CHRIST CHURCH GRAMMAR SCHOOL

YEAR 12

PHYSICS STAGE 3

TRIAL EXAMINATION 2014

Stick Label Here

1		
2		
3		
Total		/ 180 = %

Time allowed for this paper

Reading time before commencing work: ten minutes
Working time for paper: three hours

Materials required/recommended for this paper

To be provided by the supervisor

This Question/Answer Booklet
Formulae and Data Booklet

To be provided by the candidate

Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters

Special items: non-programmable calculators approved for use in the WACE examinations, 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 Answers	12	12	50	54	30%
Section Two: Problem-Solving	6	6	90	90	50%
Section Three: Comprehension	2	2	40	36	20%
				Total	100

Instructions to candidates

1. Write your answers in this Question/Answer Booklet

2. When calculating numerical answers, show your working or reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

   When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.

3. 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.

4. The Formulae and Data booklet is **not** to be handed in with your Question/Answer Booklet.

YEAR 12
PHYSICS STAGE 3
TRIAL EXAMINATION 2014

Section One: Short Response

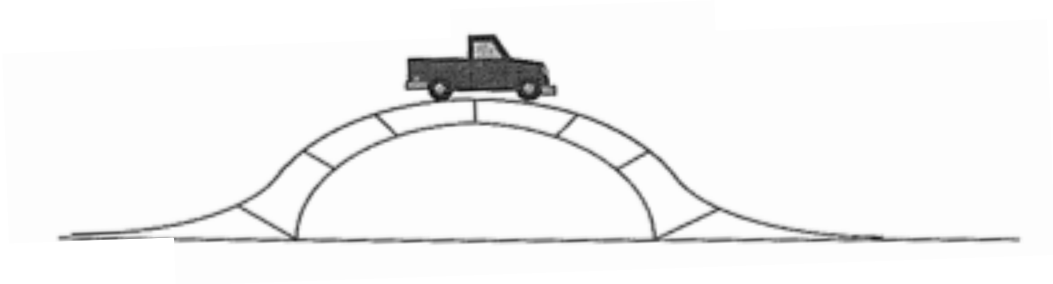
This section has **twelve (12)** questions. Answer **all** questions. Write your answers in the space provided.

Suggested working time for this section is **50 minutes**.

This page has been left blank intentionally

Question 1 **(4 marks)**

A circular bridge, as shown below, has a sign warning motorists that the maximum safe speed to travel over the bridge and not lose contact is 40.0 kmh^{-1}. Calculate the radius of the bridge.



Question 2 **(4 marks)**

A sound technician is varying the frequency of sound waves emitted from a speaker. At a particular frequency he notices that the glass in a nearby tabletop starts to vibrate. Name this phenomenon and explain why the tabletop vibrates.

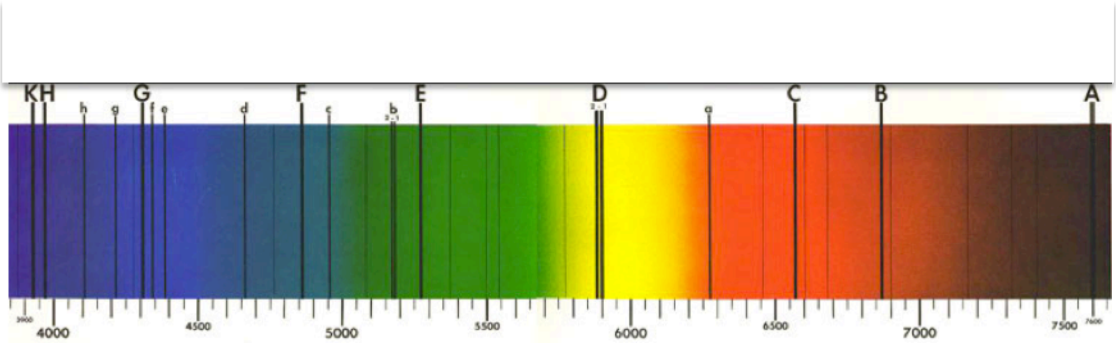
Question 3 **(5 marks)**

A nutcracker, as shown below is a device used to crack open the shells of nuts. The nutcracker is designed to fit comfortably within an average sized hand.

If 40.0 N of force (from each side) is required to crack the shell of a hazelnut, estimate the **minimum total force** that must applied to the nutcracker by the hand. It can be assumed that the same force is exerted on each of the handles and that the force acting on the nut is perpendicular to the handle. State explicitly any estimations you make.

Question 4 **(5 marks)**

The spectra below shows the Fraunhofer lines in the solar spectrum.



(a) Name the type of spectrum above.

(2 marks)

____

(b) Explain how this spectrum is formed making reference to its source (the Sun).

