



Coimisiún na Scrúduithe Stáit State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2014

PHYSICS – HIGHER LEVEL

MONDAY, 16 JUNE – MORNING, 9:30 TO 12:30

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

- N.B.** 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. The following is part of a student's report on an experiment to verify the principle of conservation of momentum.

"I ensured that no net external forces acted on body A or body B. When I released body A it was moving at a constant velocity; body B was at rest. I allowed body A to collide with body B and they moved off together after the collision."

The following data was recorded:

Mass of body A	= 325.1 g
Mass of body B	= 349.8 g
Velocity of body A before the collision	= 0.84 m s ⁻¹
Velocity of bodies A and B after the collision	= 0.41 m s ⁻¹

Draw a labelled diagram of the apparatus used in the experiment.

State what measurements the student took and how these measurements were used to calculate the velocities. (21)

Using the recorded data, show how the experiment verifies the principle of conservation of momentum. (9)

When carrying out this experiment the student ensures that there is no net external force acting on the bodies.

What are the two forces that the student needs to take account of to ensure this?

Describe how the student reduced the effects of these forces. (10)

2. In an experiment to measure the refractive index of a substance, a student used a rectangular block of the substance to measure the angle of incidence i and the corresponding angle of refraction r for a ray of light as it passed from air into the substance. The student repeated the procedure for a series of different values of the angle of incidence and recorded the following data.

i (degrees)	20	30	40	50	60	70	80
r (degrees)	13	20	27	23	36	40	43

One of the recorded angles of refraction is inconsistent with the others. Which one? (4)

Describe, with the aid of a labelled diagram, how the student found the angle of refraction. (12)

Calculate a value for the refractive index of the substance by drawing a suitable graph based on the recorded data. (18)

Using a graph to calculate a value for the refractive index is a more accurate method than calculating the refractive index for each pair of angles and then finding the mean.

Give two reasons for this. (6)

3. A student used a cylindrical column of air closed at one end and a tuning fork of frequency 512 Hz in an experiment to measure the speed of sound in air.

The following data was recorded:

$$\begin{array}{ll} \text{Length of column of air for first position of resonance} & = 16.2 \text{ cm} \\ \text{Diameter of air column} & = 1.15 \text{ cm} \end{array}$$

Draw a labelled diagram of the apparatus used in the experiment. (9)

Describe how the first position of resonance was found. (9)

Using the recorded data, calculate the speed of sound in air. (9)

Why was it necessary to measure the diameter of the air column? (6)

Another student carried out the experiment. She measured the length of the column of air for each of the first two positions of resonance but she did not measure the diameter of the air column.

Explain how this second student would find the speed of sound in air. (7)

4. In an experiment to verify Joule's law, a fixed mass of water was heated in an insulated cup. θ , the highest temperature reached, was recorded for different values of current, I . In each case the current flowed for 4 minutes and the initial temperature of the water was 20.0 °C. The recorded data is shown in the table.

I (A)	1.0	1.5	2.0	2.5	3.0	3.5
θ (°C)	22.0	24.5	28.5	34.0	38.5	45.5

Draw a labelled diagram of the apparatus used in the experiment. (12)

Draw a suitable graph to verify Joule's law. Explain how the graph verifies Joule's law. (18)

Use your graph to estimate the highest temperature of the water when a current of 1.6 A flows through the coil for 4 minutes. (6)

Explain why a fixed mass of water was used. (4)

SECTION B (280 marks)

Answer **five** questions from this section.
Each question carries 56 marks.

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

(a) State Boyle's law.

(b) The Martian moon Phobos travels in a circular orbit of radius 9.4×10^6 m around Mars with a period of 7.6 hours. Calculate the mass of Mars.



(c) On what thermometric properties are the following based:
(i) the thermocouple thermometer and (ii) the mercury-in-glass thermometer?

(d) The U -value of the material in a double-glazed window in a house is $2.8 \text{ W m}^{-2} \text{ K}^{-1}$. The window has an area of 3.0 m^2 . How much energy is lost through the window in one hour if the temperature inside the house is 20°C and the outside temperature is 11°C ?



(e) List a pair of complementary colours of light.

(f) What are the charge carriers in (i) semiconductors and (ii) metals?

(g) With reference to domestic electric circuits, what do the letters in the acronyms (i) RCD and (ii) MCB stand for?

(h) The work function of tungsten is 4.50 eV. Calculate the maximum kinetic energy of an electron ejected from a tungsten surface when electromagnetic radiation whose photon energy is 5.85 eV shines on the surface.

(i) Describe Rutherford's model of the atom.

(j) ETS Walton is Ireland's only Nobel Prize winner in the sciences. Give two reasons why the Cockcroft and Walton experiment was significant to the understanding of particle physics.



or

Describe how a galvanometer may be converted into a voltmeter.

