PHYSICS Year 12
Stage 3A 3B

Semester 2 Examination 2010
Thursday 30th September (am)

/ 176

SOLUTIONS

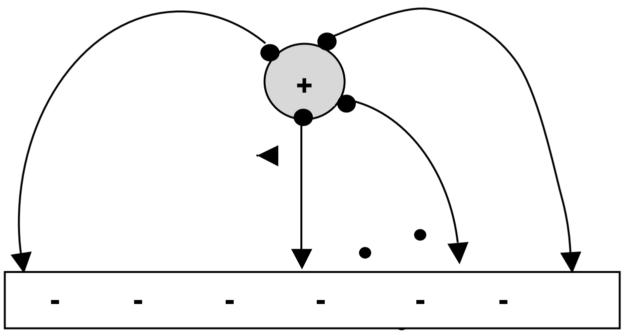
Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Short response	13	13	45	49	27
Section Two: Problem-solving	8	8	95	95	53
Section Three: Comprehension	2	2	40	36	20
					100

Section One: Short response **27% [49 Marks]**

Question 1 **[3 marks]**

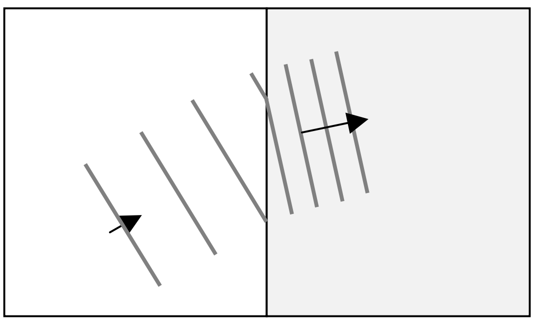
A positively charged metal sphere is located above a negatively charged conducting plate as shown in the diagram. Sketch the electric field lines between the charged sphere and the plate, using the four dots on the sphere as starting points.



Description	Marks
Require 4 lines no more	1
Field lines leave +ve perpendicularly and arrive at –ve perpendicularly also perpendicularly	1
Direction of arrow from + to -	1
	Total 3

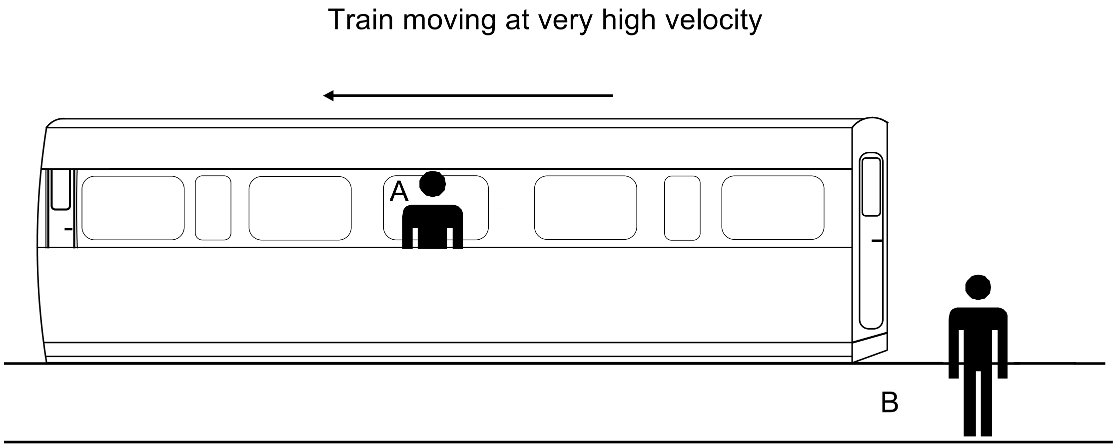
Question 2 **[3 marks]**

Water waves move slower in shallower water than in deep water. This slowing down of waves is the cause of breaking waves. Complete the diagram below to show the accurate shape and pattern of waves coming into shore at an angle as they move from the deep to the shallower water near the beach. Draw in 4 more waves on the diagram below as they move through the shallow water.



Wavelength decreases ✓
Direction rotates clockwise ✓
Spacing of lines is constant ✓

Question 3 **[5 marks]**



An observer at position A at the midpoint of a train carriage (a moving frame of reference), sends light signals to the front and back of the carriage at the same time. These light beams open doors at each end of the carriage. Another observer at position B is stationary on the platform, watching the train moving away from him at high velocity.

(a) Does observer A see the doors in the carriage open simultaneously, or at different times? (1 mark)

Description	Marks
Both doors opening at the **same time**	1
	Total 1

(b) Does observer B see the doors in the carriage open simultaneously, or at different times? (2 marks)

Description	Marks
B sees door closest to him opening before the door furthest away	2
If indicates they would make a **different** observation	1 only
	Total 2

(c) If the observations are different, whose observation is correct? Explain your reasoning. (2 marks)

Description	Marks
Both are correct	1
One set of simultaneous events are not necessary simultaneous for another observer moving at different speed / observers in different frames of reference	1
	Total 2

Note: *Many students wrote that the speed of light is constant. However the train is NOT travelling at relativistic speed, observations being different due to train moving not speed of light*

Question 4 ` **[4 marks]**

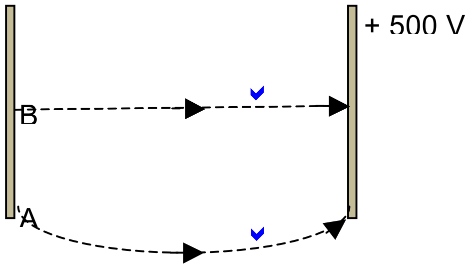
In an experiment two metal plates are attached to a 500 V power supply to produce an electric field E between the plates.

a) Calculate a value for E when the plates are placed 17.5 cm apart. [2 marks]

$E = V \div d = 500 \div 0.175 = 2.86 \times 10^3\ V\ m^{-1}$

b) Two electrons are released at points A and B on the left hand plate which are attracted towards the right hand plate. Draw in on the diagram the paths of each of these electrons as they move from left to right. [2 marks]

1 mark each line, line A must be curved:

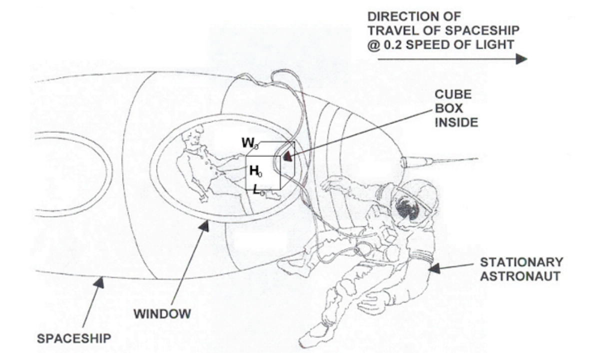


Question 5 **[3 marks]**

A spaceship travelling at 20% of the speed of light (i.e. 0.2 x c) contains a cube shaped box.

An astronaut floating freely in space outside the spaceship views the box through a window as the spaceship passes and records its dimensions as L, W and H.

A passenger on the spaceship records the dimensions of the box as L_o, W_o and H_o.



(a) Which of the following options best describes the dimensions of the box as observed by the astronaut outside the spaceship compared to the measurements made by the passenger?

A. $L<L_o$, $W<W_o$, $H=H_o$
B. $L>L_o$, $W=W_o$, $H=H_o$
C. $L<L_o$, $W=W_o$, $H=H_o$
D. $L<L_o$, $W<W_o$, $H<H_o$

Answer _______C______ [1 mark]

(b) Explain why you selected your answer. [2 marks]

For an object travelling at relativistic speed, the length in the direction of travel (as seen by a stationary observer) is shorter / length contraction. [1]
The other dimensions remain unchanged. [1]

Question 6 **[4 marks]**

The force that holds the protons and neutrons together in the nucleus is known as the strong nuclear force. This force only acts on particles known as hadrons of which protons and neutrons are members. Hadrons are thought to be made up of quarks having non integer charges. All hadrons are made of three quarks.

These quarks have different charges. The up quark has a charge of $+\frac{2}{3}e$ while the down quark has a charge of $-\frac{1}{3}e$. 'e' is the charge on an electron.

