Coimisiún na Scrúduithe Stáit

State Examinations Commission

Leaving Certificate Examination, 2025

Physics – Higher Level

Wednesday, 18th June – Morning, 9:30 to 12:30

Answer **three** questions from **Section A** and **five** questions from **Section B**.

Do not hand this up.

This document will not be returned to the State Examinations Commission.

Relevant data are listed in the *Formulae and Tables* booklet, which is available from the Superintendent.

SECTION A (120 MARKS)

Answer **three** questions from this section.

Each question carries 40 marks.

---

1. A student investigated the laws of equilibrium for a set of co-planar forces acting on a metre stick.

First, he found the centre of gravity of the metre stick, which was at the 50.0 cm mark. He then found the weight of the metre stick to be 0.96 N.

The metre stick was supported vertically from above at two points. He also hung three known weights from the metre stick. He adjusted their positions until the metre stick was in equilibrium.

The student recorded the position of each force, and the direction in which each of these forces was acting.

The following additional data were recorded.

position of force on metre stick (cm)	2.0	11.2	40.1	72.7	82.9
force (N)	3.4	3.0	2.0	5.5	3.0
direction	up	down	down	up	down

(*i*) Describe how the student found the centre of gravity of the metre stick.

(*ii*) How did the student know that the metre stick was in equilibrium?

(*iii*) Draw a labelled diagram to show all the forces acting on the metre stick.

(*iv*) Why was it important to have the forces applied vertically to the metre stick? (15)

(*v*) Using the given data, calculate the net force acting on the metre stick.

(*vi*) Using an axis at the 5 cm mark on the metre stick, calculate

(*a*) the sum of the clockwise moments,

(*b*) the sum of the anticlockwise moments.

(*vii*) Use your results to verify the laws of equilibrium for a set of co-planar forces. (25)

2. In an experiment to verify the principle of conservation of momentum, two trolleys, A and B, were held in contact and at rest with a light compressed spring between them.

When the spring was released, both trolleys moved with a constant velocity in opposite directions.

Trolley A travelled a distance s_A in a time t_A, while trolley B travelled a distance s_B in a time t_B.

The following data were recorded.

mass of A (g)	mass of B (g)	s_A (cm)	t_A (ms)	s_B (cm)	t_B (ms)
200	250	10	185	8	190

(*i*) Explain how the masses could have been measured.

(*ii*) Describe how the constant velocity of a trolley can be determined.

(*iii*) Calculate the velocity of trolley A and the velocity of trolley B after the spring was released.

(*iv*) What is the total momentum of the trolleys before they are released?

(*v*) Use the data to show that this experiment verifies the principle of conservation of momentum. (27)