(8 × 7)

6. Compare vector and scalar quantities.
Give one example of each. (8)

Describe an experiment to find the resultant of two vectors. (9)

A golfer pulls his trolley and bag along a level path. He applies a force of 277 N at an angle of 24.53° to the horizontal. The weight of the trolley and bag together is 115 N and the force of friction is 252 N.



Calculate the net force acting on the trolley and bag. (9)

What does the net force tell you about the golfer's motion? (3)

Use Newton's second law of motion to derive an equation relating force, mass and acceleration. (9)

A force of 5.3 kN is applied to a golf ball by a club. The mass of the ball is 45 g and the ball and club are in contact for 0.54 ms.



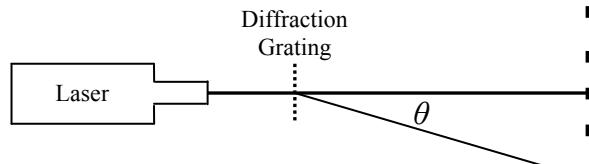
Calculate the speed of the ball as it leaves the club. (9)

The ball leaves the club head at an angle of 15° to the horizontal. Calculate the maximum height reached by the ball. Ignore the effect of air resistance. (9)

(acceleration due to gravity, $g = 9.8 \text{ m s}^{-2}$)

7. What is meant by the terms (i) diffraction and (ii) interference? (9)

A laser produces a beam of red light with a wavelength of 709 nm. The beam is incident on a diffraction grating, as shown in the diagram. A diffraction pattern is formed on a screen. A second order image is detected at an angle of 34.6° from the central image.



Calculate the energy of each photon in the laser beam. (9)

Sensors in the eye can respond to single photons. Where in the eye are these sensors located? (3)

State two differences between the electromagnetic radiation emitted from a laser and the electromagnetic radiation emitted from a vapour lamp. (6)

Derive, with the aid of a labelled diagram, the diffraction grating formula. (15)

Calculate the number of lines per millimetre on the grating used in the experiment. (9)

What would be observed on the screen if the laser was replaced by a ray of white light? (5)

8. A nuclear reactor is a device in which a sustained chain reaction takes place. From each nuclear fission, only one (on average) of the emitted neutrons hits another nucleus to cause another fission. The power output from a sustained nuclear reaction doesn't grow, but is constant.

Explain the underlined terms. (9)

A substance called a moderator is mixed with the fuel in a nuclear reactor. Control rods are used to control the rate of the reaction.



Give an example of a moderator.

Explain (i) why a moderator is needed in a nuclear reactor and (ii) how the control rods affect the rate of the reaction. (15)

A heat exchanger is used in a nuclear reactor.

Explain how the heat exchanger operates. Why is it necessary to use a heat exchanger? (10)

Plutonium is produced in a fission reactor when one of the neutrons released in the fission reaction converts uranium-238 into plutonium-239 with the emission of two beta-particles.

Write an equation for this nuclear reaction. (10)

Each fission of a uranium-235 nucleus produces 202 MeV of energy. Only 35% of this energy is used to generate electricity. How many uranium-235 nuclei are required to undergo fission to generate a constant electric power of 1 GW for a day? (12)

9. Most modern electronic devices contain a touchscreen. One type of touchscreen is a capacitive touchscreen, in which the user's finger acts as a plate of a capacitor. Placing your finger on the screen will alter the capacitance and the electric field at that point.



Explain the underlined terms. (12)

Describe an experiment to demonstrate an electric field pattern. (12)

Two parallel metal plates are placed a distance d apart in air. The plates form a parallel plate capacitor with a capacitance of $12 \mu\text{F}$. A 6 V battery is connected across the plates.

Calculate (i) the charge on each plate and (ii) the energy stored in the capacitor. (12)

While the battery is connected the distance d is increased by a factor of three. Calculate the new capacitance. (4)

A capacitor and a battery are both sources of electrical energy. State two differences between a capacitor and a battery. (6)

Touchscreens also contain two polarising filters. What is meant by polarisation of light? (6)

Give one application of capacitors, other than in touchscreens. (4)

10. Blood pressure can be measured in many ways. One technique uses the Doppler effect; another uses strain gauges contained in Wheatstone bridges.



What is the Doppler effect?

Explain, with the aid of labelled diagrams, how the Doppler effect occurs. (18)

An ambulance siren emits a sound of frequency 750 Hz. When the ambulance is travelling towards an observer, the frequency detected by the observer is 820 Hz.

