnetic flux varies as coil rotates producing alternating current rather than constant (1)

- c) The coil is rotated at 1500 rpm. Calculate the magnitude of the average induced emf in the coil as it rotates through 90° from the position shown. (3)

$$A = (0.14 \times 0.21) \text{ m}^2$$

$$N = 800$$

$$B = 9.4 \times 10^{-3} \text{ T}$$

$$f = \frac{1500}{60}$$

$$T = 0.04 \text{ s} \\ (40 \text{ ms})$$

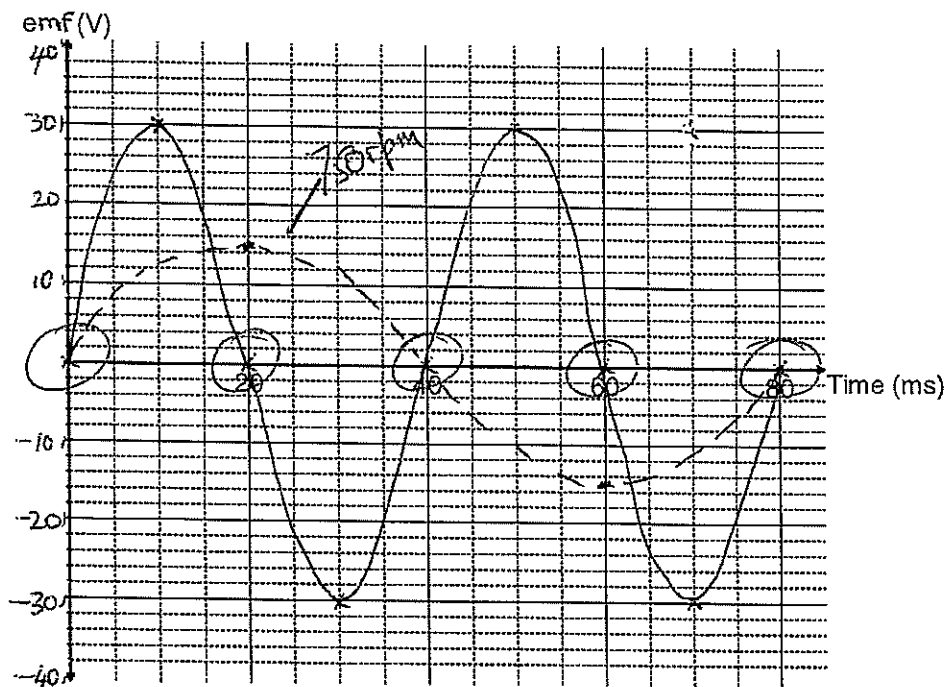
$$V_{\text{emf}} = -N \frac{\Delta \phi}{t} = -\frac{N \Delta BA}{t} \quad (3)$$

for 90° rotation ($\frac{1}{4}$ turn) $t = 0.01 \text{ s}$ (1)

$$V_{\text{emf}} = \frac{800 \times 9.4 \times 10^{-3} \times 0.14 \times 0.21}{0.01} \quad (1)$$

$$= 22.1 \text{ V} \quad (1)$$

- d) Sketch the emf output curve for this AC generator on the graph below. You must start from the position shown on the diagram and continue up to 80 ms. Make estimates for values that you cannot calculate. (3)



- e) Identify three times on the graph when the flux enclosed by the coil is a maximum value at 1500 rpm. Circle these times. (1)

Any three (1)

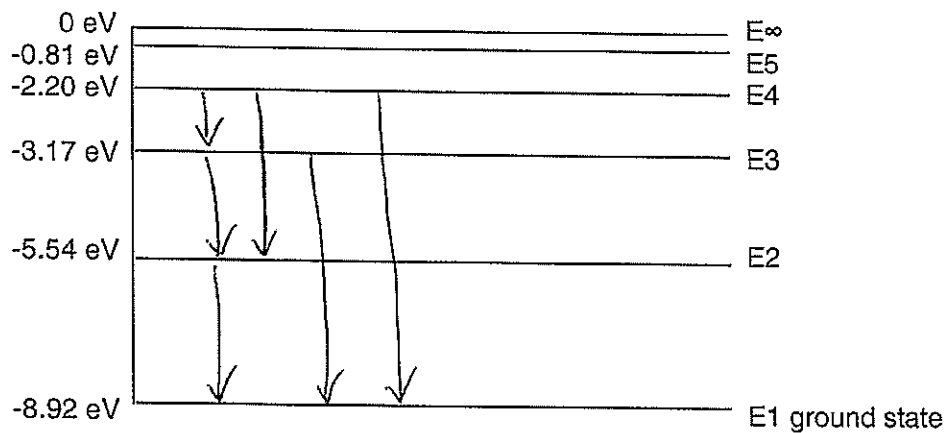
- f) When the coil is rotated at 750 rpm the emf output changes. Sketch the voltage curve for 750 rpm onto the graph and clearly label it '750 rpm'. (1)