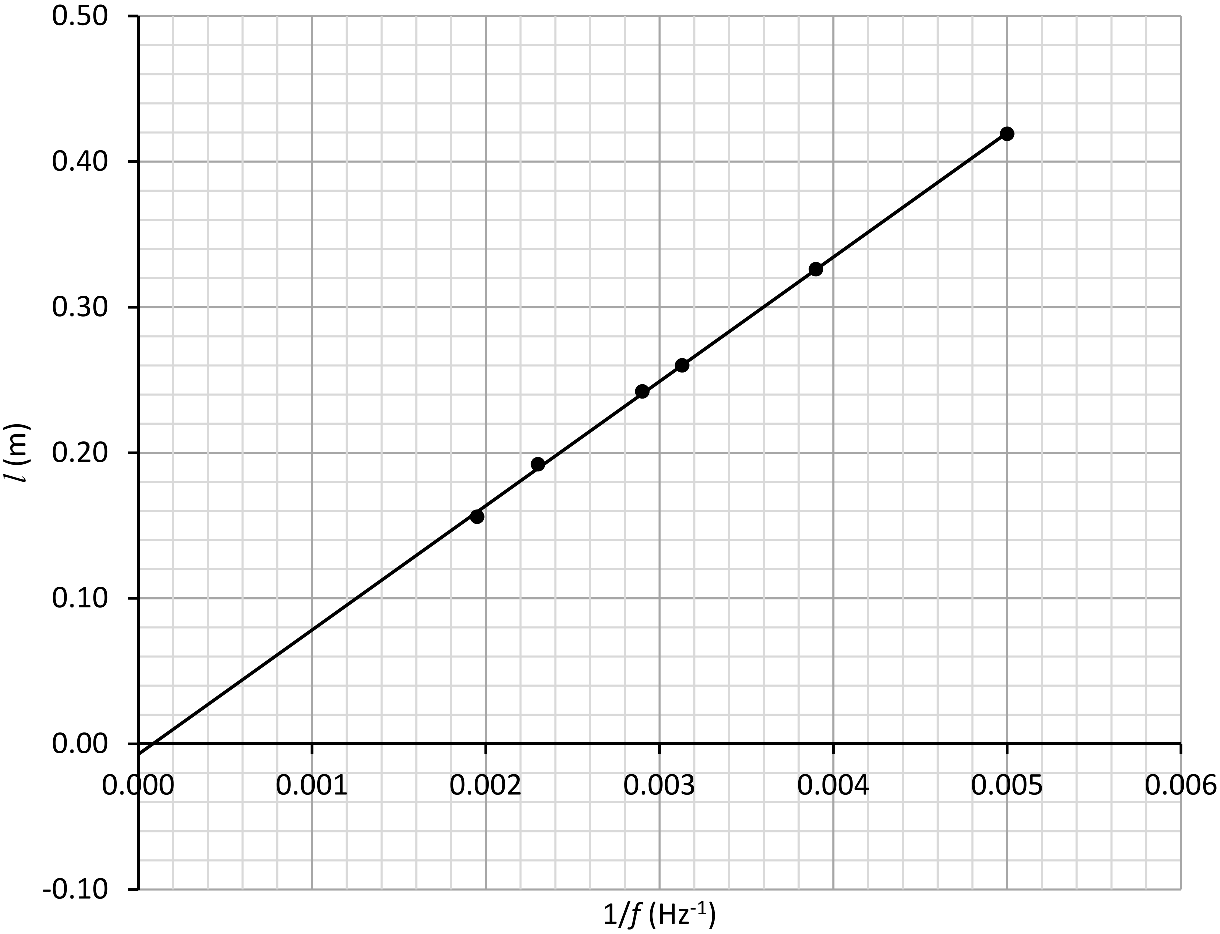
(*vi*) External forces acting on the trolleys were minimised in the experiment.

(*a*) State two principal external forces that should be minimised.

(*b*) Describe how the effect of these forces could be minimised.

(*vii*) State one other way to improve the accuracy of the experiment. (13)

3. In an experiment to measure the speed of sound in air, a student used a cylindrical column of air which was closed at one end, and *six* different tuning forks. A tuning fork of frequency *f* was set vibrating and held over the column of air. The length of the column of air was adjusted until the first position of resonance was found and its length *l* was measured. The procedure was repeated for each tuning fork. The student plotted the following graph based on his recorded data.



(*i*) Draw a labelled diagram of the arrangement of the apparatus used in this experiment.

(*ii*) Describe how the first position of resonance was found.

(*iii*) Describe how the frequency values were determined. (21)

(*iv*) Use the graph to calculate the speed of sound in air.

(*v*) Why does the student's graph not go through the origin?

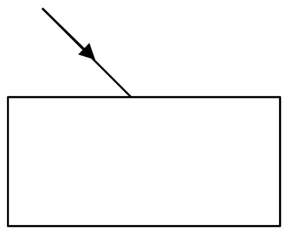
(*vi*) Identify the frequency of the tuning fork that had the lowest frequency. (19)

4. In an experiment to verify Snell's law, a student measured the angle of incidence *i* and the angle of refraction *r* for a ray of light passing from air into a rectangular glass block.

The experiment was repeated for different values of the angle of incidence.

The following data were recorded.

i (°)	20	30	40	50	60	70
r (°)	13	19	27	30	35	39



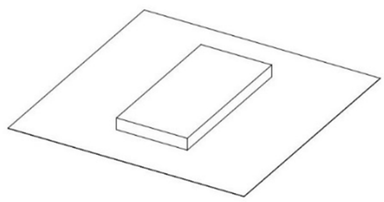
(*i*) Copy the above diagram into your answerbook and show the path of a ray of light as it enters and exits the rectangular glass block. On your diagram, clearly indicate the angle of refraction, *r*. (12)

(*ii*) Draw a suitable graph, on graph paper, to show the relationship between *i* and *r*.