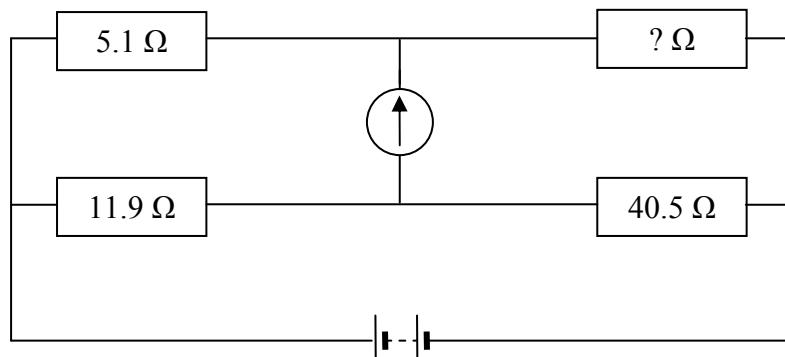
What is the speed of the ambulance? (12)

State two other practical applications of the Doppler effect. (4)

The resistance of the conductor in a strain gauge increases when a force is applied to it. Strain gauges can act as the resistors in a Wheatstone bridge, and any change in their resistance can then be detected.

How would an observer know that a Wheatstone bridge is balanced? (4)

The Wheatstone bridge in the diagram is balanced.



What is the resistance of the unknown resistor? (6)

Write an expression for the resistance of a wire in terms of its resistivity, length and diameter.

The radius of a wire is doubled. What is the effect of this on the resistance of the wire? (12)

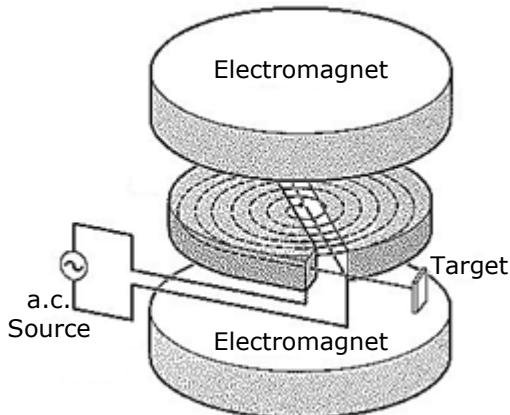
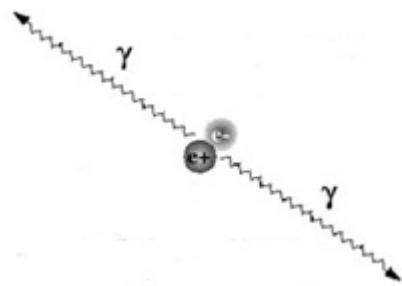
(speed of sound in air = 340 m s^{-1})

11. Answer either part (a) or part (b).

- (a) Read the following passage and answer the accompanying questions.

Cyclotrons and PET Scanners

Positron emission tomography (PET) scanners are designed to detect the pair of photons generated from the annihilation reaction between a positron and an electron. A carbon-11 nucleus, which has a half-life of twenty minutes, decays with the emission of a positron. The positron travels only a short distance before colliding with an electron in the surrounding matter. Pair annihilation occurs. The emitted photons travel in opposite directions.



Cyclotrons are located in the same hospital as the PET scanners and are used to manufacture radioactive nuclei. Cyclotrons are circular devices in which charged particles are accelerated in a spiral path within a vacuum. The particles are accelerated by a rapidly alternating voltage and acquire high kinetic energies. They spiral outwards under the influence of the magnetic field until they have sufficient velocity and are deflected into a target producing radioactive nuclei, including carbon-11.

(Adapted from "Essentials of Nuclear Medicine Physics"; Powsner & Powsner; 1998)

- (i) Electrons are leptons. List the three fundamental forces that electrons experience in increasing order of strength.
- (ii) Write an equation to represent the pair annihilation described in the text.
- (iii) Calculate the frequency of each photon produced in this pair annihilation.
- (iv) Why do the photons produced in pair annihilation travel in opposite directions?
- (v) Write a nuclear equation to represent the decay of carbon-11.
- (vi) What is the value of the decay constant of carbon-11?
- (vii) Explain why the carbon-11 nuclei used in the PET scanner must be produced in a cyclotron in, or close to, the same hospital as the scanner.
- (viii) Give an expression for the momentum of a particle in the cyclotron in terms of the magnetic flux density of the field, the charge on the particle and the radius of its circular path at any instant.

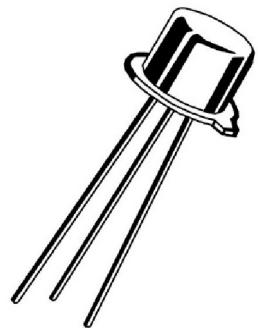
(8 × 7)

- (b) Read the following passage and answer the accompanying questions.