(a) List the quarks in a proton and justify your answer. (2 marks)

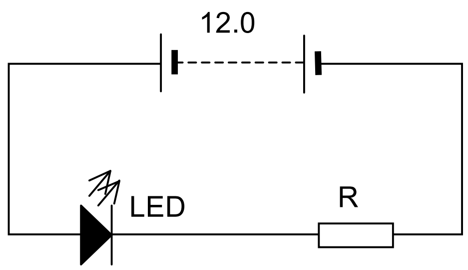
Description	Marks
List: Proton is up up down	1
$\frac{2}{3}+\frac{2}{3}-\frac{1}{3}=\frac{3}{3}=+1$	1
	Total 2

(b) List the quarks in a neutron and justify your answer. (2 marks)

Description	Marks
List: Neutron is up down down	1
$\frac{2}{3}-\frac{1}{3}-\frac{1}{3}=0$	1
	Total 2

Question 7 **[3 marks]**

A light-emitting diode (LED) can run at a safe voltage of 2.0 V and yet it can be connected effectively into a 12 volt circuit if a series resistor is used.



The circuit above shows an LED connected correctly into a 12 volt circuit.
If the LED must not carry a current exceeding 10.0 mA, calculate the value of the resistor R to be used.

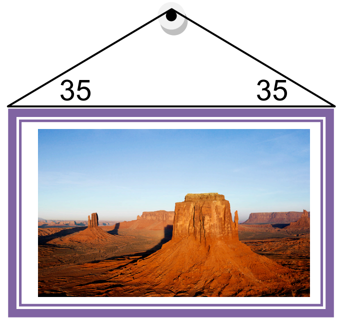
***Note**: Many students used 12V as the voltage, this is incorrect as this is a series circuit, it is clearly stated that the voltage across the LED is a maximum of 2V. Voltages add up in series circuits:* Max 2 marks if used 12V, maximum 1 mark if used 2V

If the voltage across the LED = 2 V then V_R = 12 – 2 = 10 V.
Current will be the same through both resistor and LED = 0.01 A

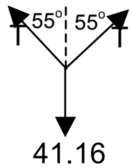
R=VI =10 x 0.01 =1000 Ω

Question 8 **[4 marks]**

A picture of mass 4.20 kg is hung from a nail in the wall by a wire, as shown in Figure 1. If the wire makes an angle of 35^{o} to the picture, calculate the tension in the wire.



Equating vertical components: 2Tsin35 = 41.16
T = 35.9 N



Question 9 **[3 marks]**

The planet Tedja has been discovered in another galaxy which could possibly have conditions to support life as we know it *if* its gravitational field strength is large enough to attract and hold molecules of oxygen, which is estimated to be > 5.6 N kg^{-1}.

If the radius of the planet is 0.85 times Earth's radius and its mass is 0.34 times Earth's mass, calculate a value for 'g' on the surface of Tedja and state whether it is likely to be able to support life.

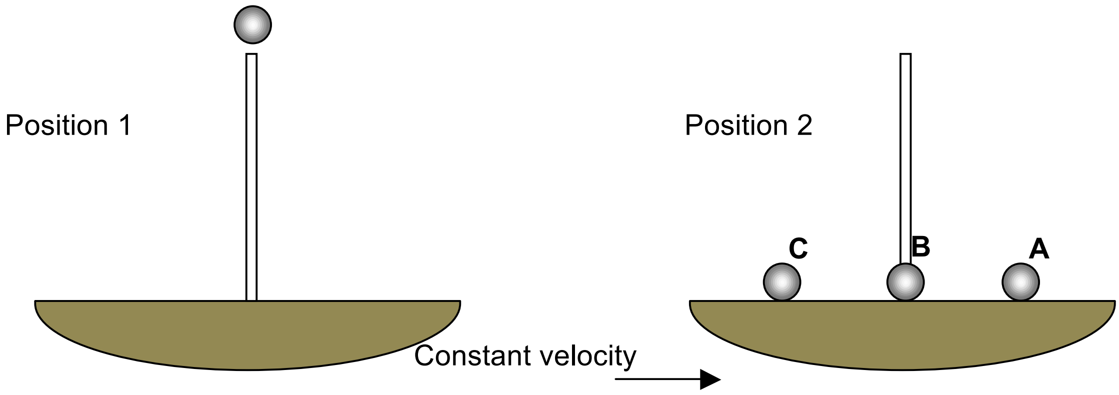
Use $g = GM / r^2$ G is constant, $g_{Earth} = 9.8$ N kg^{-1}

$M_{Tedja} = 0.34\ M_{Earth}$ **$g = g_{Earth} \times (0.34 / 0.85^2) = 4.62$ N kg^{-1} [2]**
$r_{Tedja} = 0.85\ r_{Earth}$

<u>NO</u>, Tedja cannot support life as $g_{Tedja} < 5.6$ N kg^{-1} [1]

Question 10 **[3 marks]**

Galileo set up a "thought" experiment where a ship was moving to the right with a constant velocity and a sailor, who was sitting at the top of the mast, dropped a cannon ball. He asked the question as to where this cannon ball would land as it hit the deck.



a) Circle the point where you think the ball will land in position 2:

A B C

[1 mark]

b) Explain your choice of answer to part a). [2 marks]

Ball will land at point B.

The ball is moving forward at the same rate as the ship when it is released.
So, in the time it takes to fall, it will have moved to the right by the same distance as the ship has moved.
Hence it will land directly below the point of release.

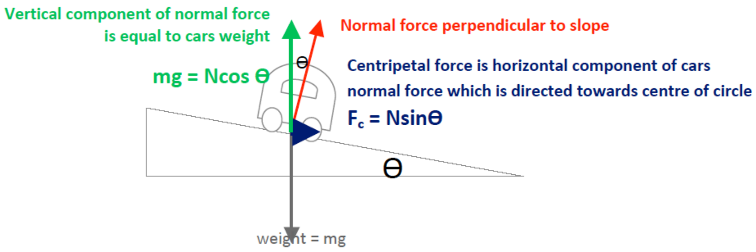
Note: *Many answers referring to frames of reference. For full maximum marks answer needs to show understanding of projectile motion and that the* ***horizontal*** *component of velocity is the same for the ball and the ship.*

Question 11 **[4 marks]**

What is the maximum speed a 30 tonne truck can corner a bend with a radius of curvature of 200m if the curve is banked at 10º to the horizontal and there is no friction force?

$$\mathbf{v_{max} = \sqrt{(gr\ tan10)}}$$
$$\mathbf{= \sqrt{(9.8 \times 200 \times tan\ 10)}}$$
$$\mathbf{= \sqrt{(346)} = \underline{18.6\ ms^{-1}}\ (67\ kmh^{-1})}$$

Note: *Incorrect calculation of centripetal force common error, see below:*



Using substitution

F_c = NsinΘ N = F_c / sinΘ

mg = Ncos Θmg = (F_c / sinΘ) / cosΘ

Therefore **F_c = mg tanΘ**

Question 12 **[5 marks]**

Aircraft flying through the Earth's magnetic field are subject to an induced EMF across the wings.

a) At which places on Earth will the aircraft experience the maximum induced EMF? [1 mark]

The aircraft will experience maximum induced EMF when the magnetic lines of force are closest together. This will occur at the poles of the Earth.

Note: *common mistake – where magnetic field lines are perpendicular. The maximum induced EMF will be where the magnetic field B has the greatest strength*

b) If the maximum magnitude of the Earth's magnetic field is 5.00 x 10^{-5} T, calculate the magnitude of the EMF that would be induced across the wings of a Boeing 747 flying at its maximum speed. A Boeing 747 wing span is about 60 m and its maximum speed is about 900 km h^{-1}. [2 marks]

Wingspan of Boeing 747 = approx 60 m

Maximum speed of Boeing 747 = 900 km h^{-1} = (250 m s^{-1})

Earth's magnetic field = 5 x 10^{-5} T

emf = *l*vB = 60 x 250 x (5 x 10^{-5})

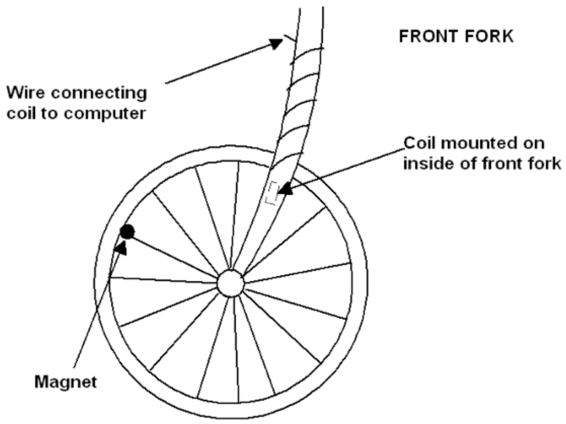
emf induced across the wings = 0.75 V

c) Would it be realistic for the induced EMF produced in this way to be used to power appliances on board the aircraft? Justify your answer. [2 marks]

No. 0.75 V is a small potential that would not be very useful in providing power for appliances in the aircraft.

