Government of Western Australia
School Curriculum and Standards Authority

Western Australian Certificate of Education Examination, 2015

Question/Answer Booklet

PHYSICS

Stage 3

Place one of your candidate identification labels in this box.
Ensure the label is straight and within the lines of this box.

Student Number: In figures

In words

Time allowed for this paper

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

Number of additional answer booklets used (if applicable):

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.

Ref: 15-113

PHY3

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	11	11	50	56	30
Section Two: Problem-solving	7	7	90	88	50
Section Three: Comprehension	2	2	40	35	20
				Total	100

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2015*. Sitting this examination implies that you agree to abide by these rules.

2. Write your answers in this Question/Answer Booklet.

3. 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.

4. 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.

5. 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 that you are continuing to answer at the top of the page.

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

Section One: Short response **30% (56 Marks)**

This section has **11** questions. Answer **all** questions.

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

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Suggested working time: 50 minutes.

Question 1 **(2 marks)**

A child on a playground swing swings higher and higher as a friend pushes.

Circle the correct answers.

The swing is undergoing

free oscillation.	forced oscillation.	natural oscillation.

The swing's behaviour is best described as

resonance.	a standing wave.	an antinode.

Question 2 **(3 marks)**

The Milky Way galaxy (our galaxy) and the Andromeda galaxy are approximately 250 000 light years apart, and they are approaching each other at a rate of 110 km s^{-1}. Scientists know this because of the blue-shift of light coming from the Andromeda galaxy.

Read the following statements and circle 'True' or 'False'.

Light reaching the Milky Way from the Andromeda galaxy arrives slightly faster than 3×10^8 m s^{-1}.	True	False
Light reaching the Andromeda galaxy from the Milky Way galaxy would be red-shifted.	True	False
The Andromeda galaxy must be on a collision course with the Milky Way galaxy.	True	False

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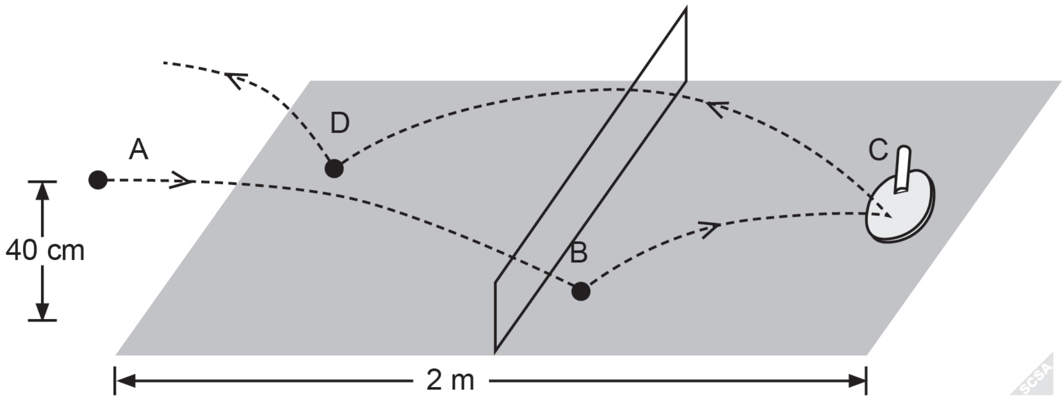
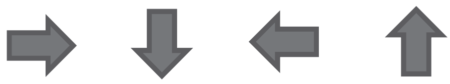
Question 3 **(6 marks)**



Two students are playing a game of ping-pong (table tennis). The ball is served and begins its path from Point ‘A’, which is 40 cm above the level of the table. The trajectory then taken by the ball is also shown on the diagram above.

Each player hits the ball and gives it the same speed. Ignore any effect of friction or resistance between the table and the ball and air when answering the questions below.

(a) Consider the instantaneous motion of the ball **at the moment** that it has maximum contact with the table at Point ‘B’. By circling the appropriate arrows, indicate the direction of its

- velocity. 
- net acceleration. 
- net force.  (3 marks)

(b) At which point (‘A’ or ‘C’) does the ball experience the greater acceleration? Justify your answer. (3 marks)

Question 4 **(4 marks)**

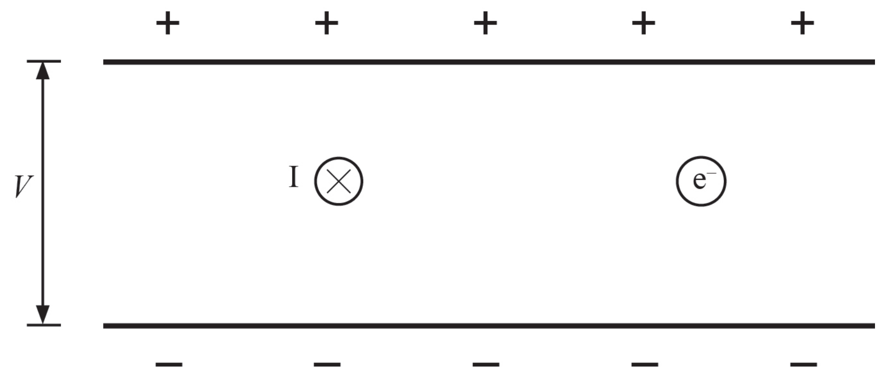
A car wheel is held in place by four nuts. Each nut was put on by a machine that tightened it with a torque of 3.00×10^2 N m.