on graph (1) $\frac{1}{2}$ Max double period

SEE NEXT PAGE

Question 19 (13 marks)

The diagram below details some of the energy levels for a metallic vapour that surrounds a star



- a) Is it possible for this atom to absorb a 6.50 eV photon whilst in the ground state? Explain briefly.

No. No 6.50 eV energy gaps (1) (1)
All photon energy needs to be absorbed

- b) Whilst in the ground state the atom absorbs a 6.72 eV photon. How many lines in the emission spectrum would be possible as the atom de-excites? Indicate them on the diagram.

Jumps to -2.20 eV (1)

Number of lines = 6

- c) Calculate the longest wavelength possible in the emission spectrum when an atomic electron at E₄ can de-excite by one or more steps to ground level.

Largest λ corresponds to smallest drop (3)

$$E_4 - E_3 = 0.97 \text{ eV} \quad (1)$$

$$E = hf \\ = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{E} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{0.97 \times 1.6 \times 10^{-19}} \quad (1)$$

$$= 1.28 \times 10^{-6} \text{ m} \quad (1)$$

- d) For the wavelength you calculated in part c) state which area of the electromagnetic spectrum this belongs to.

Infra-red (1) (1)

A **single** atom in the ground state is bombarded by **one** electron with a kinetic energy of 6.10 eV.

- e) Detail in the table below the possible photon energies observable on de-excitation and the possible electron energies of the bombarding electron after its interactions with the atom.

(3)

Possible photon energies on de-excitation (eV)	Possible bombarding electron energy after interaction with the atom (eV)
$8.92 - 3.17 = 5.75$	$6.10 - 5.75 = 0.35$
$5.54 - 3.17 = 2.37$	$6.10 - 2.37 = 3.73$
$8.92 - 5.54 = 3.38$	$6.10 - 3.38 = 2.72$

(1)
(1)
(1)

- f) Explain briefly how analysis of a line absorption spectrum of light from distant galaxies can be used to determine the composition of stars and gas clouds.

(2)

Continuous emission spectra from the hot stars are absorbed by the cooler gases in the star's outer atmosphere and gas clouds as light travels to Earth.

The elements present absorb frequencies specific to the energy levels of those elements.

(1)

- g) The line absorption spectrum is also useful to determine the speed of a galaxy. Explain the fundamental principles of this technique.

If a galaxy is moving away from Earth there is a stretching of the wavelengths of the elements line absorption spectra (Red shift)

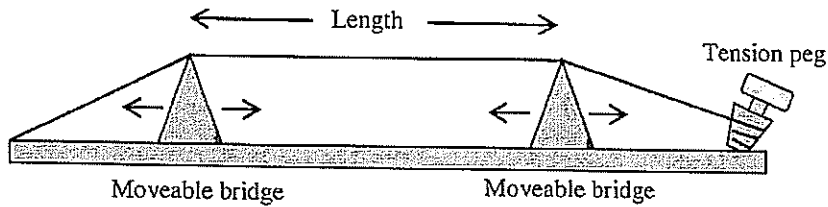
The greater this "shift" the faster the galaxy is moving away

(1)

SEE NEXT PAGE

Question 20 (13 marks)

A simple musical instrument consists of one steel string held in tension between two moveable bridges. The string is plucked between the bridges so that a musical note is heard. When the sound wave is analysed it can be seen that several frequencies are present at the same time.