(3 marks)

____

____

____

____

____

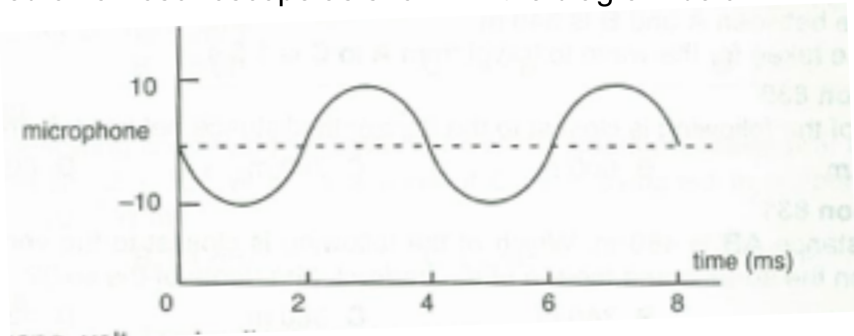
____

____

____

Question 5 **(3 marks)**

A microphone picks up a note played by an organ in a chapel. The signal is displayed on an oscilloscope as shown in the diagram below.



If the speed of sound in the chapel is 345 ms^{-1}, determine the wavelength of the sound wave produced by the organ pipe.

Question 6 **(3 marks)**

A 160 cm long string has two adjacent resonances at 85.0 Hz and 102 Hz.

(a) Calculate the fundamental frequency of the string.

(1 mark)

(b) Calculate the speed of the waves on the string.

(2 marks)

Question 7 **(4 marks)**

In the laboratory, one of the lines in the emission spectrum of sodium is emitted at a wavelength of 590.0 nm. In the light from a particular galaxy, however, this line is seen at a wavelength of 602.0 nm. State the name of this phenomenon and explain how it occurs, making reference to the relative motion of the galaxy to an observer on Earth.

Question 8 **(7 marks)**

An airplane, travelling horizontally, releases a projectile at a height of 730 m and which lands 305 m away from the release point. Calculate,

(a) The time for the projectile to reach the ground.

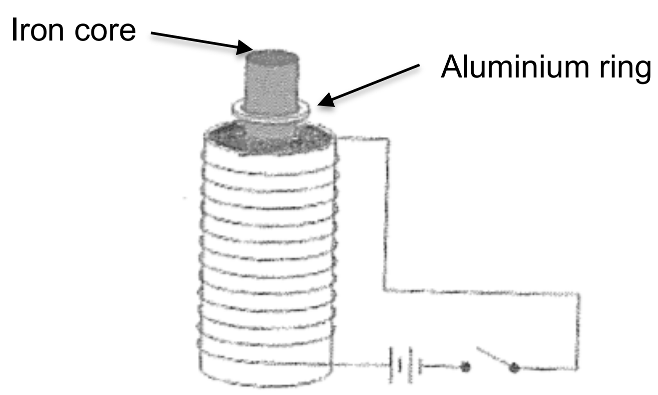
(3 marks)

(b) The initial speed of the projectile in kmh^{-1}.

(4 marks)

Question 9 **(5 marks)**

An aluminium ring is placed around the iron core of a powerful electromagnet. When the circuit is closed, the ring jumps up. Explain why the ring jumps.



Question 10 **(4 marks)**

All hadrons are composed of different combinations of fundamental particles called quarks.

Quark	**Charge**	**Quark**	**Charge**
Up	+2/3 e	Down	-1/3 e
Charm	+2/3 e	Strange	-1/3 e
Top	+2/3 e	Bottom	-1/3 e

In all reactions involving subatomic particles, charge must be conserved. Determine, showing appropriate working, if the equations below can take place by applying conservation of charge.

(a) Ξ (dss) $\rightarrow$ n + π (u$\bar{u}$)

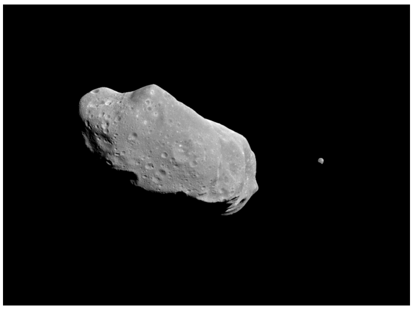
(2 marks)

(b) Ξ (dss) $\rightarrow$ Λ (uds) + π (d$\bar{u}$)

(2 marks)

Question 11 **(5 marks)**

In 1993 the spacecraft *Galileo* sent home an image of asteroid 243 Ida and a tiny orbiting moon, the first confirmed example of an asteroid-moon system. The moon is now known as Dactyl. Ida and Dactyl are shown in the diagram below.



Dactyl, the moon, is 1.50 km wide and 100 km from the centre of the asteroid, which is 55 km long. Assuming the orbit of the moon is circular with a period of 27.0 hours, calculate the mass of the asteroid.

Question 12 **(5 marks)**

A person in a spaceship holds a metre rule. The spaceship travels past the Earth, parallel to an observer on the Earth's surface, at a very high speed. The person on the spaceship rotates the rule from being;

1. parallel to the ship's motion to

2. perpendicular to the ship's motion.