The photograph below shows the 30.0 cm long horizontal lever that is used to remove the nuts from the wheel.

Assuming that it also takes 3.00×10^2 N m to undo the nut, show (by calculation) that if a person of 90.0 kg stands on the end of the lever without bouncing, the weight is **not** enough to turn the wheel nut.

Question 5 **(6 marks)**

In the diagram below, I indicates a wire carrying a direct current (DC) into the page. There is also a pair of parallel electrostatically charged plates. The voltage across the parallel plates is V. An electron, e^-, is fired into the set-up, travelling into the page as shown below. The ratio of electric force (F_e) to magnetic force (F_m) exerted on the electron is 0.6, i.e. $\frac{F_e}{F_m} = 0.6$. Ignore the effect of the Earth's magnetic and gravitational fields.

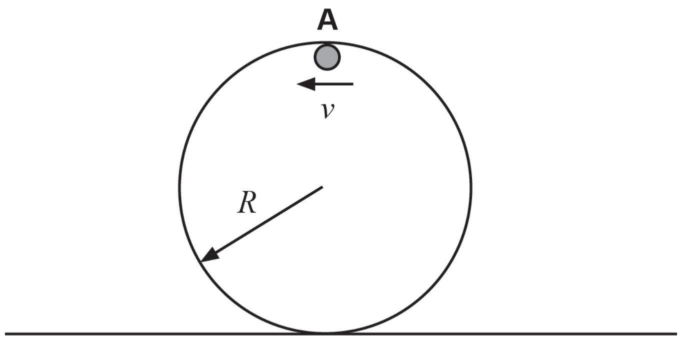


Sketch and label in the diagram above the relative magnitudes and directions of the:

- magnetic force on the electron (F_m)
- electric force (F_e) on the electron
- resultant force acting on the electron.

Question 6 **(5 marks)**

A ball of mass 1.50×10^{-2} kg rolls along a rail that includes a vertical loop of radius R = 0.500 m as shown. There is negligible friction.



At Point A the ball is **just** in contact with the rail. Draw a free body diagram of the ball when it is at Point A, and calculate the minimum velocity, v, required to keep it in contact with the rail at this point. Show **all** workings.

Free body diagram:

Calculation:

Question 7 **(7 marks)**

In order to drop a parcel, an aircraft flying horizontally 150 m above sea level with a speed of 216 km h^{-1} approaches from behind a surfaced submarine that is moving in the same direction. The speed of the surfaced submarine is 36.0 km h^{-1} and its deck is just at sea level. Ignore air resistance.

Calculate the time taken for the parcel to drop from the aircraft onto the surfaced submarine, and hence determine the horizontal distance from the submarine at which the aircraft must be when it releases the parcel. Show **all** workings.

Question 8 **(7 marks)**

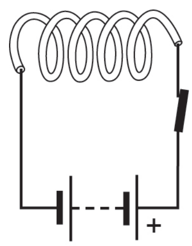
Maxine placed two speakers 12.0 m apart and facing one another. She connected them both to a sound generator, set it to 86.5 Hz, and turned it on. Then she walked at a steady speed of 0.800 m s^{-1} in a straight line from one speaker to the other.

Determine how many maximum loudness locations she walked through, and hence calculate the time it took for Maxine to walk from one maximum loudness point to the next.

Question 9 **(5 marks)**

A physics student sets up an electrical circuit that includes a small toy called a 'slinky', which is essentially a light, coiled metal spring. When the switch is closed and a current is passed through the coil from a small DC battery, the student discovers that a magnetic field exists around the slinky.

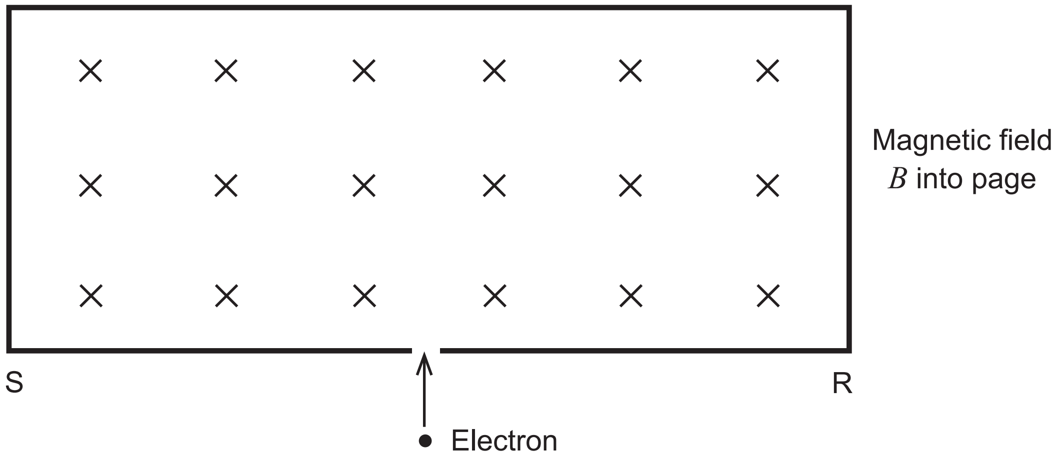
(a) On the diagram below, sketch the shape and direction of the magnetic field that will exist around the slinky when the switch is closed. (4 marks)



(b) The student also notices that at the moment that the switch is closed, there is a small movement in the slinky. Describe this movement. (1 mark)