(*iii*) Explain how your graph verifies Snell's law.

(*iv*) Use your graph to calculate the refractive index of the glass. (21)

(*v*) Explain why the student placed the glass block flat on a sheet of paper, as shown below, and not on one of its narrow faces.



(*vi*) Describe what the student would observe if the incident ray of light was perpendicular to the block. (7)

5. A student investigated the variation of the current I through a filament bulb for a range of different values of potential difference V.

The following data were recorded.

V (V)	1	2	3	4	5	6	7
I (mA)	25	47	68	80	91	100	104

(*i*) Draw a circuit diagram for this experiment.

(*ii*) Draw a suitable graph, on graph paper, to show the relationship between V and I.

(*iii*) Does the graph show that Ohm's law is obeyed for the filament bulb? Justify your answer.

(25)

(*iv*) Calculate the resistance of the bulb when the current is

(*a*) 40 mA,

(*b*) 90 mA.

(*v*) Explain what happens to the resistance of the filament bulb as the current increases. (15)

SECTION B (280 MARKS)

Answer **five** questions from this section.

Each question carries 56 marks.

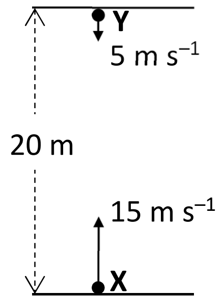
---

6. Answer any **eight** of the following parts, (*a*), (*b*), (*c*), etc.

(*a*) State the function of a hydrometer and state a practical example of its use.

(*b*) A car is driving up a hill, which has a constant steep incline to the horizontal. It travels at a constant speed against a constant frictional force.
Draw a labelled vector diagram to show the forces acting on the car.

(*c*) The diagram on the right shows a smooth particle **X** being projected vertically upwards with a velocity of 15 m s^{-1} from a point on the ground, and at the same time (t = 0 s) a smooth particle **Y** being projected vertically downwards with a velocity of 5 m s^{-1}.
Using the diagram, calculate the time it takes for the two particles to meet.



acceleration due to gravity = 9.8 m s^{-2}

(*d*) Explain what is meant by complementary colours of light. State an example of complementary colours.

(*e*) Draw a ray diagram to show the formation of a virtual image using a concave mirror.

(*f*) The Atlantis XII is a submarine which takes tourists to a depth of 30 m to view a reef off the coast of Cozumel in Mexico.
Calculate the total pressure on the submarine at this depth.

acceleration due to gravity = 9.8 m s^{-2};
density of seawater = 1025 kg m^{-3};
atmospheric pressure = 101 kPa.

(*g*) A 12 μF parallel-plate capacitor is connected to a 2 V cell.
Calculate

(*i*) the charge stored on one of the plates,

(*ii*) the energy stored by the capacitor.

(*h*) A guitar string is vibrating at its first harmonic with a frequency of 196 Hz.

(*i*) Draw a diagram of the string vibrating at its third harmonic.

(*ii*) Determine the frequency of the third harmonic.

(*i*) A spectral line in a distant galaxy is observed in a laboratory on Earth to have a frequency of 7.14×10^{14} Hz. The same line produced and observed in the laboratory has a frequency of 7.59×10^{14} Hz.
Calculate the velocity of the galaxy.

(*j*) Indicate on a diagram the sections of a p-n junction that are positively charged, negatively charged and neutral.

(*k*) Explain the principle of the source of the Sun's energy.

(*l*) Under Rutherford's supervision, Geiger and Marsden carried out an experiment where alpha particles were scattered by a thin film of gold.
State two conclusions drawn from their experiment about the distribution of mass and charge in the atom.

(8 × 7)

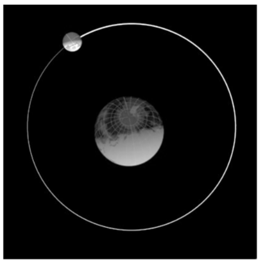
7. (*i*) Explain what is meant by

(*a*) weight,

(*b*) centripetal force.

(*ii*) State Newton's law of universal gravitation.