- a) Explain why several frequencies of sound are present when the single string is plucked. (2)

The string can vibrate in different ways so long as there is a Node at either end. (2)

This gives rise to different wavelengths (frequencies) of notes produced in the standing waves in the string

(1) But be flexible

- b) Explain how standing waves can form along the string. (2)

(1) The waves in the string reflect at the bridges producing waves travelling in opposite directions with the same speed, amplitude and λ . (2)

These waves interfere to produce the standing wave

Again be flexible

- c) The length of the string is set to 30.0 cm and the speed of the transverse waves along the string is 535 m s^{-1} . Calculate the fundamental frequency of the string. (2)

$$\lambda = 2l = 0.6 \text{ m}$$

$$v = 535 \text{ m s}^{-1}$$

$$f = \frac{v}{\lambda} = \frac{535}{0.6}$$

$$= 892 \text{ Hz}$$

(2)

For a given note played on a musical instrument, the dominant frequency heard is called the fundamental frequency or the first harmonic. The sequence of harmonic frequencies above the fundamental frequency, that are actually present, are known as **overtone**s. So those harmonics above the fundamental are known as the first overtone, the second overtone etc., eg the second harmonic is the first overtone.

- d) The bridges can be moved and the tension set so that the wave speed along the string stays the same. What length of string is required so that its fundamental frequency is the same as the second **overtone** of the 30.0 cm string?

$$\text{2nd overtone} = \text{3rd Harmonic} \quad (2)$$

$$f_3 = 3f_1 = 3 \times 892 = 2676 \text{ Hz}$$

$$3f_1 \text{ needs wavelength} = \frac{1}{3}\lambda_1 \quad (1)$$

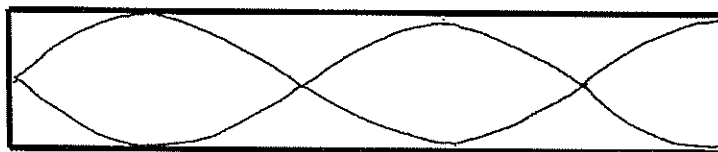
$$\left(\frac{1}{3} \times 0.6 = 20.0 \text{ cm}\right) \quad (1)$$

$$l = \frac{\lambda}{2} = 10.0 \text{ cm}$$

Another simple musical instrument is a pipe, which is an air column closed at one end.

- e) Sketch the particle displacement wave envelope for the second **overtone** in the closed pipe. (2)

$$\text{2nd overtone} = 5f_1 \quad (1)$$



(1)

1 mark if $3f_1$ is drawn

- f) Calculate the frequency of the second **overtone** in a closed pipe of length 15.0 cm when the air temperature is 25°C. (3)

Follow through from e)

$$15 \text{ cm} = \frac{5\lambda}{4}$$

$$\lambda = 12.0 \text{ cm} \quad (1)$$

$$f = \frac{v}{\lambda} = \frac{346}{0.12} = 2880 \text{ Hz}$$

(1)

(1)

End of Section 2

SEE NEXT PAGE

Section Three: Comprehension 20% (36 Marks)

This section contains **two (2)** questions. You must answer both questions. Write your answers in the space provided. Suggested working time for this section is 40 minutes.

Question 21 Hubble's Law (18 marks)

When a source of waves is moving, a stationary observer notices a change in frequency of the waves. This effect is observed for both longitudinal and transverse waves. For example, if an ambulance moves towards you the sound frequency you hear is higher than the frequency its siren is emitting. This is known as the Doppler Effect.

If a source of electromagnetic waves, such as a star, is travelling away from an observer then the wavelengths of the lines in its electromagnetic spectrum are shifted to higher values. This is called red shift. An equation for the relationship is as follows:

$$z = \frac{\Delta\lambda}{\lambda}$$

It can also be shown that:

$$z = \frac{v}{c_0}$$

z = red shift

$\Delta\lambda$ = change in wavelength (moving source) (nm)

λ = wavelength of stationary source (nm)

v = recessional speed of galaxy (m s^{-1})

c_0 = speed of light in a vacuum (m s^{-1})

Edwin Hubble analysed the red shifts of various galaxies in 1920 and deduced that most galaxies are moving away from the Earth, this suggests that the Universe is expanding. Hubble also discovered that the further away a galaxy is, the bigger its red shift and the faster it is moving away. This relationship is known as Hubble's Law and can be stated algebraically as follows:

$$v_{\text{galaxy}} = H_0 \cdot d$$

v_{galaxy} = recessional speed of galaxy (km s^{-1})

d = distance to galaxy (Mpc)

H_0 = Hubble's constant ($\text{km s}^{-1} \text{Mpc}^{-1}$)

The distances to galaxies can be estimated by observing Cepheid Variables within a galaxy. A Cepheid Variable is a class of star that pulsates. The relationship between the period of pulsation and the size of the star is very precise. An understanding of how brightness diminishes with distance allows astronomers to estimate distances to galaxies with a high degree of confidence.