Question 10 **(4 marks)**

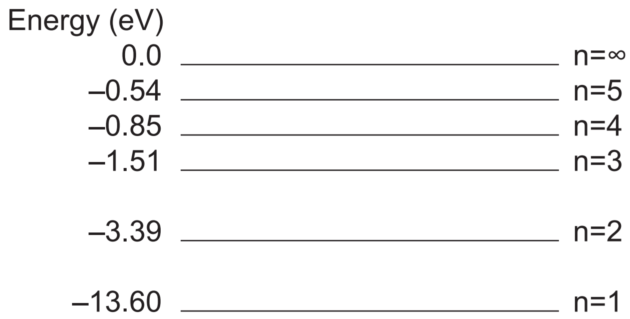
An electron travelling at 1.26×10^7 m s^{-1} entered a uniform magnetic field of intensity 1.50×10^{-3} T at right angles to the field lines, as shown in the diagram.



An electron detector located along the line SR recorded an interaction with the electron. Calculate the distance between the entry point and the detector.

Question 11 **(7 marks)**

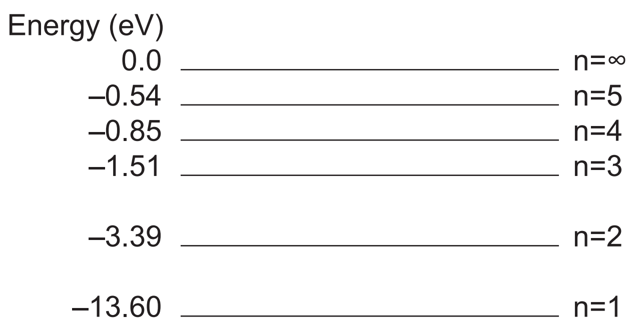
The first five energy levels (not to scale) of a hydrogen atom are shown in the figure below.



(a) Calculate the highest and lowest frequency photons that an excited electron in the n=5 level within a hydrogen atom can emit. Show **all** workings. (4 marks)

Highest: ____________________ Hz Lowest: ____________________ Hz

(b) In the diagram below, indicate the possible pathways by which an electron at energy level n=3 can return to ground state. (3 marks)



End of Section One

Section Two: Problem-solving **50% (88 Marks)**

This section has **seven (7)** questions. Answer **all** questions. Write your answers in the spaces provided.

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

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Suggested working time: 90 minutes.

Question 12 **(12 marks)**

An exoplanet is a planet that revolves around a star that is not our Sun. As one such exoplanet revolves around a distant star, it causes the star to oscillate, or wobble, in its path as the star and the exoplanet orbit their common centre of mass.

In the following calculations, assume that the centre of the exoplanet's orbit coincides with the star's centre of mass, and that the orbit is circular.

Some details of the star and the exoplanet are shown below:

Mass of star	$M_s = 2.15 \times 10^{30}$ kg
Mass of exoplanet	$M_p = 1.95 \times 10^{27}$ kg
Distance between centre of planet and centre of star	$d_{sp} = 7.50 \times 10^9$ m.

(a) Show that the magnitude of the gravitational force acting on the exoplanet is 4.97×10^{27} N. (3 marks)

(b) Calculate the exoplanet's orbital velocity. Show **all** workings. (3 marks)

(c) Calculate the exoplanet's orbital period, and express your answer in hours. Show **all** workings. (3 marks)

(d) About 20% of exoplanets discovered so far have a period of 120 hours or less. Explain briefly how red shift and blue shift can be used to identify which stars have such exoplanets. (3 marks)

Question 13 **(12 marks)**

A mobile phone, of resistance 4.00 Ω was connected to a charger (actually a small step-down transformer). The details of the charger are shown below.

Assume the charger to be 100% efficient.

PRIMARY COIL
Input voltage: 240 V AC 50 Hz
Turns: 432
Power: 6.25 W

SECONDARY COIL
Output voltage 5.00 V AC 50 Hz
Turns: 9

The 5.00 V AC output of the charger was rectified to 5.00 V DC before charging the battery in the phone.

(a) State the power output of the secondary coil of the charger. ______________ W (1 mark)

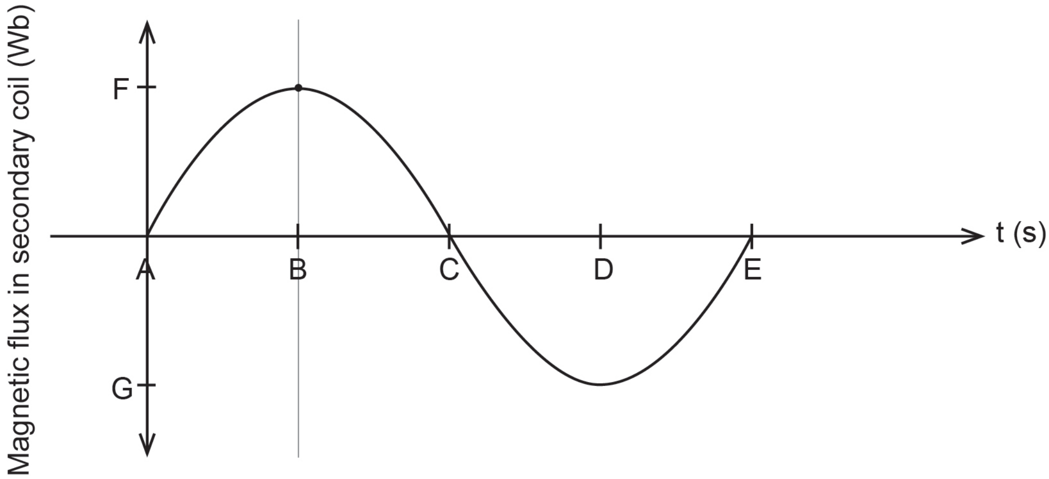
(b) Calculate the current flowing through the secondary coil while the battery was charging. Show **all** workings. (2 marks)

(c) When the mobile phone is charging, 5.00 V DC is used to charge the battery.