(*iii*) Derive an equation for the angular velocity of an object in terms of its linear velocity when the object moves in a circle. (21)



Sir Isaac Newton was appointed a Professor of Mathematics at Trinity College, Cambridge in 1669. Legend has it that he formulated his gravitational theory in 1666 after watching an apple fall. He showed that the force that makes an apple fall and that which holds us on the ground is the same as the force that keeps the Moon and the planets in their orbits.

The distance from the centre of the Earth to the centre of the Moon is 3.84×10^8 m. The Moon orbits the Earth every 27.3 days.

(*iv*) Calculate

(*a*) the angular velocity of the Moon,

(*b*) the linear velocity of the Moon.

(*v*) Calculate the force of gravity that the Earth exerts on the Moon according to Newton's law of universal gravitation.

(*vi*) Why does the Moon not fall down to Earth? (23)

A person of mass 80 kg is standing at the equator of the Earth. The person rotates in circular motion with a linear velocity of 463 m s^{-1} at the equator.

(*vii*) Calculate the centripetal force needed to keep the person moving in circular motion.

(*viii*) Calculate the resultant normal reaction force acting on the person.

(*ix*) Draw a labelled diagram to show the forces acting on the person. (12)

mass of the Earth = 5.97×10^{24} kg;

mass of the Moon = 7.35×10^{22} kg;

radius of the Earth at the equator = 6.4×10^{6} m;

acceleration due to gravity = 9.8 m s^{-2}.

8. Light and all other electromagnetic radiation are transverse waves and can undergo diffraction and interference.

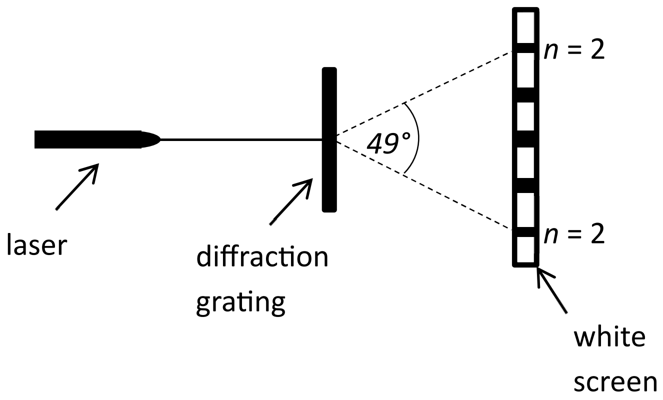
(*i*) Explain what is meant by a transverse wave.

(*ii*) Describe an experiment to demonstrate that light waves are transverse waves.

Destructive interference can be observed when waves meet.

(*iii*) State two conditions necessary for total destructive interference to occur. (21)

Laser light of wavelength 691 nm is used to produce the interference pattern shown in the diagram.



(*iv*) Explain how this pattern is formed from the laser light.

(*v*) Calculate the number of lines per mm on the diffraction grating.

(*vi*) Calculate the maximum number of images that could be observed.

(*vii*) Describe the effect on the pattern when

(*a*) the wavelength of the laser light is increased,

(*b*) a diffraction grating of more lines per mm is used.

(*viii*) State one type of electromagnetic radiation that has a shorter wavelength than visible light. (35)

9. In 1887, Henrich Hertz discovered the photoelectric effect. However, it was Albert Einstein, in 1905, who first successfully explained it. He was awarded the Nobel Prize in 1921 for this groundbreaking work.

(*i*) Explain what is meant by

(*a*) a photon,

(*b*) the photoelectric effect.

(*ii*) Outline Einstein's explanation of the photoelectric effect. (18)

(*iii*) Draw a labelled diagram of the structure of a photocell.

(*iv*) Monochromatic radiation falls on a photocell whose work function is 2.7 eV. The maximum kinetic energy of an emitted electron is 2.24×10^{-19} J and the maximum photocurrent observed is 0.005 mA.
Calculate

(*a*) the energy of a photon falling on the photocell,

(*b*) the frequency of the photon,

(*c*) the number of electrons emitted per second. (30)

(*v*) Explain how thermionic emission differs from photoelectric emission.