Observations of the **length** of the rule are made by the observer on Earth and by the person on the spaceship.

(a) For scenarios 1 and 2, state what will be seen by the observer on Earth. (2 marks)

(b) For scenarios 1 and 2, state what will be seen by the observer on the spaceship and explain your reasoning.
(3 marks)

End of Section One

This page has been left blank intentionally

YEAR 12
PHYSICS STAGE 3
TRIAL EXAMINATION 2014

Section Two: Problem-Solving

This section has **six (6)** questions. Answer **all** questions. Write your answers in the space provided.

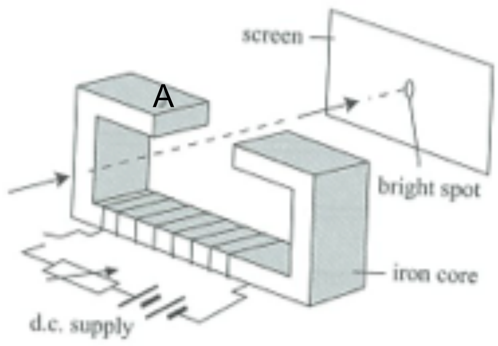
Suggested working time for this section is **90 minutes**.

NAME:____

This page has been left blank intentionally

Question 1 **(16 marks)**

The diagram below shows a beam of protons projected between the poles of an electromagnet. The beam produces a bright spot on a specially treated screen. Assume effects due to gravity are negligible.



(a) State the magnetic pole created at A when the switch is closed.

(1 mark)

(b) Explain how closing the switch creates a magnetic field and the function of the iron core.

(4 marks)

(c) State the direction the spot on the screen will move when the switch is closed.

(1 mark)

____

(d) If a beam of electrons were used instead of the protons, one change that would be noted is that the spot wound be deflected in the opposite direction. State one other change to the position of the spot that would be observed. Explain your reasoning.

(4 marks)

____

____

____

____

____

____

____

The electrons have kinetic energy of 22.5 eV and the magnetic flux density between the poles of the electromagnet is 4.55×10^{-4} T.

(e) Calculate the speed of the electrons.

(3 marks)

(f) Calculate the initial force acting on the electrons as they enter the region between the poles.

(3 marks)

Question 2 **(16 marks)**

An amusement park ride is called the 'Rotor'. It consists of a large hollow cylinder that is rotated rapidly around its central axis.

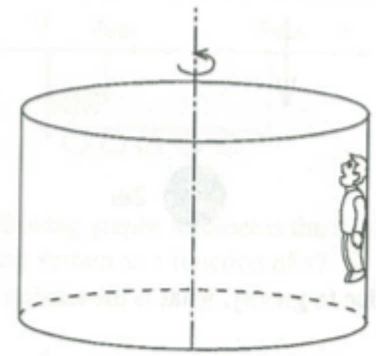
Before the ride begins, the rider enters through a door on the side and stands on the floor against a rough, fabric-covered wall. The door is closed and the ride starts to rotate about its central vertical axis.

At a pre-determined speed the floor drops away, but the rider does not. The rider remains at rest with respect to the wall, as shown in the diagram below – particularly note the upside down people to the left of the diagram.

The radius of the cylinder on the Rotor is 3.00 m.

(a) On the diagram below draw a free-body diagram showing the forces acting on the person when the ride is rotating. Label the forces appropriately.

(3 marks)



(b) Name the force that is providing the centripetal force on the riders in the Rotor.

(1 mark)

The frictional force experienced by the riders is related to the normal force on the riders by;

$$F_f = \mu_s F_N$$

Where μ_s is a measure of the amount of friction between two surfaces. For the rough fabric used; $\mu_s = 0.4$

(c) If the riders must remain at rest against the wall, show that the normal force must equal;

(2 marks)

$$F_N = \frac{mg}{\mu_s}$$

(d) Calculate the minimum rotation speed of the Rotor if the riders are to remain at rest against the wall.

(4 marks)

(e) Calculate the period of revolution of the Rotor.

(2 marks)

(f) If the side of the cylinder were not covered in a rough fabric but instead there was just a smooth wall, for the riders to stay at rest relative to the wall, will the speed of the Rotor need to; (Circle your chosen answer)

(i) increase

(ii) decrease

(iii) stay the same

(1 mark)

(g) Explain your reasoning for your selection in (f).

(3 marks)

Question 3 **(13 marks)**

A power station produces power at 2500 kW and steps it up (using an ideal transformer) to 8.50 kV to be distributed across power lines to houses.

An ideal transformer on a power pole (connected to the power lines from the power station) then supplies power to a house at 240 V.

(a) State the type of transformer used to provide power to the house from the power lines and determine the turns ratio of the transformer. It can be assumed that there is no power loss in the lines.

(3 marks)

Real power lines will always have a resistance to the flow of current. The power lines above are 20.0 km in length (total) and have a resistance of 0.0300 Ωkm^{-1}

(b) Calculate the voltage drop across the power lines.