(i) State the number of joules carried by each coulomb of charge. (1 mark)

(ii) Calculate the amount of energy, in joules, carried by each electron as it charges the battery. Show **all** workings. (3 marks)

(d) The graph below shows the change in flux experienced by the secondary coil over one complete cycle.



By calculating any required values, and showing **all** workings, determine the magnitudes of the

(i) time interval AE: ______________________ s. (1 mark)

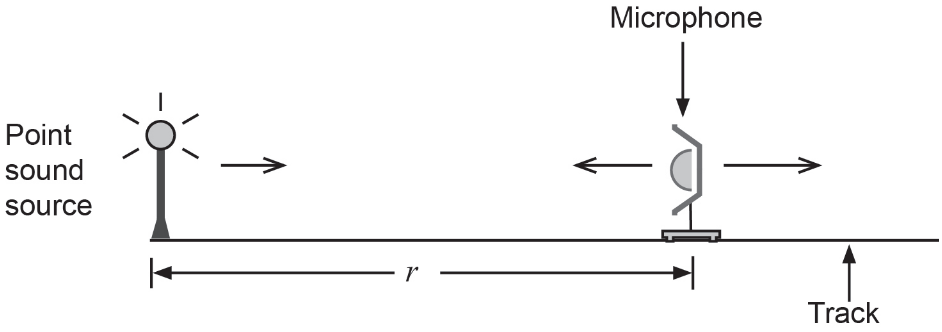
(ii) time interval AB: ______________________ s. (1 mark)

(iii) flux value F at time B: ______________________ Wb. (3 marks)

Question 14 **(17 marks)**

Sound intensity is defined as sound power per unit area, $Intensity = \frac{Power}{Area}$ $(I = \frac{P}{A})$. Hence, the further away from a source, the more area (spherical area = $4\pi r^2$) the sound is spread across, and the less intense a sound appears to a person.

A physics student was asked to verify the formula $I = P/A$. The experimental set-up was as follows.



The student used a microphone to monitor the level of the intensity of the sound at various distances. As the student moved the microphone along the track, the values were recorded in a table as follows.

Intensity, I (W m^{-2})	**Distance from speaker, r (m)**	**$1/r^2$ (m^{-2})**
48 ± 1	0.5	4.0
10 ± 1	1.0	1.0
5 ± 1	1.5	
3 ± 1	2.0	0.25
2 ± 1	2.5	

(a) Complete the last column in the table above with values expressed to **two** significant figures. (3 marks)

(b) Use the data from the table to plot a straight line graph (including error bars) on the grid provided, demonstrating the relationship between the intensity (W m^{-2}) and $1/r^2$ (m^{-2}). (5 marks)

If you wish to make a second attempt at this item, the grid is repeated at the end of this Question/Answer Booklet. Indicate clearly on this page if you have used the second grid and cancel the working on this page.

See next page

Question 14 (continued)

(c) Determine the gradient of your line of best fit. Show **all** workings, and include units in your answer. (3 marks)

(d) Use your graph to determine the intensity at a distance of 0.70 m from the source. Show **all** workings, and express your answer using appropriate significant figures. (3 marks)

(e) Using the answer from (d), calculate the power output of the source. Show appropriate units. (2 marks)

(f) Using your answers to (c) and (e), did the physics student verify the formula $I = P/A$? (1 mark)

See next page

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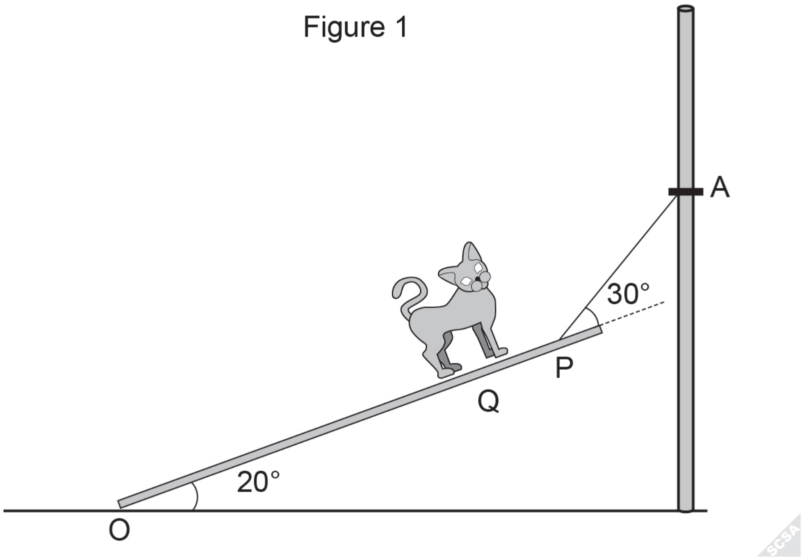
Question 15 **(10 marks)**