The following data was recorded by the Hubble Space Telescope for five galaxies.

Distance (Mpc)	Red shift - z	Recessional speed of galaxy v_{galaxy} (km s^{-1})
3.1	0.00095	285
8.6	0.00212	636
12.2	0.00273	819
16.1	0.00402	1206
19.4	0.00473	1419

- a) Calculate the appropriate values in the final column of the table (the first value has been done for you)

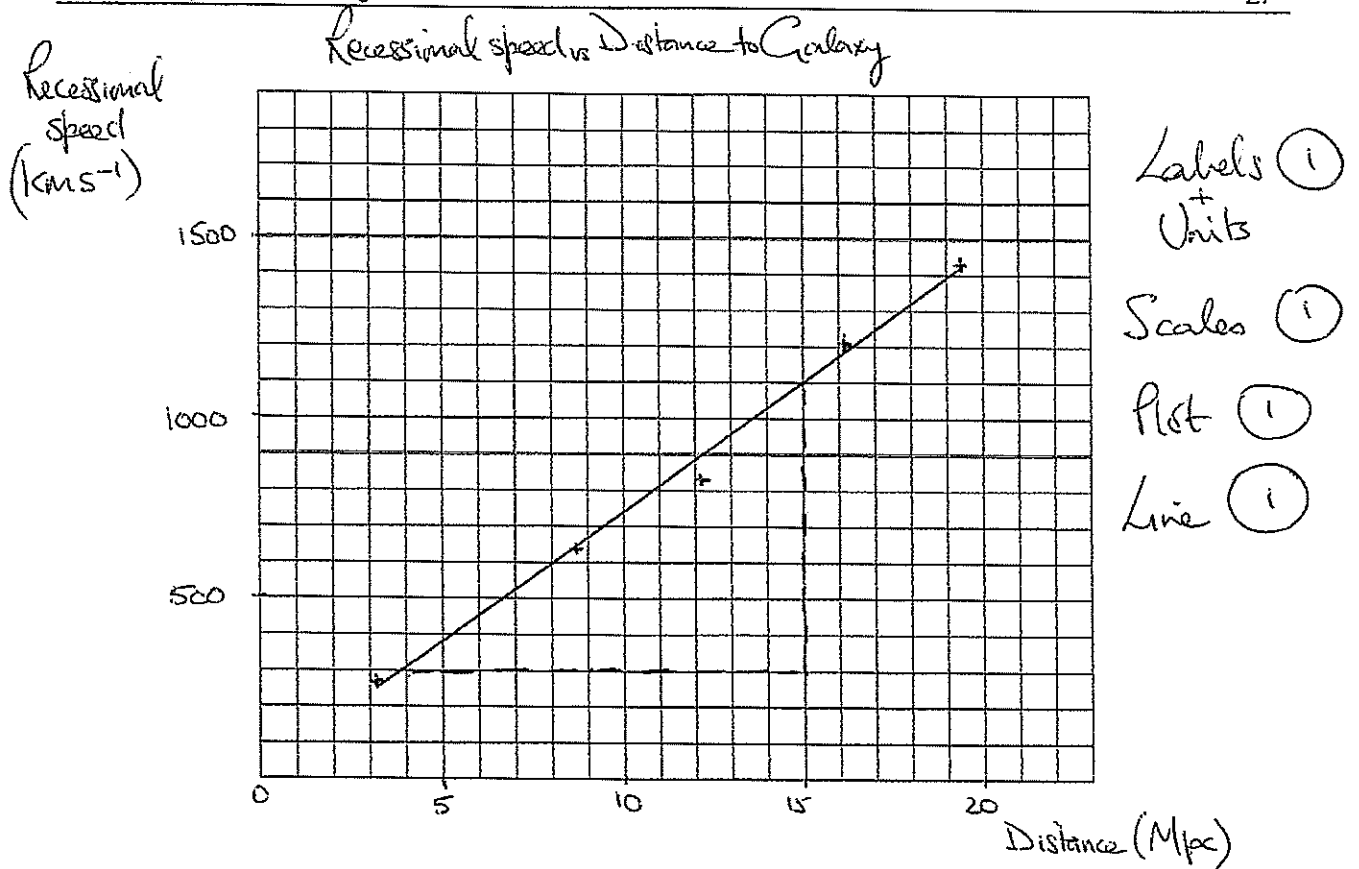
table ↑

(2)

- b) Plot a correctly labelled graph of **recessional speed** versus **distance to galaxy** on the graph paper and draw a line of best fit. (Spare graph paper is provided on page 33 if needed).