(3 marks)

(c) Calculate the useable voltage at the house.

(2 marks)

(d) If the average rate of energy consumption in the house is 7.80 kW, calculate the current in the secondary coil of the transformer.

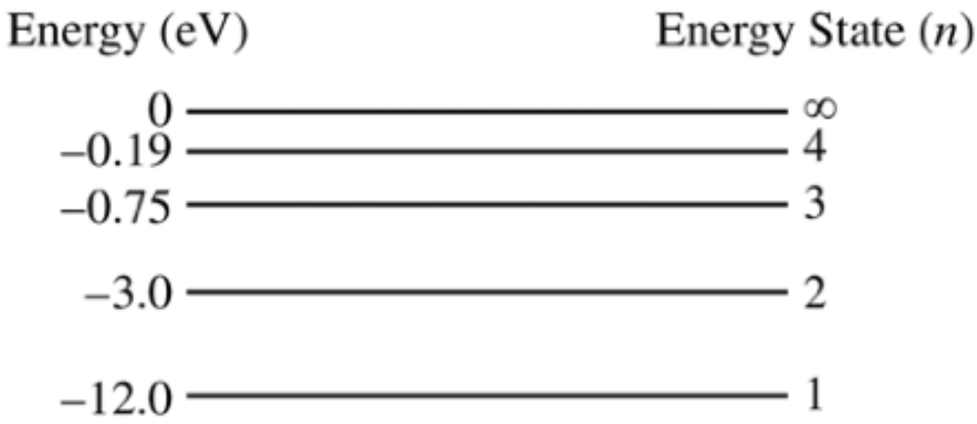
(2 marks)

(e) Explain why power is transmitted at very high voltages.

(3 marks)

Question 4 **(15 marks)**

An energy level diagram is shown for an atom below.



(a) An atom with an electron in the n=4 state can only undergo transitions in which the atom emits photons. The electron eventually ends in the ground state. Use arrows on the diagram above to show the transitions that produce all possible energies of photons in decay from this level.

(2 marks)

(b) Calculate the longest wavelength of photon that the atom can emit during the transitions identified in (a).

(3 marks)

(c) What is the ionisation energy of the atom (for electrons in the ground state)?

(1 mark)

(d) Photons of energy 11.0 eV and 14.0 eV are incident on the atom. For each of these incident photons describe the outcome for the atom.

(4 marks)

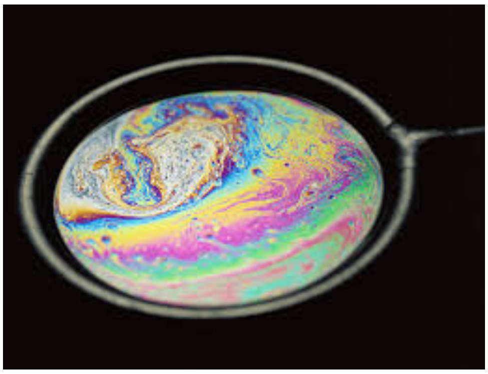
The emergency exit signs above doorways, as shown below, are often painted with a phosphorescent paint, so they will remain visible even if there is a power failure.

(e) Explain, with the aid of a suitable diagram, how the phenomenon of phosphorescence works and enables the sign to remain illuminated.

(5 marks)

Question 5 **(16 marks)**

Interference effects are commonly observed in thin films, such as a thin layer of oil on water or in soap bubbles, as shown in the diagrams below. The colours that are observed from white light are from the interference of waves reflected from the opposite surfaces of the film.



To determine whether the reflected rays interfere constructively or destructively a number of conditions need to be considered.

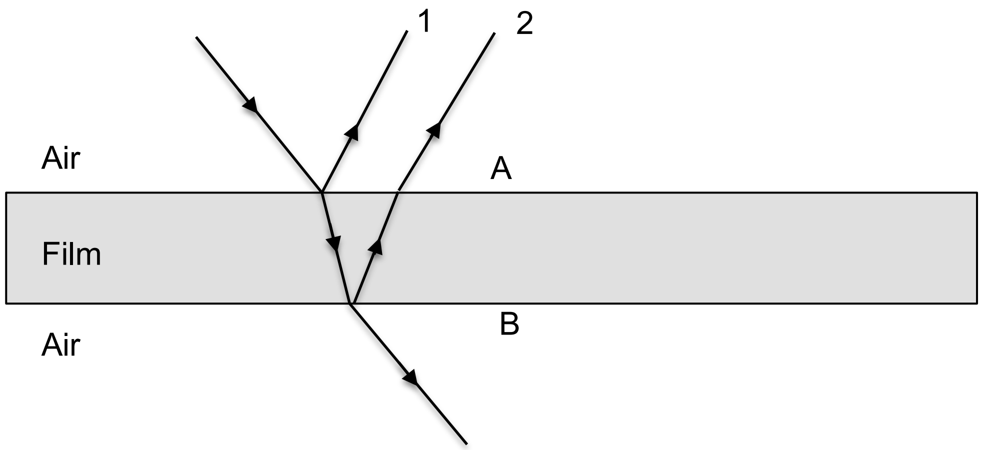
1. A wave travelling in a medium of low refractive index undergoes a 180° phase change upon reflection from a medium of higher refractive index.