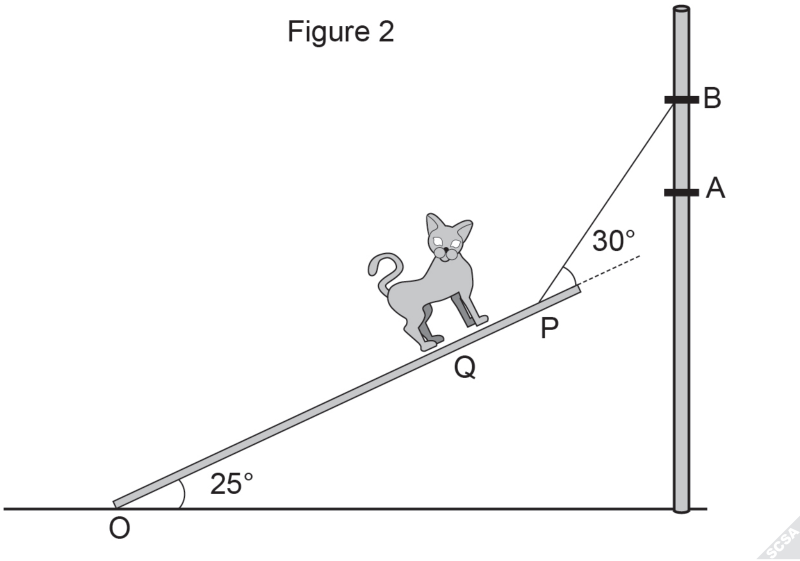
A 3.00 m long plank with a mass of 10.0 kg is held by a cable at Point P, 0.200 m away from the upper end of the plank. The angle between plank and ground is 20.0° and the angle between plank and cable is 30.0°. A 2.00 kg cat moves up the plank up to Point Q, 2.40 m from the bottom, Point O.

Figure 1



(a) Assuming that Point O is the pivot, calculate the tension in the cable. Show **all** workings. (6 marks)

Figure 2



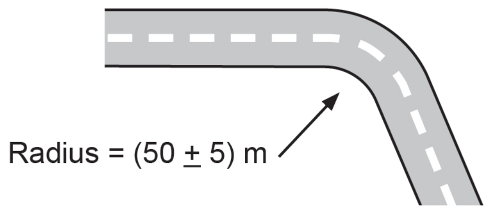
(b) The cable is then moved up from Point A to Point B while maintaining the angle between the plank and cable at 30.0°. The angle between the plank and ground increases to 25.0°, as in Figure 2. Assume Point O as the pivot.

(i) State whether the tension in the cable increases or decreases. (1 mark)

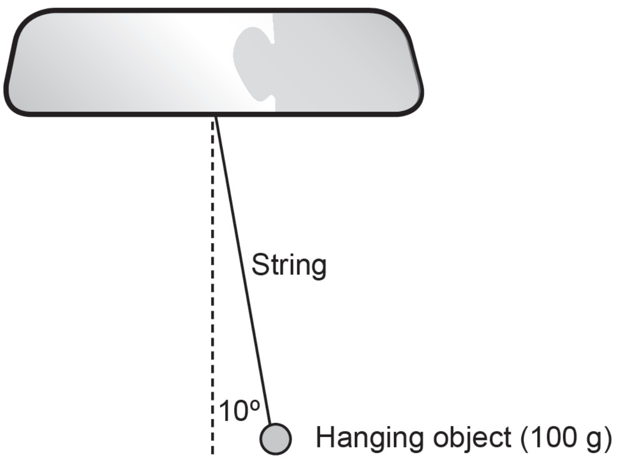
(ii) Justify your answer. (3 marks)

Question 16 **(13 marks)**

Somnang is an engineer and designed a road that had a horizontal curved section of radius (50 ± 5) m. After construction, it was necessary to check that the curvature of the road was constructed within tolerance.



To test the curvature of the road, Somnang hung a small mass of 1.00×10^2 g from the rear-view mirror of his car using a light string. He then travelled at a constant speed of 35.0 km h^{-1} around the curve. Somnang observed that the string holding the mass settled at an angle of 10.0° to the vertical.



(a) On the diagram above, draw and label the forces acting on the hanging object. (2 marks)

(b) Calculate the tension in the light string. Show **all** workings. (3 marks)

(c) Calculate the centripetal force experienced by the hanging mass. Show **all** workings. (3 marks)

(d) From the information supplied and your previous answers, determine whether the curvature of the road was correct. Show **all** workings. (5 marks)

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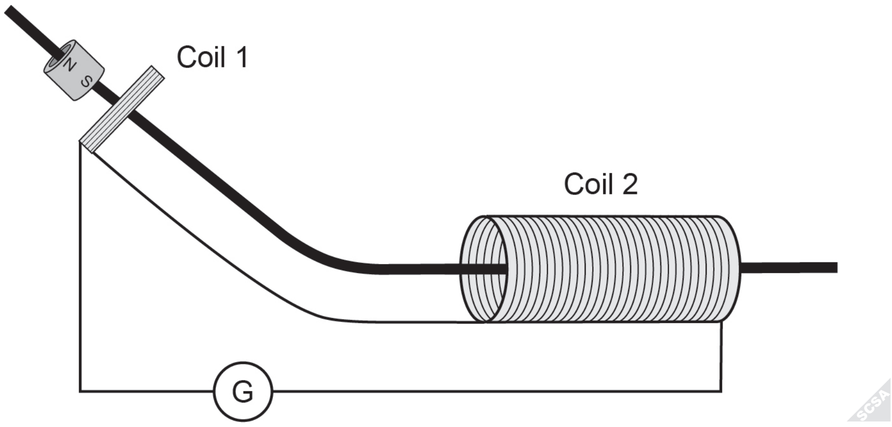
Question 17 **(14 marks)**