(4)

Use eqn ①



- c) Calculate a value for Hubble's constant, in the correct units, showing how you obtained this value from your graph.

$$g_{\text{H}} = \frac{v_{\text{galaxy}}}{\text{Distance}} = H_0 \quad (1) \quad (3)$$

$$= \frac{1100 - 310}{15 - 4} = 72 \text{ km s}^{-1} \text{ Mpc}^{-1}$$

(2) Accuracy mark (±2)

- d) State three reasons why you think that measurements of Hubble's constant have varied widely since Hubble's first determination in 1920.

Accuracy of red shift has increased (3)

More Cepheids have been measured giving greater accuracy to distance calibration

More distant galaxies have been observed, adding to data available.

3 reasonable answers.

- e) Why does the value of red shift z , have no units?

It is the ratio of 2 speeds/lengths (1)

- f) A line in the spectrum of ionised calcium has a wavelength of 393.3 nm when measured in the laboratory. When similar light from the galaxy NGC 3350 is measured, its wavelength is 394.64 nm. Use the red shift formulae to determine the recessional speed of this galaxy. (2)

$$z = \frac{\Delta\lambda}{\lambda} = \frac{v}{c_0}$$

$$\frac{394.64 - 393.3}{393.3} = \frac{v}{3 \times 10^8} \quad (1)$$

$$v = 1.02 \times 10^6 \text{ ms}^{-1} \quad (1)$$

- g) For the recessional speed you calculated in part f), use your graph and the line of best fit to determine the distance to this galaxy in Mpc. (1)

$$v = 1020 \text{ kms}^{-1}$$

$$\Rightarrow 13.9 \text{ Mpc} \quad (1)$$

accuracy
should be close to 14

- h) Determine how many years it takes for light from galaxy NGC 3350 to reach Earth (± 0.2) (1 parsec = 3.26 ly)

$$13.9 \times 10^6 \times 3.26 = 45.3 \times 10^6 \text{ ly} \quad \text{Follow through (2)}$$

It takes 45.3 million years from value calculated

Question 22**(18 marks)****Particle Physics – basic principles and techniques**

Particle physics is the modern version of the age old quest – to find the smallest particles that cannot be broken down. Particle accelerators are the 'laboratory equipment' in this area of study. Charged particles can be accelerated in two senses – by their change of direction in circular paths or by increasing their speed. Studies can be made on the radiation that they emit whilst being accelerated or the after effects of collisions between high speed particles.

The **cyclotron** first came into use in 1928 using a combination of magnetic and electric fields to accelerate particles in a spiral path. Development of this technology led to the **synchrotron** which uses an evacuated circular tube with many magnets placed around its circumference. As particles are accelerated the electric field is adjusted and the strength of the magnets is increased to maintain a constant radius and compensate for relativistic effects that become important at high particle energies.

Any charged particle that accelerates will radiate electromagnetic energy. This is true even at a constant speed in a circular path. So a continual supply of energy is required in synchrotrons to just maintain a constant particle speed let alone increase their speed. The emitted radiation is known as **synchrotron radiation** and can cover the entire electromagnetic spectrum.

Linear accelerators (LINAC) use a straight path and a series of accelerating voltages as the particles move along the line. LINACs are often used to provide the early stages of acceleration before particles are fed into large synchrotrons.

Collider experiments take two beams of particles that have been separately accelerated in opposite directions and smash them into each other. This is difficult to achieve but if successful it is an efficient use of energy.

When two particles with an equal magnitude of momentum collide head on, the total momentum is zero before and after the collision. If particles are stationary after the collision then their kinetic energy is zero. By the conservation of energy and mass principle, the energy before the collision is transformed into the mass of new particles formed in the collision. The particles that are present after a collision reaction can be different to those that went in. This is exactly what particle physicists aim to achieve and the discovery and study of these new particles underpins their work.