Question 13 **[5 marks]**

Small computers mounted on bicycles measure the speed and distance a rider has achieved on a ride. A permanent magnet is attached to a spoke in the front wheel and a coil is mounted on the front fork of the bicycle. A wire connects the coil to a small computer on the handlebars which provides a read out of the bicycle's speed and distance. When the computer is first used the rider programs into it the circumference of the wheel. The diagram below shows the arrangement.



a) Briefly describe in terms of electromagnetic induction how the bicycle's speed is measured. [3 marks]

As the magnet on the spoke passes the coil it <u>induces a current</u> pulse in the coil which is conducted via the wire to the computer on the handlebars. [1]
The computer recognizes successive pulses and <u>measures the time interval</u> between pulses [1]
If the circumference of the wheel (and hence the distance travelled by one complete revolution of the wheel), is programmed into the computer, then the computer <u>calculates the speed</u> using the time interval and the distance using $v = 2\pi r / T$. [1]

b) Is it necessary to mount the magnet on the circumference of the wheel, as shown in the diagram, for the system to function properly? Explain your answer. [2 marks]

<u>NO</u> It is not necessary to mount the magnet on the circumference of the wheel. As long as the magnet is close enough to the coil to induce a current the coil/magnet arrangement can be located at any distance from the axle of the wheel.
The <u>time taken</u> for the wheel to complete one revolution <u>is the same</u> no matter where the measurement is recorded within the usual error limitations.

(There will be less error in the time reading when the distance travelled by the magnet is at its maximum compared to a shorter distance. So cyclists usually mount the magnet/coil arrangement towards the circumference of the wheel rather than closer to the axle.)

End of Section One

Section Two: Problem-solving **53% [95 Marks]**

This section has **eight (8)** questions. You must answer **all** questions. Write your answers in the space provided.

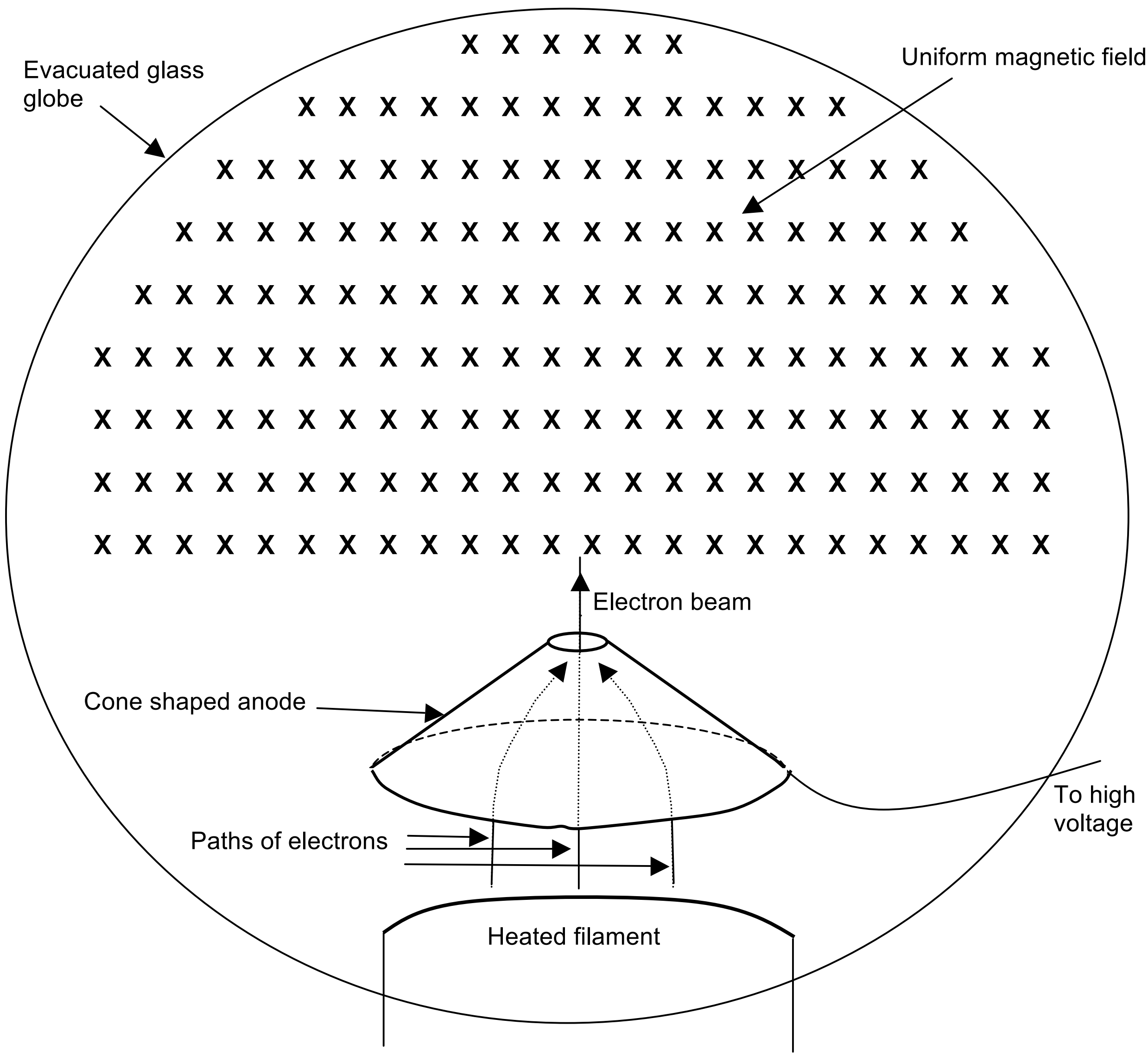
Suggested working time for this section is 95 minutes.

Question 1 **[14 marks]**

The diagram below shows a glass globe containing a heated filament that emits electrons by thermionic emission. Initially, the space inside the globe is a vacuum. The electrons are attracted to, and then pass through, a hollow conical anode. This forms a narrow beam of electrons.

The electron beam then enters a region of uniform magnetic field. The magnitude of this field can be changed.

This device can be used for a range of experiments.



(a) Is the anode positively or negatively charged? Explain your answer. (2 marks)

Description	Marks
+ ve charged	1
required charge to attract –ve charged electrons	1
	Total 2

(b) Show clearly on the diagram the trajectory of the electron beam whilst in the uniform magnetic field. (2 marks)

Description	Marks
Shape (curves **evenly**) – if circle gets tighter, do not allow mark	1
Direction (curves to the **right**).	1
	Total 2

***Note**: Be careful when using right hand rule for electron to reverse direction of your thumb!!*

(c) Using the equation $F = Bqv$ and an equation for circular motion, show that $r = \frac{mv}{Bq}$.

Show your working. (3 marks)

Description	Marks
$F = Bqv$ and $F = \frac{mv^2}{r}$ r	1
So $Bqv = \frac{mv^2}{r}$	1
$Bq = \frac{mv}{r}$ $\frac{q}{m} = \frac{v}{rB}$	1
	Total 3

(d) One experiment using this apparatus gives the following experimental measurements:

electron speed = 2.00×10^7 m s^{-1}
magnetic field strength = 1.20×10^{-3} T
radius of electron path = 10.0 cm.