2. There is no phase change in the reflected wave if it reflects from a medium of lower refractive index.

3. The wavelength of light in a medium whose refractive index is *n* (the index of refraction of a substance is the ratio of the speed of light in air/vacuum to the speed of light in the substance) is λ_n is given by;

$$\lambda_n = \frac{\lambda}{n}$$

A film of oil of thickness '*t'* and refractive index *n* is surrounded by air as shown below. The incident ray of light undergoes both reflection and refraction at the boundaries between the oil and the air.



(a) Based on the conditions given on the previous page, what will be the phase change for ray 1 and for ray 2?

(2 marks)

Ray 1: ____________________________

Ray 2: ____________________________

(b) If the passage of ray 2 through the film is neglected, what type of interference would occur between ray 1 and ray 2 at surface A?

(1 mark)

____

The passage of ray 2 through the film must be considered, however, as otherwise no interference patterns could occur. If it can be assumed that the ray strikes perpendicular to the surface of the film – i.e there is no bending of the light rays as they pass though surface A or B,

(c) What distance (in terms of *t*) would ray 2 travel extra to ray 1?

(1 mark)

(d) For constructive interference to occur between ray 1 and ray 2, what must λ_n be equal to in terms of *t*?

(2 marks)

Soap bubble film with n = 1.26 is produced in the air. The soap bubble film is illuminated with orange light of wavelength 600 nm.

(e) Calculate the minimum thickness of a soap bubble film that will result in constructive interference in the reflected light.

(2 marks)

(f) Calculate the next thickness of soap bubble film that will also produce constructive interference.

(2 marks)

(g) Calculate the minimum thickness (>0 m) of soap bubble film that will produce destructive interference.

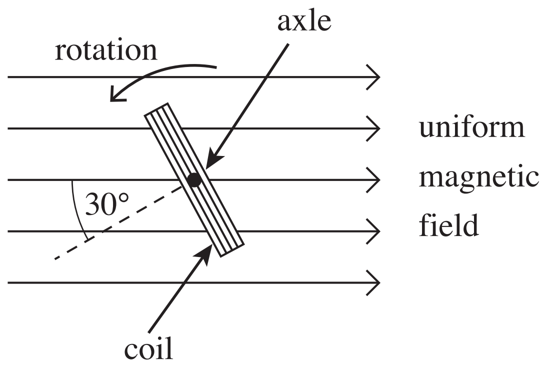
(2 marks)

(h) Explain why the coloured interference patterns as seen on Page 30 are observed when white light is shone on thin film of oil or soap.

(4 marks)

Question 6 **(14 marks)**

A rectangular coil is rotating anticlockwise at constant speed with its axle at right angles to a uniform magnetic field. The diagram below shows an end-on view of the coil at a particular instant.



At the instant shown in the diagram, the angle between the normal to the plane of the coil and the direction of the magnetic field is 30°.

(a) State the minimum angle through which the coil must rotate from its position in the diagram for the emf induced in the coil to reach its maximum value.

(1 mark)

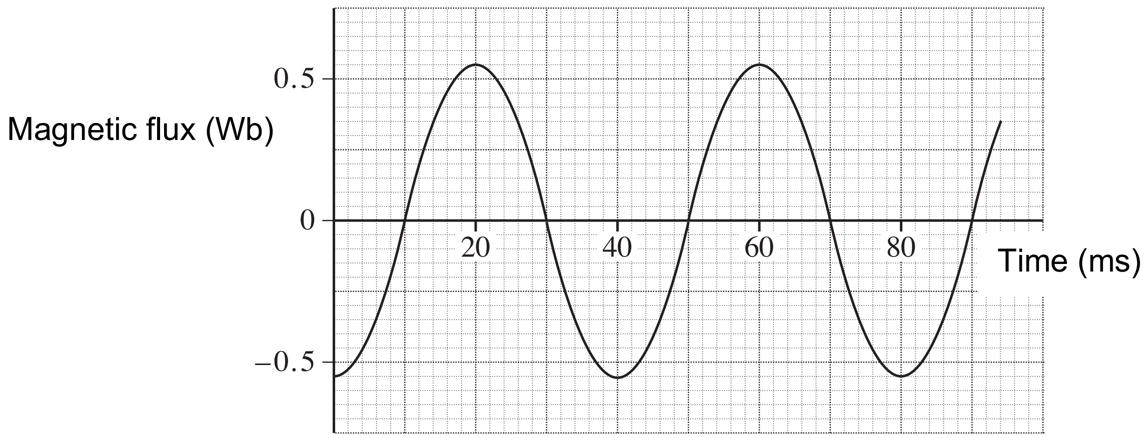
____

(b) Calculate the minimum angle through which the coil must rotate from its position in the diagram for the magnetic flux through the coil to reach its maximum value.