(*vi*) Explain why X-ray production can be described as the inverse of the photoelectric effect. (8)

10. (*i*) Explain what is meant by

(*a*) specific heat capacity,

(*b*) specific latent heat. (12)

Dry steam at 100 ˚C was passed into an insulated copper calorimeter of mass 200 g, which contained a mixture of 450 g of cold water and 50 g of ice. The calorimeter, water and ice were all initially at 0 ˚C. The final temperature of the water and the calorimeter was 20 ˚C.

(*ii*) Calculate

(*a*) the energy gained by the calorimeter,

(*b*) the energy needed to melt the ice,

(*c*) the mass of steam added to the water in the calorimeter. (21)

The SI unit of temperature is the kelvin.

(*iii*) State the equation that defines temperature on the Celsius scale.

(*iv*) Suggest a reason why the Celsius scale is used for most everyday purposes.

(*v*) When a mercury-in-glass thermometer with no markings is placed in melting ice, the length of the mercury column is 3.0 cm. When it is placed in boiling water, the length of the mercury column is 30.0 cm.
Calculate the length of the mercury column when placed in water at 42 ˚C.

(*vi*) Explain why it is necessary to have a standard thermometer. (23)

specific heat capacity of copper = 390 J kg^{-1} K^{-1};

specific heat capacity of water = 4180 J kg^{-1} K^{-1};

specific latent heat of fusion of ice = 3.3 x 10^{5} J kg^{-1};

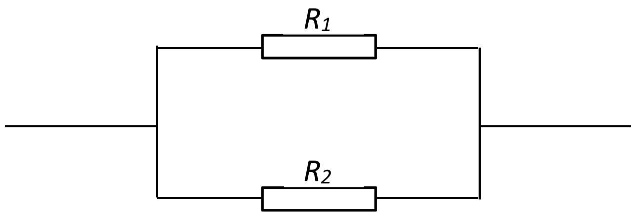
specific latent heat of vaporisation of water = 2.3 x 10^{6} J kg^{-1}.

11. (*i*) Explain what is meant by

(*a*) resistance,

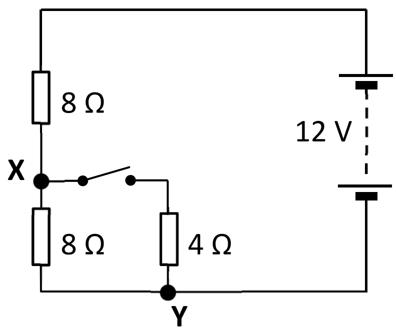
(*b*) potential difference.

(*ii*) Derive an expression for the total resistance of resistors R_1 and R_2 as shown in the following diagram.



(21)

The circuit diagram to the right shows three resistors connected to a 12 V power supply.



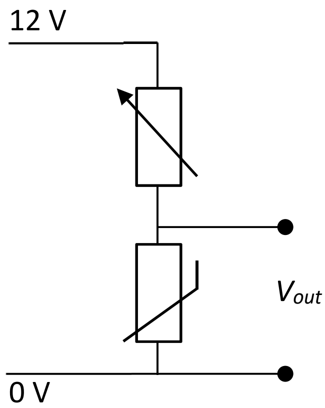
(*iii*) Calculate the total resistance of the circuit when the switch is closed.

(*iv*) Calculate the potential difference between **X** and **Y** when the switch is closed.

(*v*) What happens to the potential difference between **X** and **Y** when the switch is opened?

(16)

The diagram below shows a potential divider circuit with a thermistor that can be found inside a thermostat.



(*vi*) Explain what is meant by a thermistor.

(*vii*) The thermostat switches on an electric heater when the output potential difference V_{out} reaches 8 V. The value of the variable resistor is 5 kΩ.
Calculate the minimum value of the thermistor's resistance that is required to switch on the heater.

(*viii*) What change must be made to the resistance of the variable resistor so that the thermistor switches on the heater at a higher temperature?

(19)

12. Answer **either** part (*a*) or part (*b*).

(*a*) In an experiment conducted in 1932, Cockcroft and Walton accelerated protons through a potential difference and used them to bombard lithium nuclei. Two alpha particles were produced by each collision.

They subsequently determined the energy of the alpha particles.

They provided the first major experimental proof of Einstein's prediction that mass and energy are equivalent.

(*i*) State the nuclear equation for the reaction in the experiment.