Use **these** values to calculate the charge to mass ratio $\frac{e}{m}$ for an electron. (3 marks)

Description	Marks
$Bq = \frac{mv}{r}$	1
$\therefore r = \frac{mv}{Bq}$	1
$\frac{q}{m} = \frac{2 \times 10^7}{(0.1)(1.2 \times 10^{-3})}$	1
= 1.66×10^{11} C kg^{-1}	1
	Total 4

***Note**: even though this is a ratio is still has units as it is charge divided by mass!*

(e) If the glass bulb is filled with neon gas, a glowing pink ring appears within the globe when the electron beam is turned on. Explain why this glowing ring appears. (3 marks)

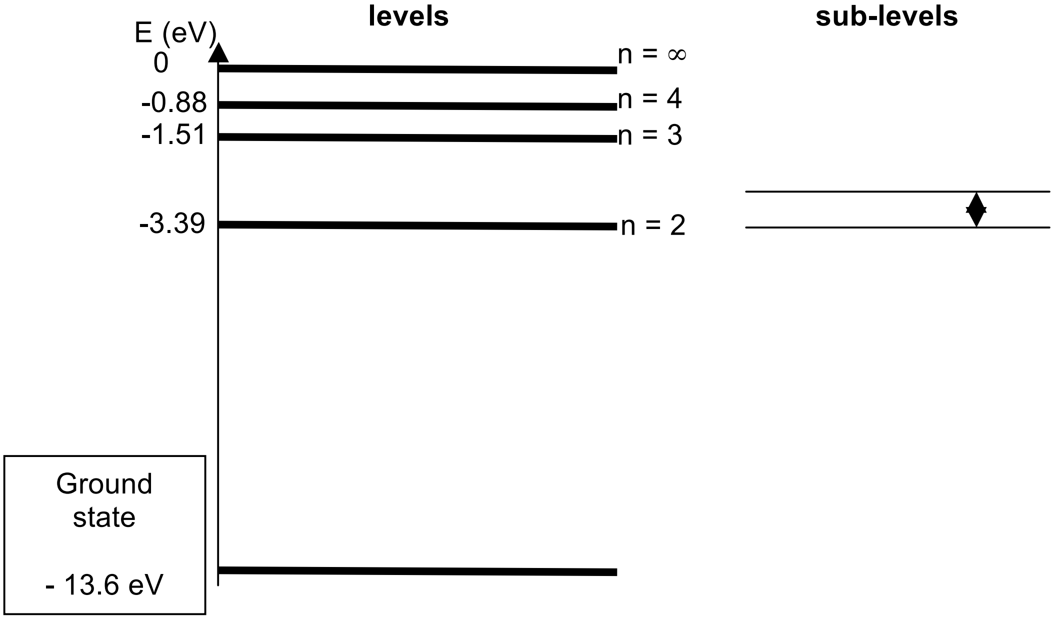
Description	Marks
Electrons collide with the gas atoms	1
This ionises the gas / causes electrons to jump up energy levels	1
Its **emission** spectrum has a bright pink line / as electrons return to lower levels photons emitted in frequency that corresponds to wavelengths in pink part of spectrum	1
	Total 3

(f) Suggest how could the colour of the glowing ring could be changed. (1 mark)

Description	Marks
The colour can be changed by changing the gas	1
	Total 1

Question 2 **[14 marks]**

The diagram below shows some of the possible electron energy levels in a hydrogen atom. The ionisation energy for a hydrogen atom is 13.6 eV.

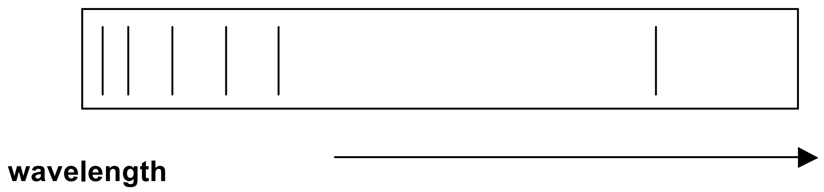


Description	Marks
- 13.6 eV	1
	Total 1

(b) Explain what is meant by the term ‘ionisation energy’. (2 marks)

Description	Marks
The ionisation energy is the energy to allow the most bound electron / electron in ground state to escape the attraction of the nucleus,	1 1
	Total 2

(c) Light from a hydrogen discharge tube can be seen as a line emission spectrum. Using a labelled diagram, describe what a line emission spectrum looks like. (3 marks)

Description	Marks
 Lines are sharp (distinct **wavelength**) coloured unique to a particular atom not evenly distributed	 1 1 1
	Total 3

The diagram on page 22 is based on the Bohr model, which is the simplest model of the hydrogen atom. In more physically accurate (and more complex) models the $n = 2$ energy level is split into two sub-levels. An electron making a transition between these sub-levels emits a photon with a wavelength of 21 cm.

(d) Calculate the energy difference (in eV) between the two n = 2 sub-levels. (3 marks)

Description	Marks
E = h f = hc / λ	1
$= \dfrac{6.64 \times 10^{-34} \times 3 \times 10^{8}}{0.21} = 9.47 \times 10^{-25}$ J	1
9.47×10^{-25} J ÷ 1.6×10^{-19} = $\underline{5.92 \times 10^{-6}\text{ eV}}$	1
	Total 3

This 21 cm wavelength in the hydrogen spectrum is used by radio astronomers to measure the velocities of stars and galaxies.

(e) Describe the difference you would expect to see between a hydrogen spectrum emitted by a galaxy that is not moving toward or away from our galaxy, and a hydrogen spectrum emitted by a galaxy moving away from our own. (2 marks)

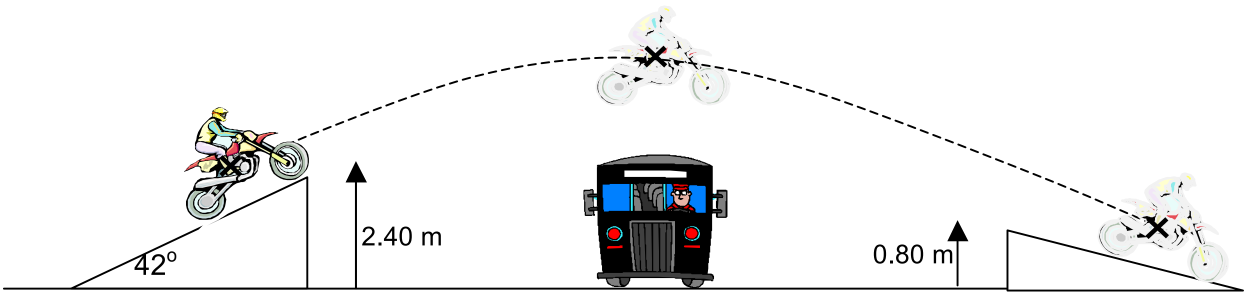
Description	Marks
The entire frequency spectrum would be shifted, on a horizontal axis representing wavelength, toward the right i.e. each line would have a (slightly) increased wavelength.	2
***Note**: To say "red shifted" is too vague for full marks – 1 mark at most*	
	Total 2

(f) How does your answer to (e) provide evidence for the Big Bang model of the formation of the Universe? (3 marks)

Description	Marks
By measuring the shift in wavelengths or frequencies scientists can **measure the speed** of distant galaxies	1
They discovered that the further away a galaxy was, the greater the frequency shift (red shift) so the Universe was **expanding** ***Note**: this mark was missed out by many!*	1
Extrapolating backwards we see that a long time ago (13 billion years) the Universe was very, very much smaller	1
	Total 3

Question 3 **[12 marks]**

Plucky McClintock likes to jump over buses on her trail bike. In an exhibition one day she drives her motorcycle up a ramp, over a bus and lands safely on the ramp at the other side. The left hand ramp has an incline of 42 ° and when she takes off the centre of gravity of her and her machine is 2.4 m above the ground. Her speed at this point is 45 km h^{-1}.



a) What is the vertical component of Plucky's take off velocity? [2 marks]

45 km h^{-1} ÷ 3.6 = 12.5 m s^{-1} u_v = usinΘ = 12.5 sin42 = <u>8.36 m s^{-1}</u>

Note: *Beware units, speed is given in **km h^{-1}**.*

b) What is the maximum height reached by Plucky and her bike (centre of gravity) above the ground? [3 marks]

$v^2 = u^2 + 2as$ $0 = 8.364^2 + 2 \times (-9.8)s$

s = 3.57 m above take-off point [2]

so h = 3.57 + 2.4 = 5.97 m [1]

Plucky and her machine land on another ramp at the other side of the bus, at which point the centre of mass of the combination is 0.80 m above the ground.

c) What is the vertical speed of the motorcycle when Plucky lands? [3 marks]

When she lands **s = 0.8 – 2.4 = -1.6 m**

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

$v^2 = 8.364^2 + 2 \times (-9.8) \times -1.6$

v = <u>-10.1 m s^{-1}</u>

d) Calculate the how far away horizontally the motorcycle is from its take-off position when it lands. [4 marks]

Finding time of flight:

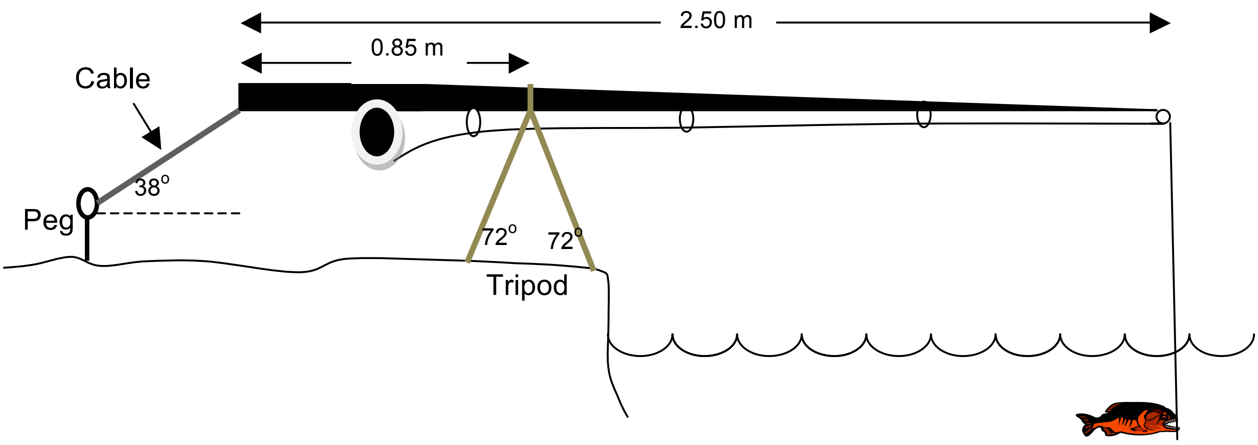
$$v = u + at$$
$$-10.06 = 8.634 - 9.8t$$
$$t = 1.884 \text{ s} \qquad [1]$$

$$u_H = 12.5 \cos 42 = 9.289 \text{ m s}^{-1} \qquad [1]$$

$$s = u_H\, t$$
$$= 9.289 \times 1.88 = \underline{17.5 \text{ m}}. \qquad [2]$$

Question 4 **[13 marks]**

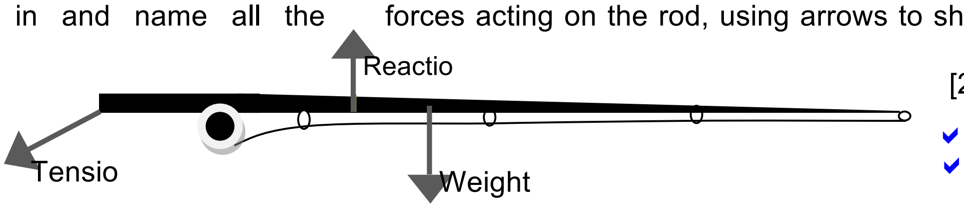
Olivia decides to go fishing one day with her new rod and tripod. She sits on the banks of the Swan river and sets the 900 gram rod up with the tripod close to the bank and a cable at the left hand end anchored into the ground with a tent peg. The centre of mass of the rod is 1.00 m from the left hand end of the rod. She has not caught a fish yet!



a) Explain why Olivia needs to secure the end of the rod with a peg and cable. [2 marks]

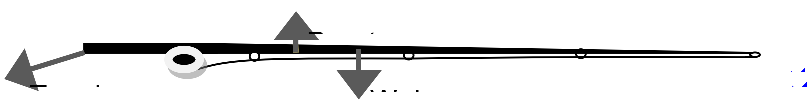
The weight force of the rod exerts a <u>clockwise torque</u> about the tripod as a pivot
So the cable tension must pull downwards to give a <u>balancing anticlockwise torque</u> so the rod doesn't rotate.

b) Draw in and name all the forces acting on the rod, using arrows to show their directions. [2 marks]



Olivia eventually manages to hook a 1.50 kg fish on the end of her line.

c) Calculate the **vertical** force that *cable* has to exert to keep the rod in a horizontal position. [3 marks]



Taking torques, tripod is pivot: $\Sigma\tau_C = \Sigma\tau_{AC}$ $\tau = Fd$

Anticlockwise torque is vertical force from cable on far left; clockwise torques are from weight of rod and from weight of fish

$F_V \times 0.85 = (0.9kg \times 9.80 \times 0.15m) + (1.5kg \times 9.81 \times 0.65m)$

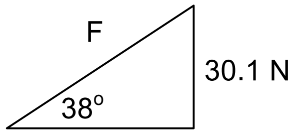
$F_V = \underline{30.1\text{ N}}$

d) If the cable makes an angle of 38° to the ground, calculate the total force of tension needed in the cable when the fish is caught. [2 marks]

From vector triangle

Sin 38 = *30.1* $F_{TENSION}$

$F_{TENSION}$ = 48.9 N



(Follow through, answer (c) ÷ sin38)

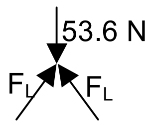
e) If the legs of the tripod make an angle of 72° to the ground, calculate the compressive force in each leg of the tripod when the fish is on the end of the line. [4 marks]

Total force on tripod = F_{Tripod}
Σ Forces $F_{up} = F_{down}$

$F_{Tripod} = F_{cable} + F_{fish} + F_{weight\ rod}$

F_{Tripod} = 30.1 + 14.70 + 8.82

F_{Tripod} = 53.6 N



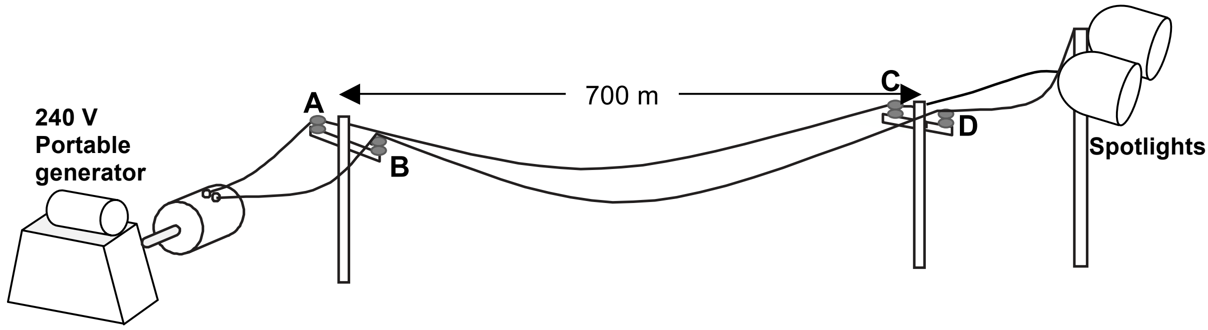
Forces from 2 legs upwards (F_L) equal this force (force diagram)

Components: $2F_L\sin72$ = 53.6 N

<u>F_L= 28.2 N</u>

Question 5 **[9 marks]**

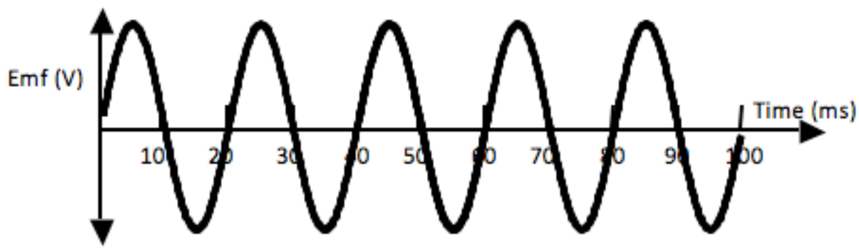
A portable AC generator is hired by an Outback cricket team to power the spotlights needed for a night game. The cable linking the generator to the lights has a length of 700 m and a total resistance of 7.50 Ω. The lights consume an electrical power of 2.40 kW at a frequency of 50.0 Hz and an AC voltage of 240 V when they are operating at full power.