(1 mark)

____

The graph below shows how, starting in a different position, the magnetic flux through the coil varies with time.



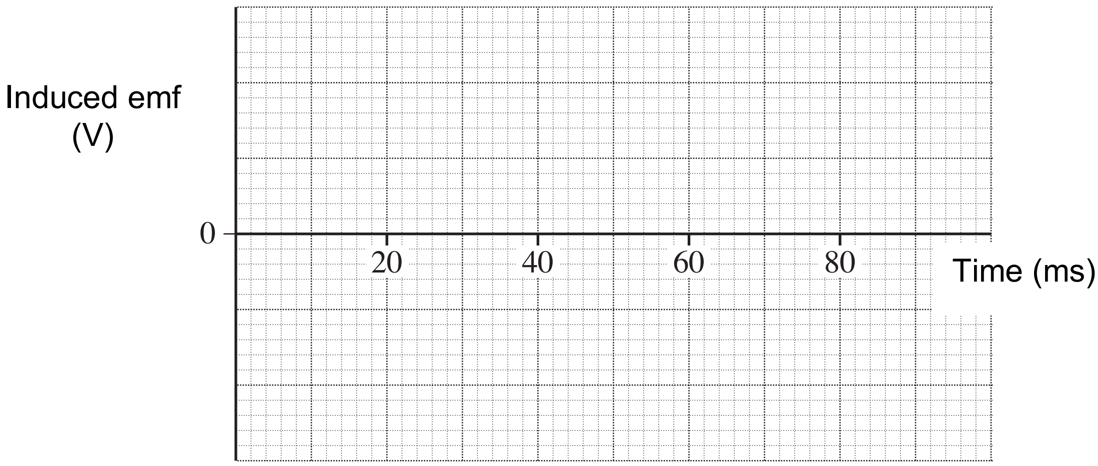
(c) What physical quantity is represented by the gradient of the graph?
(1 mark)

(d) Calculate the number of revolutions per minute made by the coil.
(2 marks)

(e) Using the graph calculate the peak value of the emf generated.
(3 marks)

(f) Sketch a graph on the axes shown below to show how the induced emf varies with time over the time interval shown in the first graph.

(3 marks)



The coil has 550 turns and a cross-sectional area of 4.00×10^{-3} m^2.

(g) Using any information required from the graphs, calculate the magnetic flux density of the uniform magnetic field.

(3 marks)

End of Section Two

YEAR 12
PHYSICS STAGE 3
TRIAL EXAMINATION 2014

Section Three: Comprehension

This section has **two (2)** questions. Answer **all** questions. Write your answers in the space provided.

Suggested working time for this section is **40 minutes**.

NAME:____

Question 1 **(22 marks)**

The Bohr model of the atom was successful in describing the spectra of atomic hydrogen and hydrogen-like ions. One of the basic assumptions of the model was that the electron could only exist in discrete orbits. If circular orbits are assumed then the energies of the levels for hydrogen can be calculated (in electron-volts) using the formula;

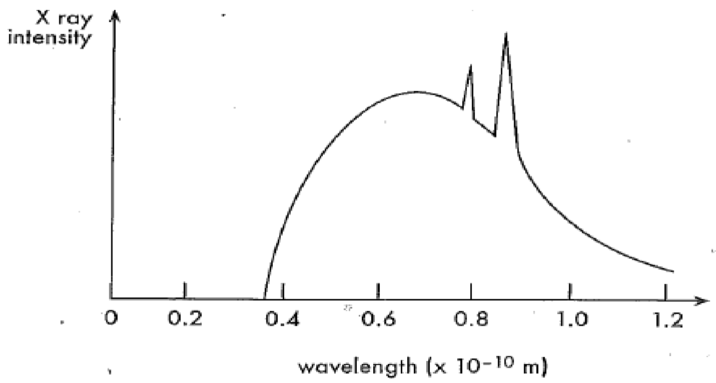
$$E_n = -\frac{13.6\,Z^2}{n^2} \qquad \text{-①}$$

where Z is the atomic number of the atom (i.e. the number of protons in the nucleus).

Atoms are filled from their inner shell outwards i.e n=1 is filled with electrons first then n=2, n=3 etc. This will mean there can be significant changes in the number of electrons that are found in the outer shell of atoms with consecutive values of Z. It is these outermost electrons that take place in optical transitions – i.e. those that produce emission spectra. It is observed that the spectra that occur in the optical range undergo abrupt changes in the frequencies and wavelengths of the emission lines from element to element.

In the characteristic lines of X-ray spectra, however, the frequencies and wavelengths of the lines vary smoothly from element to element. This is because the binding energies (the amount of energy required to bind the electron to the atom) of the innermost electrons does not vary as much as it does for the outermost electrons as the value of Z increases.