(*ii*) In addition to mass and energy, state two other properties that are conserved in the reaction.

(*iii*) A proton is an example of a baryon. Identify a baryon that could not have been used in their experiment. Justify your answer. (20)

(*iv*) Protons were accelerated through a potential difference of 1 MV. Calculate the energy of the incident proton in joules.

(*v*) Given that the mass of the lithium nucleus is 1.16461×10^{-26} kg, calculate the energy released due to the nuclear reaction.

(*vi*) Given that the alpha particles produced had a kinetic energy of 2.77×10^{-12} J, show how the given data can be used to verify Einstein's prediction that mass and energy are equivalent. (24)

Also in 1932, the American physicist Carl Anderson of Caltech, USA, carried out an experiment to show the existence of the anti-particle of the electron, called the positron, which had been proposed in 1928.

(*vii*) Name the English physicist who proposed the existence of anti-particles in 1928.

(*viii*) State a difference between an electron and a positron.

A PET scanner is used to see how cancer patients respond to treatment. It uses the isotope F–18 which emits a positron as it decays.

(*ix*) Write a nuclear equation for this decay. (12)

(*b*) (*i*) Draw a labelled diagram of an a.c. generator.

(*ii*) What is the principal energy transformation that takes place in an a.c. generator?

(*iii*) Draw a circuit diagram showing how a smooth d.c. output can be obtained from an a.c. source. (24)

(*iv*) State the principle on which the induction motor is based.

(*v*) State one advantage of an induction motor over a simple d.c. motor.

(*vi*) A simple induction motor is connected to a 50 Hz a.c. supply. Calculate the maximum number of revolutions per minute of the motor. (15)

(*vii*) List three principal components of a moving-coil galvanometer.

(*viii*) A galvanometer has a resistance of 40 Ω. The full-scale deflection of the galvanometer is 2 mA.
Calculate the maximum potential difference that should be applied across its terminals.

(*ix*) Draw a circuit diagram to show how a galvanometer can be converted to a voltmeter. (17)

13. Read the following passage and answer the accompanying questions.

The work of Michael Faraday (1791 – 1867), who is generally regarded as one of the greatest of all experimental scientists, ushered in the electrical age. From his work on electric currents and magnetism he developed the concept of "lines of force" or "field lines". Faraday's major discovery was electromagnetic induction.
After Oersted and Ampere had shown that electric currents produce magnetic fields, it seemed reasonable to assume that magnetic fields should produce electric currents.
The electrification of American cities began in the 1880s, using direct current, following the invention of the filament light bulb by Thomas Edison. However, in 1886, alternating current was used to provide street lighting in Buffalo, New York. Alternating current was more efficient to transmit because its voltage can be easily changed using a transformer, which had been invented by Joseph Henry in 1838.

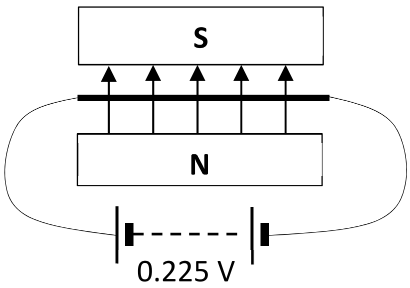
Adapted from "Physics: Teacher's Reference Handbook", Department of Education and Science

(*i*) Explain what is meant by (*a*) a magnetic field (*b*) a magnetic field line. (7)

A magnetic field is described as a vector field.

(*ii*) Distinguish between scalar and vector quantities. (7)

(*iii*) The diagram shows a 5 cm long nichrome wire with a diameter of 0.3776 mm and a resistivity value of $1.12 \times 10^{-6}\ \Omega$ m. It is in a uniform magnetic field of flux density 150 mT.
Calculate



(*a*) the resistance of the wire,

(*b*) the force acting on the wire. (14)

A coil consists of 150 turns of wire and is connected to an a.c. supply. The flux threading each turn of the coil increases by 4.5×10^{-4} Wb over a time of 1.1 ms.