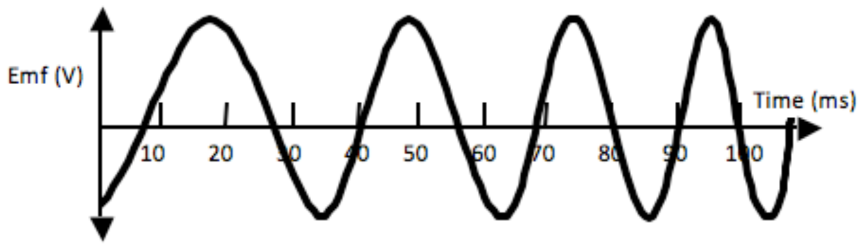
When testing the system a voltmeter is connected across points A and B and the generator started up.

a) Which of the graphs below would display the voltage across points A and B as the generator is starting up and reaching full speed? (circle the correct answer). C [1 mark]

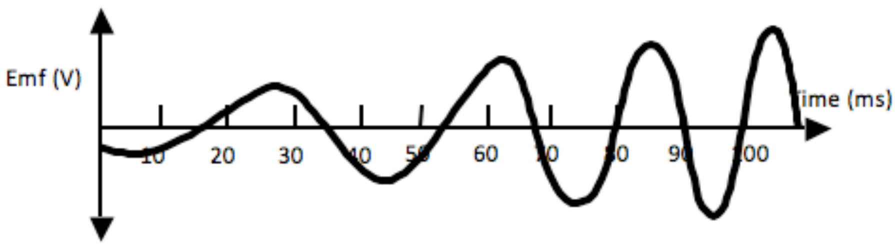
A.



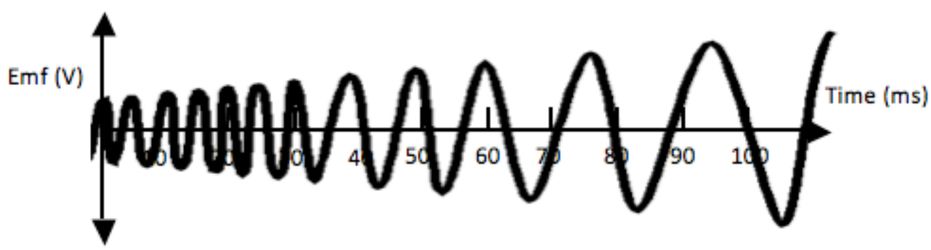
B.



C.



D.



b) When the technicians test the voltage in the powerlines across points C and D they find that the voltage is no longer 240 V. Calculate the voltage delivered to the spotlights at CD. [3 marks]

Power in: P = VI 2400 = 240 I so I = 10 A [1]

Voltage drop across wires = IR = 10 x 7.5 = 75 V [1]

V_{CD} = 240 – 75 = 165 V [1]

Note: *you cannot use V = IR and 240V to calculate current as this assumes there is no voltage drop in wires!*

c) What is the power loss in the wires? [2 marks]

$P_L = I^2R$ $= 10^2 \times 7.5 = 750$ W

When the lights are turned on they appear much dimmer than they should be and the technicians realise that there is a design fault in the system. They remedy this by installing transformers at points AB and CD in the cables.

d) Explain how this modification produces brighter lights at the cricket ground. [3 marks]

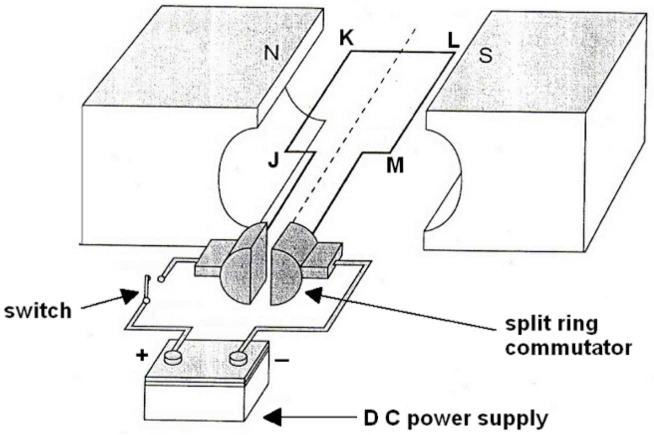
The voltage must be stepped up at AB to a higher voltage by a transformer and then stepped down again to 240 V at CD. [1]

For the same power delivered, if voltage is increased then current can be made smaller. [1]

If current is increased then there will be less power loss in the wires as $P_L = I^2R$. [1]

Question 6 **[12 marks]**

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



(b) In which direction, clockwise or anticlockwise will the motor rotate when the switch is closed? (1 mark)

anticlockwise

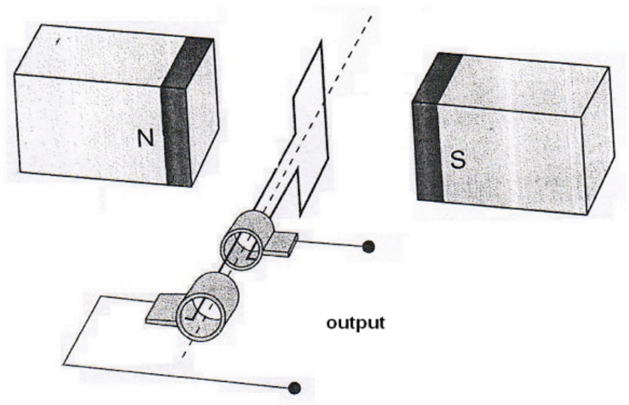
(c) Explain your answer to 3(b). (2 marks)

Using the right hand rule - the forces on the wire are due to the interaction of the field around the coil and the field of the permanent magnet. [1]

the force on the side JK is downwards and the force on side LM is upwards. This will rotate the coil in the anticlockwise direction about the axis. [1]

Note: *Must give indication that there are* ***2*** *forces acting in opposite directions OR a* ***torque*** *for maximum 2 marks*

The figure below represents an ***alternator*** consisting of a rectangular coil with sides of 0.15 m x 0.20 m and 1200 turns, rotating in a magnetic uniform field. The magnetic flux through the coil in the position shown is 2.5×10^{-4} Wb.



(d) Calculate the magnitude of the magnetic field strength. (3 marks)

area of coil (A) = 0.15 x 0.20 = 0.03 m^2

magnetic flux (Φ) = 2.5 x 10^{-4} Wb

Φ = B A

B = Φ / A

2.5 x 10^{-4} = B x 0.03

B = 2.5 x 10^{-4} / 0.03

B = 8.3 x 10^{-3} T

Note: *no need to multiply by number of coils as questions states that the flux is 2.5 x 10^{-4} Wb as shown in diagram, i.e. this is total flux for the 1200 coils.*

(e) If the coil rotates ***half*** a revolution from its starting position in 0.03 s, calculate the magnitude of the average induced emf in the coil in this time. (3 marks)

time for ¼ of a revolution = 0.0.015 s (Φ goes from max to 0 during this time)

magnetic flux Φ = 2.5 x 10^{-4} Wb

number of turns = 1200

emf = -N (Φ - Φ)/t

emf = -1200 (2.5 x 10^{-4} – 0)/0.015

emf = 20 V

Note: *maximum 2 marks if used t = 0.03s*

Maximum 1 mark if used t = 0.06s

Refer to p 133 of textbook for explanation as to why maximum flux change occurs during a ***quarter*** *of a cycle.*

(f) How could you modify the alternator to increase the magnitude of the emf? (3 marks)

Any 3 from:

Increase the magnitude of the magnetic field B of the magnet.

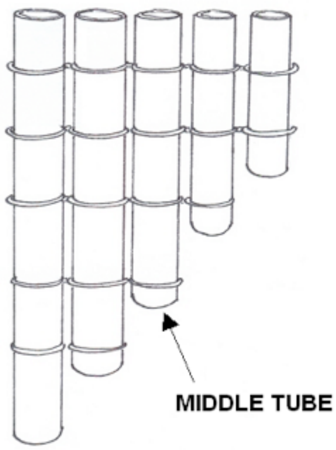
Increase the number of coils.

Increase the speed at which the coil is rotated.

Increase the area of the coil.

Question 7 **[12 marks]**

A crude musical instrument can be made by tying several lengths of hollow metal tube together, as shown in the diagram below. When India gently blows across the tops of the tubes, musical notes are produced.
For all parts of this question assume that India blows with the same strength.



(a) If all the tubes are of equal diameter, which tube would you expect to produce the note with the highest fundamental frequency? Explain your answer. (2 marks)

The tube with the <u>shortest</u> length would produce the highest frequency note. [1]

Explanation [1]: The wavelength of the fundamental note would be smaller in the short tube compared to the others. Using v = f λ, if c is a constant and λ is small then the value of f will be greater.