X-rays are emitted when a metal target is bombarded by high-energy electrons. The X-ray spectrum consists of a broad continuous band and a series of sharp lines (characteristic lines) that are dependent on the type of material used for the target. A typical X-ray spectrum is shown below.



(a) Explain, with the aid of a diagram, how the characteristic peaks in the X-ray spectrum are formed.

(5 marks)

(b) Explain why the frequencies and wavelengths of the characteristic peaks of the X-ray spectrum are less likely to change abruptly unlike those of the optical spectrum.

(2 marks)

The presence of the characteristic lines was discovered in 1908 but their origin remained unexplained until the details of atomic structure were developed.

In 1914, Henry G.J. Moseley took the basic energy relationship (equation ①) and found a relationship between the Z value of an atom and the wavelength of its K_α line. In doing this he showed there was a correlation between the nuclear charge of an atom and its ordering in the periodic table of the elements. He also used this information to show that there were gaps in the periodic table at Z = 43, 61, 72 and 73 – elements for which have since been discovered. Moseley's contributions were brought to a halt by his service in World War I, from which he did not return.

(c) Rewrite equation ①, ignoring the negative sign, to show that the relationship between Z and wavelength is given by;

$$\sqrt{\frac{hc}{\lambda}} = 3.69Z$$

As the K_α line is being used, n =1.

(2 marks)

(d) If a graph of ' _____' vs Z is to yield a straight line, what should be plotted against Z?

(1 mark)

(e) Process the data in the table below to allow you to plot the graph from (d).

(2 marks)

Z	λ (nm)	
20	0.3366	
21	0.3038	
22	0.2755	
30	0.1445	
35	0.1051	
42	0.07227	

(f) Plot the graph from (d)

(5 marks)

(g) Calculate the gradient of the graph, show your working below.

(3 marks)

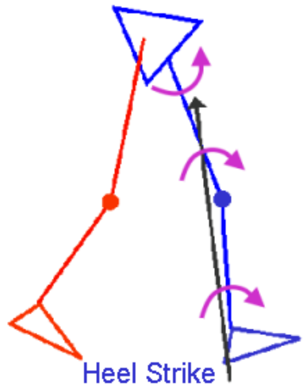
(h) Use the gradient of your graph to determine the wavelength of the K_{α} line for Technetium, Z = 43.

(2 marks)

Question 2 **(14 marks)**

Why do we swing our arms when we walk?

The basic process of walking has been understood for some time. At each step, we vault over the standing leg, our bodies moving like an inverted pendulum with the stationary foot as the pivot. The stationary foot is the one that is undergoing heel strike, as shown in the diagram below. The blue foot is the stationary foot and the red leg is swinging through.



The amount of energy input required to move is minimised because there is a continual interconversion of kinetic and gravitational potential energy; we slow down as the body rises at the middle of each step and then speed up again as the body falls towards the end of the step. A small amount of energy is lost through sound and heat when we put each foot down on the ground, but basically we carry on moving more or less continuously, requiring only a small push-off from our feet to keep going.

When the foot strikes the ground, the ground exerts an equal in magnitude but opposite in direction reaction force on the foot.

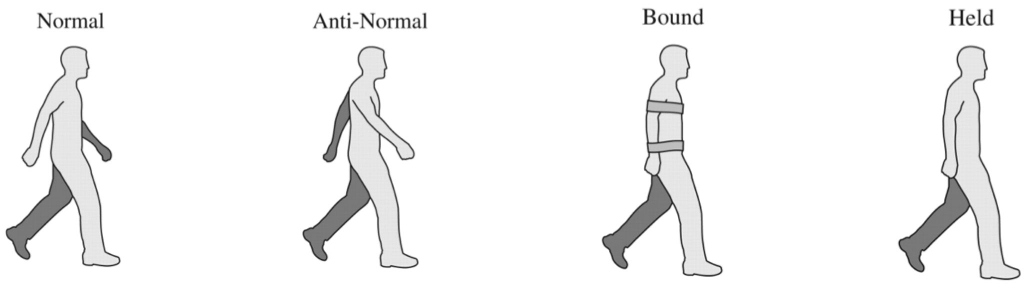
(a) In the diagram below draw in the direction of the force on the foot for each of the three positions – heel strike, flat foot and toe strike.

(3 marks)

When walking, humans tend to swing their arms, a movement which plays no obvious role in the bipedal (two-legged) gait. The muscles exert some amount of effort to swing the arms but it is unclear whether potential benefits elsewhere in the body during walking would justify such energy costs.

A research group in 2009 developed an experiment to examine the costs and benefits of arm swinging. The experiment consisted of two sections, the first used a dynamic walking model and the second, human trials.

In the study different types of arm swinging were compared with normal arm motion, as described and shown in the diagram below.



Normal Arm Motion
Also referred to as Normal. In normal arm motion, the opposite arm to the forward foot is swung to the front.