A permanent magnet slides down a plastic track and passes through two solenoid coils. The coils are connected in series and their windings are in the same direction. A centre-zero galvanometer (a very sensitive ammeter) is also connected in series with the coils. Assume that the contact between the magnet and plastic track is frictionless.



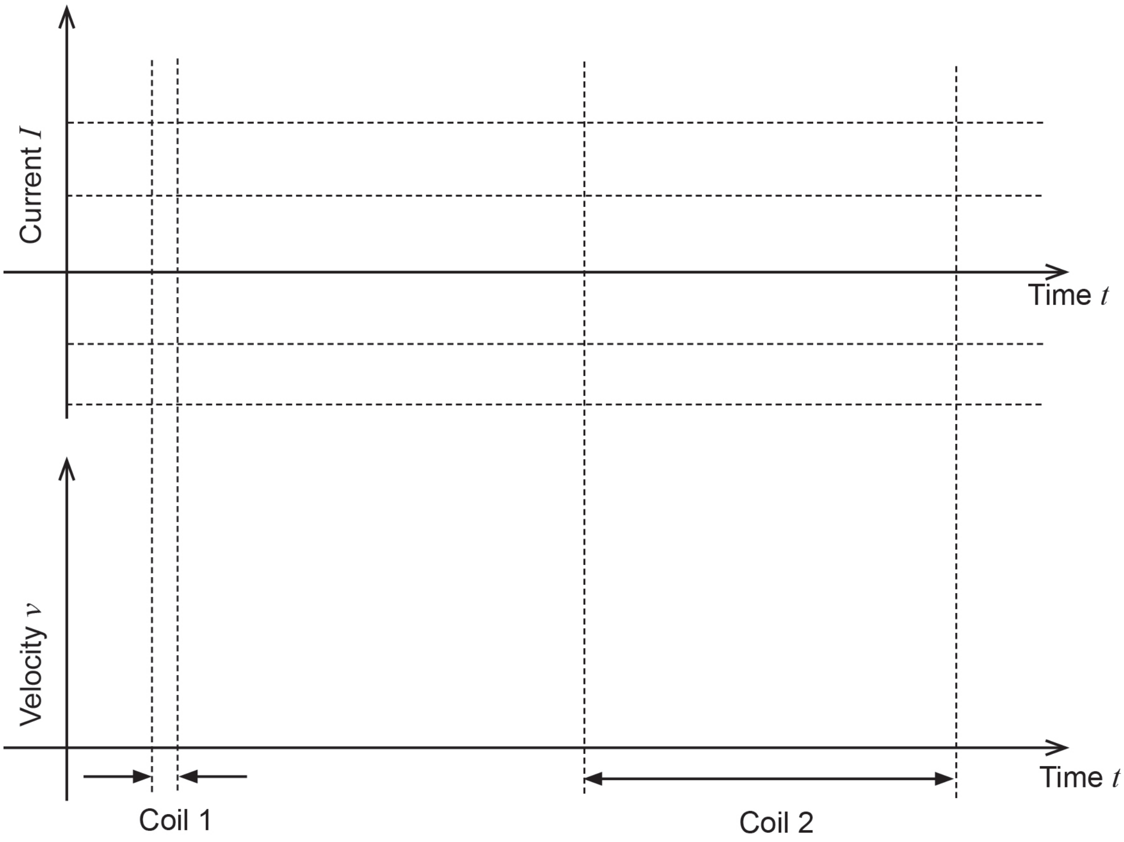
(a) Explain why a current is induced in a coil when the magnet enters and leaves it. (4 marks)

(b) State the expected reading on the galvanometer G as the magnet travels inside Coil 2. Justify your answer. (2 marks)

Reading:

Justification:

(c) Sketch the graphs of current versus time and velocity of the magnet versus time on the axes provided below. (8 marks)



If you wish to make a second attempt at this item, the axes are repeated at the end of this Question/Answer Booklet. Indicate clearly on this page if you have used the second set of axes and cancel the working on this page.

Question 18 **(10 marks)**

The recession speed of a Cepheid variable star was determined as 28 800 km s^{-1} moving away from the Earth. Assume that the star's motion was due only to the expansion of space.

The star's recession speed v_{rec} is linked to Hubble's constant, H_0, by the relationship $v_{rec} = H_0 \times d$ where d is the distance of the star from the observer.

(a) Using appropriate assumptions and Hubble's constant of 1.86×10^{-5} km s^{-1} light-$year^{-1}$, determine the star's distance from an observer on the Earth. Include units in your answer, and show **all** workings. (3 marks)

(b) Estimate the star's current distance from the Earth (in light-years), taking account of the distance that the star travelled while the light from the star travelled to Earth. Show **all** assumptions and workings. (5 marks)

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(c) Estimate how long it would take for light to travel from the current position of the star to an observer on Earth. Explain why this must be an estimate. (2 marks)

End of Section Two

Section Three: Comprehension **20% (35 Marks)**

This section has **two (2)** questions. You must answer **both** questions. Write your answers in the spaces provided.