(b) If the fundamental resonant frequency of the middle tube is 440 Hz and the speed of sound in the tube is 346 m s^{-1}, calculate the length of the tube. (2 marks)

f = 440 Hz
v = 346 m s^{-1}
λ of fundamental frequency in an open tube is 2 times the length of the tube.

v = f λ
λ = 346/440 = 0.786 m [1]

so the length of the tube is ½ of 0.786 = <u>0.39 m</u> [1]

(c) If India blocked the bottom end of the middle tube would you expect it to produce the same fundamental note as the open tube? Explain your answer. (3 marks)

NO. The note would be a different frequency. [1]

By blocking the tube it is now a closed pipe so the wavelength of the note will be altered. In this case the wavelength is 4 times the length of the tube. [1]

Frequency would be <u>lower</u> [1]

(d) Determine the fundamental frequency of the note produced by the middle tube when it is closed at one end. (2 marks)

The note played will have a frequency of ½ the note played when the tube is open. The new frequency in this case would be 220 Hz

***Note**: this is a simple question, part (b) tells you that the fundamental frequency of this tube when open at both ends is 440Hz. You should be able to recognise that blocking one end **halves** the fundamental frequency as the wavelength is doubled.*

(e) The instrument relies upon standing waves being set up in the tubes. State the conditions that need to exist for standing waves to be produced in an air column. (3 marks)

The two waves that superimpose to produce a standing wave must have

equal amplitudes [1]
equal frequencies / wavelength [1]
be travelling in opposite directions [1] (and in the same medium / same speed).

Question 8 **[9 marks]**

A satellite provides information about the receding glaciers on the Earth's surface. It has a mass of 395 kg and is in a circular orbit of radius 1.45×10^4 km. By orbiting for 12 days it can map most of the Earth's glaciers.

a) Calculate the orbital speed of the satellite. (3 marks)

***Note**: it is incorrect to think that the period is 12 days!!!! This is not what you are told, you are told that it takes 12 days to observe the entire planet - therefore this is in low earth orbit! Zero marks for this assumption!*

$r = 1.45 \times 10^4$ km $= 1.45 \times 10^7$ m

Use data sheet to equate centripetal force and gravitational force
$m_s v^2 / r = GM_E m_s / r^2$
re-arrange:
$v^2 = GM_E/r$
$v^2 = (6.67 \times 10^{-11}) \times (5.98 \times 10^{24})/(1.45 \times 10^7)$
$v^2 = 27.508 \times 10^6$
$\underline{v = 5.20 \times 10^3 \text{ m s}^{-1}}$

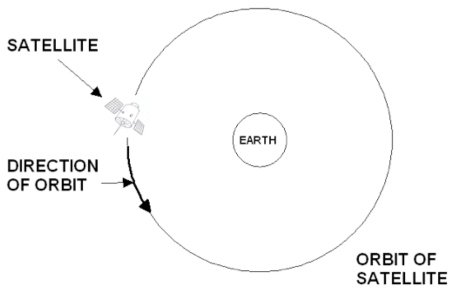
b) At what **altitude** above the Earth is the satellite orbiting? (2 marks)

$r_e = 6.37 \times 10^6$ m
$r_s = 1.45 \times 10^7$ m
altitude $= r_s - r_e$
altitude $= (1.45 \times 10^7) - (6.37 \times 10^6)$
the altitude of the satellite = $\underline{8.13 \times 10^6 \text{ m}}$

c) List the force(s) that keep the satellite in its stable circular orbit. (1 mark)

the centripetal force that acts towards the centre of the orbit provided by the gravitational attraction between the Earth and satellite.

d) On the diagram below draw one or more **labelled** arrows to show the direction of the force(s) on the satellite as it orbits the Earth. (1 mark)



e) Would you expect this satellite to be in a geostationary orbit about the Earth? Explain your answer. (2 marks)

The satellite would not be in a geostationary orbit. [1]
If it was it would remain in orbit above the same location on the Earth and would not be able to map most of the glaciers on Earth. For the mapping to be complete the satellite would be in an orbit other than geostationary. [1]

***Note:** Max 1 mark of implied that orbit time is 12 days!!!*

Section Three: Comprehension & Data Analysis **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 1 **[18 marks]**

Hubble's Law

When a source of waves moves, the waves it emits change frequency relative to a stationary observer. This applies to both transverse and longitudinal (sound) waves. As a car moves away from you the frequency of the sound you hear is lower than the frequency it is emitting. A similar effect using radar waves is used by police to measure the speed of cars.

Thus if a source of electromagnetic waves such as a star is moving away from an observer on Earth then the frequencies of the lines in the star's emitted electromagnetic spectrum are shifted to lower values. This is known as red shift.

In 1920, Edwin Hubble measured the red shifts of several galaxies and discovered that most galaxies are moving away from the Earth, suggesting that the Universe is expanding. Hubble also found that the further away a galaxy is, the larger its red shift; that is, the faster it is moving.

The following data together with the associated errors were recorded by Hubble at Mount Wilson in California in the 1940s using an optical telescope.

Object name	Speed of recession ($\times 10^4$ km s^{-1})	Distance ($\times 10^6$ light years)
Virgo	0.2 ± 0.1	10.2
Corona Borealis	2.4 ± 0.2	400
Hydra	6.2 ± 0.3	1100
Kip	4.8 ± 0.2	900

(a) Graph these data on the graph paper below, including error bars. Plot recession speed (*y*-axis) against distance (*x*-axis) and draw a line of best fit. (5 marks)

Description	Marks
Graph axes labelled correctly	1
Points plotted correctly	2
Error bars include to size	1
Line of best drawn through 0,0	1
-2 marks if axes wrong way round	**Total 5**

b) Use the graph to predict the recession speed of a galaxy that is 710 × 10^6 light years from Earth. Clearly indicate on the graph how you have done this. (2 marks)

Description	Marks
Evidence they have used graph to predict the recession speed	1
Value 4×10^4 km s^{-1}	1
	Total 2

(c) Hubble's Law can be stated as

$$v_{galaxy} = (H_o)(distance)$$

where the term H_o is called Hubble's constant.

Use your graph to calculate a value for H_o. Clearly indicate on the graph how you have done this. Take care with the units! (4 marks)

Description	Marks
Correct calculation of Gradient of graph Clearly shown on graph how gradient calculated H_o= 5.6×10^{-5} km s^{-1} Ly^{-1} Units correct	1 1 1 1
(allow range of answers 4.5 to 6.5 due to line of best fit)	
	Total 4

(d) The shift in wavelength $\Delta\lambda$ due to recession of a spectral line of wavelength λ is given by the formula

$$v_{galaxy} = \left(\frac{\Delta\lambda}{\lambda}\right)c$$ where c is the speed of light, 3×10^8 m s^{-1}.

A line in the spectrum of ionised calcium has wavelength 393.3 nm when measured in the laboratory. When similar light from the elliptical galaxy Carrara is measured its wavelength is 401.8 nm. Determine the recession speed of Carrara. (3 marks)

(3 marks)

Description	Marks
$\text{recession speed} = \frac{(4.108\times10^{-9}) - (3.93\times10^{-9})}{3.93\times10^{-9}} \times 3\times10^{8}$	2
= 6.48×10^6 m s^{-1}	1
	Total 3

Note: *of used 401.8 as λ instead of 393.3, maximum 1 mark*

(e) Edwin Hubble could estimate the age of the Universe from his data by calculating the time for which one of the galaxies has been receding. Determine Hubble's value for the age of the Universe by using the data for Corona Borealis given in the table on page 35 (should have read p30). Take care with the units! (4 marks)

***Note**: most people correctly used table on page 30 to identify values for corona borealis*

Description	Marks
1 light year = $3 \times 10^8 \times 365 \times 60 \times 60 \times 24 = 9.4608 \times 10^{15}$ m	1
$v = s/t$ therefore $t = s \div v$ from table: $s = 400 \times 10^6$ light years $= 400 \times 10^6 \times 9.4608 \times 10^{15}$ m $= 3.78 \times 10^{24}$ m $v = 2.4 \times 10^4$ kms^{-1} $= 2.4 \times 10^7$ ms^{-1} $t = 3.78 \times 10^{24}$ m $\div 2.4 \times 10^7 =$ <u>1.58×10^{17}</u> <u>years</u> ***Note:** common mistakes:* *not multiplying distance by c* *incorrect conversion* kms^{-1} *into* ms^{-1} (÷ by 3.6 is for converting km**h**$^{-1}$ *into* ms^{-1}) *incorrect units for final answer (not seconds as you have calculated distance light travels in 1 year)*	3
	Total 4