Every collision is governed by one of the **fundamental forces** (except the force of gravity which has no significant influence on such tiny particles in this context):

- The **electromagnetic force** leads to simple collisions between charged particles. No new particles are formed when this force is at work. e.g. $p + p \rightarrow p + p$
- The **strong force** dominates reactions between hadrons (which contain quarks). e.g. $p + p \rightarrow p + n + \pi^0$
- The **weak force** is likely to be involved in lepton reactions, especially if one of the leptons is a neutrino. e.g. $\nu_e + \mu^- \rightarrow e^- + \nu_\mu$

Einstein's theory of **special relativity** has led us to the idea that the mass of a moving object is not the same as its rest mass (m_0). The mass of a moving object cannot be measured directly; it must be calculated from a measurement of momentum and velocity. The relativistic equations for momentum p and total energy E are as follows:

$$p = \frac{m_0 v}{\sqrt{1 - \frac{v^2}{c^2}}} \quad E = \frac{m_0 c^2}{\sqrt{1 - \frac{v^2}{c^2}}} \quad \text{(These equations are only applicable for non-zero mass)}$$

SEE NEXT PAGE

Relativity has also given us the idea of mass-energy equivalence. In Newton's version of mechanics a lone particle not influenced by gravity or electromagnetism but moving at a given speed could only have a single form of energy – kinetic. At rest it had no energy at all. This is not the case in relativity. The relationship is described by the equation: $E^2 - p^2c^2 = m_0^2c^4$

Photons are packets of energy travelling at the speed of light. Surprisingly it has been proved that although photons have zero mass they do have momentum. It can be shown for a photon that

if: $E^2 - p^2c^2 = m_0^2c^4$ then: $p = \frac{E}{c}$ and since $E = hf$ then: $p = \frac{hf}{c} = \frac{h}{\lambda}$

Particle physics has also proven to be vital in understanding the nature of the universe a few fractions of a second after the Big Bang. The conditions created in the mightiest accelerators are very similar to those that existed when the universe was 10^{-12} seconds old.

Questions

- a) In what sense can a particle be accelerated if its speed remains constant? Explain.

$acc = \frac{\Delta v}{t}$, requires a change in velocity. (1) (2)
Changing direction constitutes a change in velocity
 (1)

- b) Once a charged particle has been accelerated to a given speed in a circular path, is further energy required to maintain a constant speed? Explain.

Yes, further energy is required. (1) (2)
 The accelerated particle loses energy by emitting radiation, this energy has to be supplied to maintain the speed. (1)

- c) Can electrons and neutrinos be subject to the strong force? Explain

No. (1) (2)
 Strong force acts between hadrons (1)
 (protons and neutrons)

- d) If neutrinos are involved in a collision reaction why is it unlikely that this was governed by the electromagnetic force?

Neutrinos are uncharged and (1) (1)
e-m force acts between charged particles.

- e) If you hit a ping pong ball with a table tennis bat which of the three fundamental forces described governs this collision? Justify your answer.

The electro-magnetic force (1) (2)
Interaction is between atoms in ball and bat (1)
ie Electric fields of electrons between ball and bat

- f) Calculate the momentum of a **proton** travelling at 95% of the speed of light. The rest mass of a proton is given in the formula and constant sheet.

$$p = \frac{M_0 v}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{1.67 \times 10^{-27} \times 0.95 \times 3 \times 10^8}{\sqrt{1 - \frac{(0.95 \times 3 \times 10^8)^2}{(3 \times 10^8)^2}}} \quad (3) \quad (1)$$

$$= \frac{4.7595 \times 10^{-19}}{0.3122}$$

$$= 1.52 \times 10^{-18} \text{ kg m s}^{-1} \quad (1)$$

No deduction for incorrect units.

- g) The equation for Einstein's mass-energy equivalence is: $E^2 - p^2c^2 = m_0^2c^4$
 Show that for a particle at rest this simplifies to $E = m_0c^2$

A particle at rest has zero momentum (2)

$$p = 0$$

$$E^2 - \cancel{0} = m_0^2c^4$$

Square root

$$E = m_0c^2$$

- h) From the starting point: $E^2 - p^2c^2 = m_0^2c^4$ show that the momentum of a **photon** with zero mass can be given by $p = \frac{E}{c}$

$$m_0 = 0$$

$$E^2 - p^2c^2 = 0$$

$$E^2 = p^2c^2$$

$$E = pc$$

$$p = \frac{E}{c}$$

- i) Calculate the momentum of a photon of 550 nm yellow light.

$$p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{550 \times 10^{-9}}$$

$$= 1.21 \times 10^{-27} \text{ kg ms}^{-1}$$

End of questions