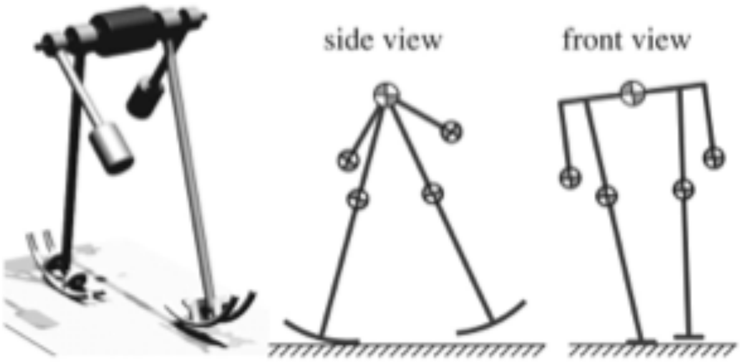
Anti-Normal Motion
In anti-normal motion, the same arm as the forward foot is swung to the front.

Bound
The arms are bound against the body using a bandage. The arms are not free to move.

Held
The arms are held by the walker against their side. The onus is on the walker to prevent their arms from moving.

1. The Dynamic Walking Model

The passive dynamic model, as shown in the diagram below, consisted of two curved feet, two straight legs, a pelvis and two free-swinging arms. Mass properties of the limbs were based on human measurements with each arm comprising 4% of body weight, each leg 16% of body weight and the pelvis/trunk 60% of body weight.



The dynamic walking model was powered by descending a gentle slope. The stance foot rolled along the ground which, because it was sloped, provided the model with a small amount of energy (from gravitational potential energy) during the single-support phase of each step, which balanced the energy that was dissipated in the collision during each step-to-step phase.

(b) Explain why it was necessary for the dynamic model to move down a slope if it were to be able to continue walking.

(2 marks)

The ground reaction moment was measured for the dynamic walking model for three different modes of walking; normal, anti-normal and bound. The ground reaction moment is the torque on the body, due to the push of the foot off the ground. A certain amount of torque is required to swing the body forward, but this does not all need to be provided by the ground reaction moment.

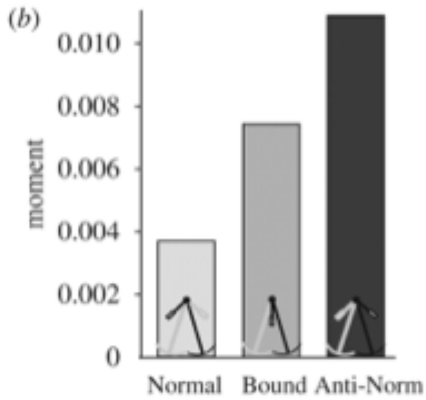
(c) Describe the relationship between the magnitude of the force applied on the foot and the ground reaction moment.

(1 mark)

(d) Why wouldn't it be advantageous for the human body if there is a large force on the foot?

(2 marks)

The graph below shows the peak ground reaction moment for the dynamic walking model in the three different modes



(e) Which mode of arm swing provides the greatest benefit for walking?

(1 mark)

____

(f) Give a reason for why this mode would provide the greatest benefit for walking.

(2 marks)

____

____

____

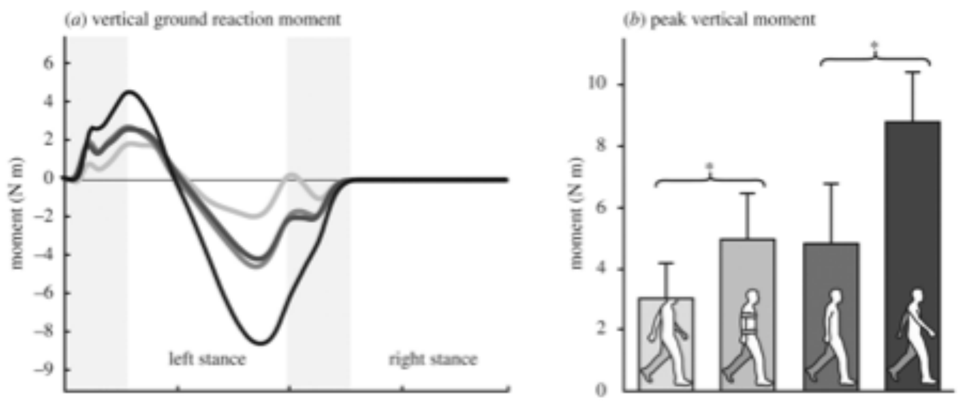
____

____

____

2. Human Trials

The results for the four modes of walking in human trials are shown below.



(g) Using the bar graph, calculate the percentage difference between the moments in the normal and anti-normal mode.

(2 marks)

(h) Explain why the held trial may have a slightly smaller ground reaction moment than the bound trial.

(1 mark)

End of Section Three

This page has been left blank intentionally