Question 2 **[18 marks]**

The Australian Synchrotron

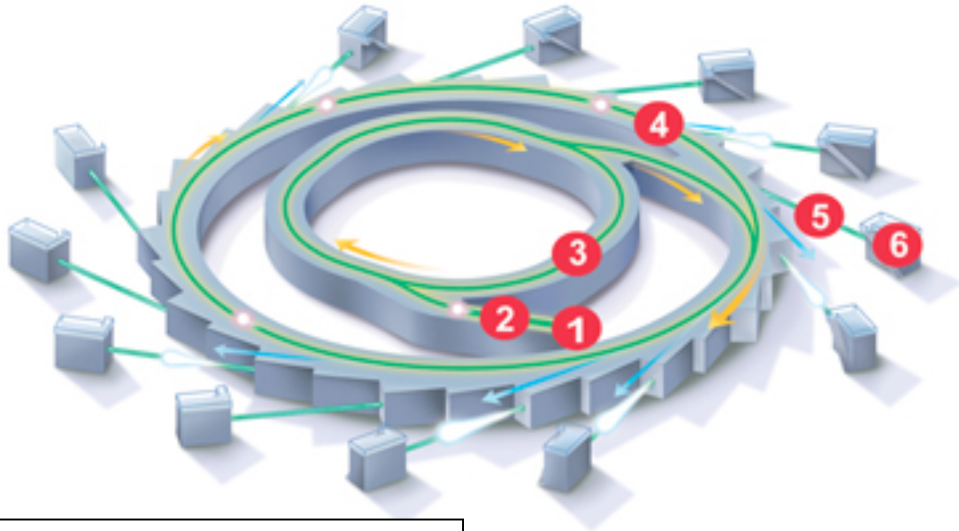


Figure 1

1. electron gun
2. linac
3. booster ring
4. storage ring
5. beamline
6. end station

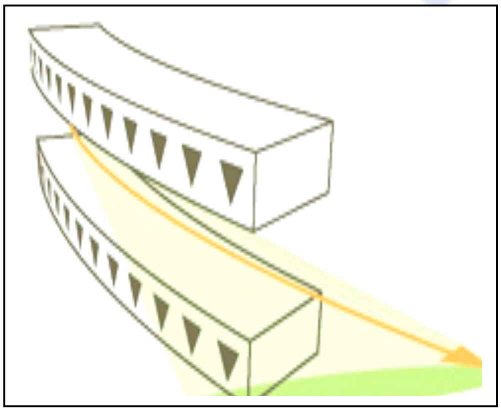


Figure 2

Illustration of a bending magnet. At each deflection of the electron path a beam of light is produced. The effect is similar to the sweeping of a search light.

Synchrotron light is the electromagnetic radiation emitted when electrons, moving at velocities close to the speed of light, are forced to change direction under the action of a magnetic field. The electromagnetic radiation is emitted in a narrow cone in the forward direction, at a tangent to the electron's orbit.

Synchrotron light is unique in its intensity and brilliance and it can be generated across the range of the electromagnetic spectrum: from infrared to x-rays.

Synchrotron light beamline specifications:

Source: 1.9 Tesla wiggler magnet
Available energy range: 4 - 50 keV
Diameter of storage ring: 16 m
Beam size at sample (horizontal x vertical) is 0.5 mm (h) x 0.2 mm (v)
Photon flux at sample > 5×10^{12} photons / second

Features of the synchrotron

- x-ray imaging which allows much greater contrast from weakly absorbing materials such as soft tissue than is possible using conventional methods
- two and three-dimensional imaging at high resolution
- lower tissue doses than conventional x-ray methods, making longitudinal studies (serial imaging) possible
- tuneable beam energy, which enables the imaging of specific elements with very high sensitivity

Examples of uses of the synchrotron:
• Studies of lung function and development are assisting the development of better asthma treatments and improved clinical practice options for neonatal care
• Measurements of bone density and porosity, enhanced mammography techniques, and studies of nerve cell regrowth to assist the development of biopolymers to treat spinal injuries
• The contrast mechanisms used to visualise soft tissues can also be used to study structures inside plants, and are of particular interest for investigating drought- and salt-tolerant plants to develop more efficient crops for Australian conditions

The observation that normal tissue has remarkable resistance to cell death when irradiated with very thin X-ray beams has led to the development of microbeam radiation therapy (MRT). Dr Peter Rogers and colleagues from the Monash Medical Centre and Monash Centre for Synchrotron Science have found that normal tissue tolerates doses up to 100 times greater than those permitted in treatments using conventional methods, and that entire tumours are destroyed when only 10 per cent of their volume has been irradiated. These beams can be captured and focussed to a specific wavelength appropriate for a particular technique.

Questions

a) Draw in the direction of the magnetic field lines in Figure 2. [2 marks]

field direction is up

***Note**: Be careful when using right hand rule for electron to reverse direction of your thumb!!*

b) Assuming that the electrons are accelerated to close to the speed of light, this would take them about 1.4 million times around the outer storage ring in one second. However, in the *frame of reference* of an electron in the ring, it would appear that they had travelled round many more times than this in the same amount of time. Explain this in terms of Einstein's Special Theory of relativity. [3 marks]

According to Einstein's special theory of relativity, the faster an object moves, the slower time passes in the moving frame of reference / Time Dilation [1]

and hence the shorter distances appear as c is constant. [1]

With the distance around the ring seems to be less in a moving frame of reference, hence in one second measured by a moving observer a greater distance can be covered / electron has moved many more times around synchrotron in 1 second. [1]

***Note:** incorrect to say speed increases, c is constant*

c) Why is synchrotron radiation preferable to normal x- or gamma ray therapy in the treatment of cancers? [2 marks]

can use very thin beam widths with higher intensities to target specific areas of tumour / only need to irradiate part of tumour to treat cancer [1]

healthy cells can tolerate huge doses of synchrotron radiation without being destroyed [1]

maximum 1 mark if some reference to less damaging to healthy organ / tissue

d) One of the features of synchrotron radiation is that the location of specific elements can be accurately located within the body. Give an example where this ability could be valuable for use in Forensic Science. [2 marks]

Example: In cases of poisoning [1]
toxic elements (e.g. arsenic) can be shown to be present in the body [1]

Note: *must refer to idea of a specific material / element not an object being detected in body*

e) By equating the 50 keV electrical energy given by the Linac with the kinetic energy, calculate a value for the velocity of the electrons emerging from it. [3 marks]

$E_K = Vq = \frac{1}{2} mv^2 = 50\text{keV}$ **[1]**

So $v = \sqrt{(2 E_K / m)} = \sqrt{(2 \times 50{,}000 \times 1.6 \times 10^{-19} / 9.11 \times 10^{-31})}$ **[1]**

$\underline{v = 1.33 \times 10^{8}\ \text{ms}^{-1}}$ **[1]**

f) The final energy of photons colliding with the target sample is around 4×10^{-14} J. What would the wavelength of the emerging electromagnetic waves be? [3 marks]

$E = h f = hc / \lambda$

re arrange $\lambda = hc / E$

$\lambda = (6.63 \times 10^{-34} \times 3 \times 10^{8}) \div 4 \times 10^{-14}$
$\underline{\lambda = 4.97 \times 10^{-14}\ \text{m}}$

Note**:** *use of answer to (e) instead of c for velocity is incorrect. Relationship* $v = f\lambda$ must use c
to determine *Wavelength / frequency of photons*

g) am size data given, calculate a value for the power absorbed per square metre when 5×10^{12} photons strike the target per second. [3 marks]

Energy emitted per second = no photons x energy per photon (given in f)
$= 5 \times 10^{12} \times 4 \times 10^{-14} = 0.20\ \text{J s}^{-1} = 0.20\ \text{W}$ **[1]**

Area of target = $0.5\ \text{mm} \times 0.2\ \text{mm} = 0.5 \times 10^{-3} \times 0.2 \times 10^{-3} = 1 \times 10^{-7}\ \text{m}^2$ **[1]**

Power per $\text{m}^2 = 0.2\ \text{W} \div 1 \times 10^{-7}\ \text{m}^2 = \underline{2.00 \times 10^{6}\ \text{W m}^{-2}}$ **[1]**

Note**:** *many calculated the number of photons per* m^2*, question clearly asks for power (energy per sec) absorbed per* m^2.

END OF EXAM ☺