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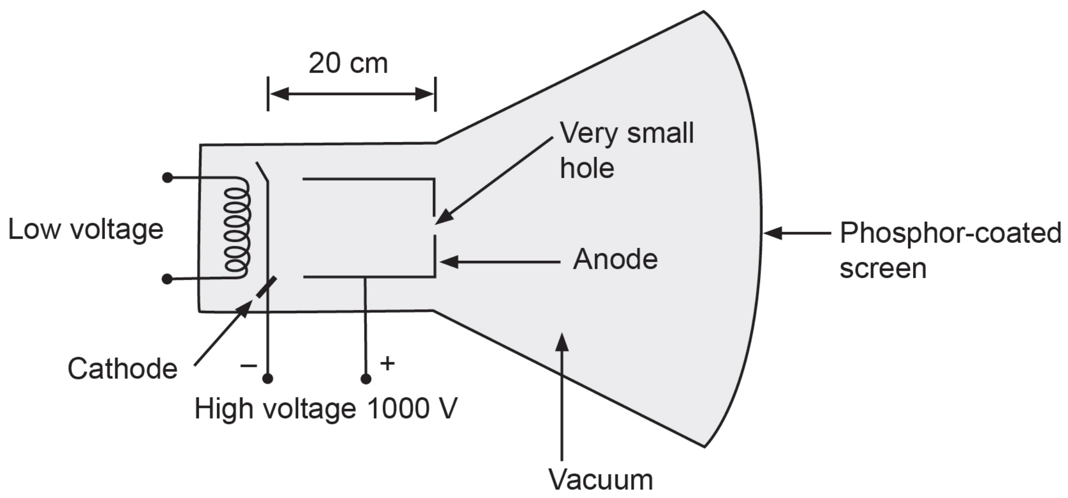
Suggested working time: 40 minutes.

Question 19 **(21 marks)**

Cathode ray tube (CRT) television screens worked by firing a stream of electrons through a vacuum at a phosphor-coated screen. The electrons left the cathode and were accelerated by a uniform electric field toward the anode. Some passed through the very small hole at a high velocity. These electrons then travelled at a constant speed toward the screen.

These moving electrons excited the electrons within the phosphor atoms on the screen. Each phosphor-electron then emitted green, red or blue light as that phosphor-electron decayed back to its ground state.



A feature of the CRT technology was that a person who touched the screen during, or immediately after, operation could experience a mild electric shock, often accompanied by a spark, or a crackling sound.

(a) Calculate the force experienced by each electron as it left the cathode. Show **all** workings. (2 marks)

(b) Calculate the kinetic energy of each electron just prior to it colliding with a phosphor atom. Show **all** workings. (3 marks)

(c) Calculate the velocity of each electron as it struck the phosphor, assuming that these electrons began their journey from rest (and were free of their parent atoms). Show **all** workings. (3 marks)

Question 19 (continued)

(d) These electrons collided with the phosphor screen to produce a red light of wavelength 700 nm. Calculate the difference, in joules, between energy levels of the phosphor atoms associated with this emission. Show **all** workings. (5 marks)

(e) Not all of the electron's kinetic energy was passed on to the phosphor atom to cause the emission of visible light. Give **two** possible ways in which the 'missing' energy might be dissipated. (2 marks)

One: ____________________

Two: ____________________

(f) Would the cathode ray tube work if its interior was **not** a vacuum? Justify your answer. (2 marks)

____

____

____

(g) Explain the effects experienced by a person who touched the screen of a CRT while it was operating. (4 marks)

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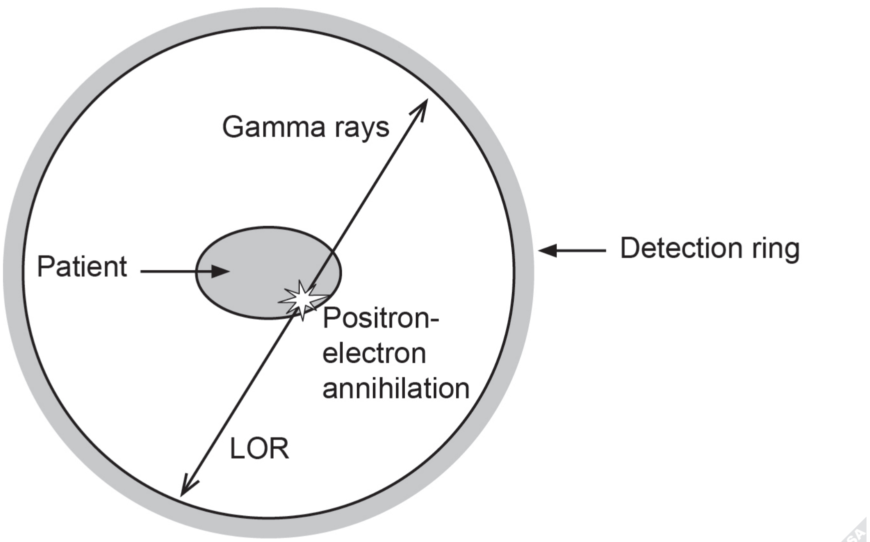
Question 20 **(14 marks)**

Positron emission tomography (PET) is a modern technique used in medicine for imaging soft tissue. The patient lies within a detection ring of approximately 1 m diameter. A sugar-like substance called fluorodeoxyglucose (FDG) is injected directly into their bloodstream. The FDG molecule is absorbed into various tissues within the body in about an hour. This FDG molecule has a radioactive isotope ^{18}F added to it which undergoes radioactive decay, emitting a positron. A positron is identical to an electron except that it carries an equal but opposite charge.