(*iv*) Calculate the average EMF induced in the coil. (7)

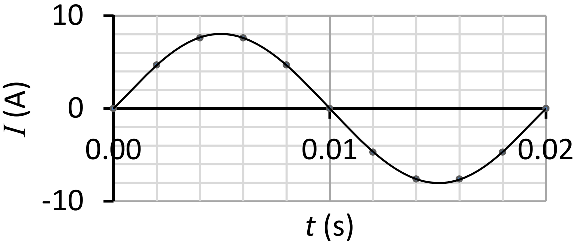
(*v*) (*a*) Explain what is meant by self-induction.

(*b*) State one practical use of self-induction. (7)

(*vi*) (*a*) A step-down transformer converts 345 kV to 230 V. State the ratio of the number of turns in the primary coil to the number of turns in the secondary coil.

(*b*) Explain why a transformer does not work with direct current. (7)

(*vii*) The diagram shows a graph of current I against time t for an alternating current flowing through an appliance.
Calculate the RMS current flowing in the appliance. (7)



14. Answer any **two** of the following parts, (*a*), (*b*), (*c*), (*d*).

(*a*) (*i*) State Hooke's law.

A mass attached to a spring hangs vertically at rest. It will oscillate with simple harmonic motion if pulled down and released.

(*ii*) Using Hooke's law, show that the mass executes simple harmonic motion.

(*iii*) For a mass undergoing simple harmonic motion, explain what is meant by amplitude.

A 150 g mass is attached to a spring that is hanging vertically. The mass is displaced vertically so that it oscillates with simple harmonic motion. The spring constant of the spring is 25 N m^{-1}.

(*iv*) Calculate the period of the oscillation. (28)

(*b*) National Broadband Ireland is responsible for bringing high speed fibre to all homes across Ireland. They use optical fibre cables to connect premises to local exchanges.

An optical fibre consists of a core made from glass surrounded by cladding made from a different type of glass. The following table shows the refractive index for three types of glass.

types of glass	core	**Y**	**Z**
refractive index	1.47	1.44	1.50

(*i*) State which glass **Y** or **Z** would be suitable for the cladding. Justify your answer.

(*ii*) Explain what is meant by critical angle. (12)

(*iii*) Explain, with the aid of a labelled diagram, how a signal is transmitted along the optical fibre.

(*iv*) Calculate the critical angle between the core and the cladding.

(*v*) Identify the type of glass, from the table, in which light travels fastest. (16)

(*c*) In 2011, an accident in the Fukushima nuclear power station in Japan released radioactive Iodine, I–131, into the environment. Iodine–131 is a radioactive isotope with a half-life of 8 days, and it emits beta particles and gamma rays.

(*i*) Determine the number of neutrons in an atom of Iodine–131.

(*ii*) Write a nuclear equation to represent the beta decay of Iodine–131.

(*iii*) Calculate the decay constant of Iodine–131. (17)

(*iv*) A sample of Iodine–131 contains 2×10^{15} atoms.
Calculate

(*a*) the rate of decay of the sample,

(*b*) how long it would take for 1.75×10^{15} nuclei to decay. (11)

(*d*) (*i*) State Coulomb's law.

(*ii*) Explain what is meant by electric field strength.

(*iii*) Describe how an electric field pattern may be demonstrated in the laboratory. (16)

An insulated metal sphere has a diameter of 10 cm and is positively charged. The electric field strength at a distance of 1.3 cm from the surface of the sphere is 4×10^4 N C^{-1}.

(*iv*) Draw a diagram to show the electric field pattern around the sphere.

(*v*) Calculate the total charge on the sphere. (12)

Acknowledgements

Images

Image on page 7: cozumeltourbase.com
Image on page 9: moon.nasa.gov/system/resources/detail files/429/orbit from north pole.jpg
Image on page 17: nbi.ie

Do not hand this up.

This document will not be returned to the State Examinations Commission.

Copyright notice
This examination paper may contain text or images for which the State Examinations Commission is not the copyright owner, and which may have been adapted, for the purpose of assessment, without the authors' prior consent. This examination paper has been prepared in accordance with Section 53(5) of the *Copyright and Related Rights Act, 2000*. Any subsequent use for a purpose other than the intended purpose is not authorised. The Commission does not accept liability for any infringement of third-party rights arising from unauthorised distribution or use of this examination paper.

Leaving Certificate Examination – Higher Level

Physics

Wednesday, 18 June

Morning, 9:30 – 12:30