The positron travels about 1 mm through the soft tissue of the patient losing virtually all of its kinetic energy as it travels. Eventually, when moving slowly enough, it interacts with an electron from within the tissue. At this point the electron and the positron annihilate[1] each other, producing a burst of two gamma rays, each with 512 keV of energy. These two gamma rays leave the site of the annihilation in opposite directions and are detected by the detection ring surrounding the patient.



The gamma rays arrive on opposite sides of the detection ring at approximately the same time and are known as 'temporal pairs'. The line that connects where the two temporal gamma rays were detected is known as the line of response (LOR). The source of emission must lie somewhere along the LOR.

If the source of the gamma rays is in the exact centre of the LOR, then the rays arrive simultaneously. If the source of emission is not in the centre of the LOR, there is a slight delay in the arrival of one of the temporal gamma rays. Sophisticated electronics analyse the signal from the detection ring to isolate the true temporal pairs and ignore any background noise. Modern PET scanners can detect temporal pairs of gamma rays that arrive within 500 picoseconds of each other.

[1] annihilate – destroy completely

Question 20 (continued)

(a) Determine the energy, in joules, of a single emitted gamma ray. (1 mark)

(b) Using the masses of the particles involved, show by calculation that the energy of each gamma ray is 512 keV. (5 marks)

(c) How far from the centre of a LOR would the source of emission be if the temporal gamma rays (travelling at the speed of light) arrived 500 picoseconds apart? Show **all** workings. (4 marks)

(d) As the gamma rays leave the patient's body (mostly water) and travel through air to the detection ring, a slight change in velocity occurs. Name this phenomenon and explain the reason for it. (2 marks)

(e) What evidence is there for the particle nature of electromagnetic radiation (emr) in the quoted text? (2 marks)

End of questions

Additional working space

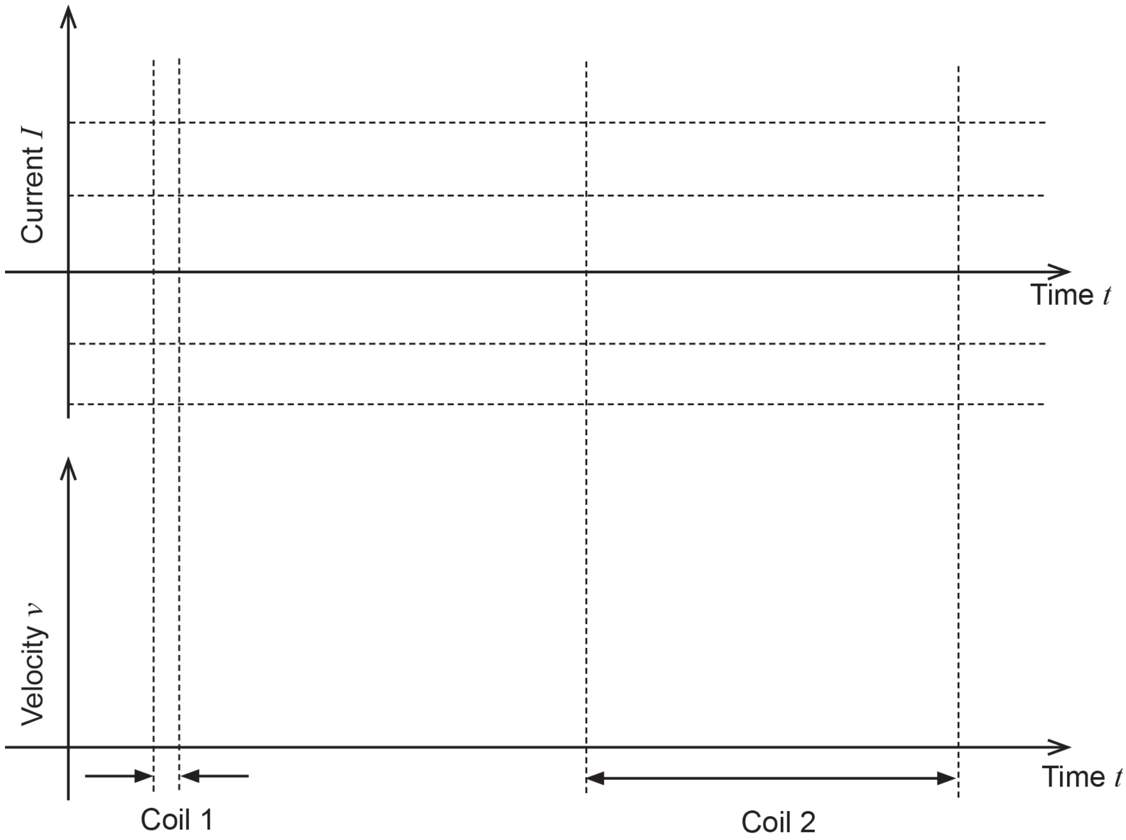
Question number: ____________

Additional working space

Question number: ________________

Question 14

Question 17



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