Silicon

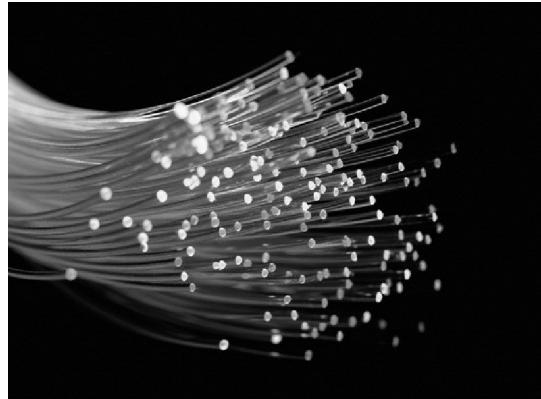
At the end of June 1948, *Bell Labs* announced the invention of the transistor by Shockley, Bardeen and Brattain. Like the vacuum tube, which it had the potential to replace, the transistor could amplify electric signals and act as an on-off switch.

Any computational problem can be broken down into a set of simple logical steps. These steps are controlled by logic gates, which are the basic building blocks of digital circuits. Logic gates are made from transistors and other simple components, and they use transistors as switches to send signals. A computer is simply a number of these transistor-based logic gates linked together to produce a complex output. Transistors are used because they are very small, very cheap and use little power. Transistor switches can be turned on and off well over a billion times every second. Silicon's semiconducting properties make it ideal for making these switches.



Today's communication infrastructure also depends on silicon in a very different format. Silica-glass optical fibres were developed in the 1980s, replacing copper for long-distance telecommunication lines. LEDs and photodiodes may be used to transmit and receive signals that travel in optical fibres.

(Adapted from "Seven Elements that Changed the World"; Browne; 2013)



- (i) Draw a labelled diagram to show the basic structure of a transistor.
- (ii) State the relationship between the three currents flowing in a transistor.
- (iii) Draw a circuit diagram for a voltage amplifier.
- (iv) Draw the symbol and truth table for an AND gate.
- (v) Give two ways in which the operation of a photodiode differs from that of an LED.
- (vi) What event inside an LED causes the release of a photon?
- (vii) Explain, with the aid of a labelled diagram, how a ray of light is guided along an optical fibre.
- (viii) Give an expression for the critical angle of the glass in an optical fibre in terms of the speed of light in the glass and the speed of light in air.

(8 × 7)

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

(a) State Hooke's law.

(4)

The elastic constant of a spring is 12 N m^{-1} and it has a length of 25 mm. An object of mass 20 g is attached to the spring.

What is the new length of the spring?

(6)

The object is then pulled down until the spring's length is increased by a further 5 mm and is then released. The object oscillates with simple harmonic motion.

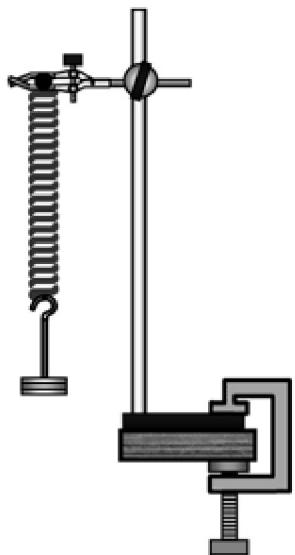
Sketch a velocity-time graph of the motion of the object.

(9)

Calculate the period of oscillation of the object.

(9)

(acceleration due to gravity, $g = 9.8 \text{ m s}^{-2}$)



(b) What is reflection?

(3)

Spherical mirrors can be either convex or concave.

Draw a ray diagram to show the formation of an image in a convex mirror.

(9)

A person looks at her image in a shiny spherical decoration when her face is 30 cm from the surface of the decoration. The diameter of the decoration is 20 cm. Find the position of the image.

(12)

Concave mirrors, rather than convex mirrors, are used by dentists to examine teeth. Explain why.

(4)



(c) Define specific latent heat. (6)

A drinking glass contains 500 g of water at a temperature of 24 °C. Three cubes of ice, of side 2.5 cm, are removed from a freezer and placed in the water. The temperature of the ice is –20 °C.

Calculate the mass of the ice. (6)

Calculate the minimum temperature of the water when the ice has melted. (16)

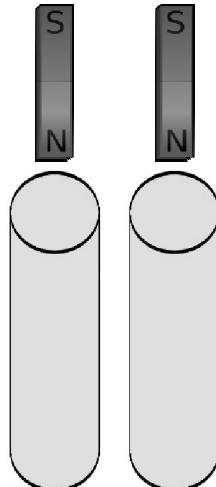
density of ice	= 0.92 g cm ⁻³
specific heat capacity of water	= 4200 J kg ⁻¹ K ⁻¹
specific heat capacity of ice	= 2100 J kg ⁻¹ K ⁻¹
specific latent heat of fusion of ice	= 3.3×10^5 J kg ⁻¹



(d) State Faraday's law of electromagnetic induction. (6)

Describe an experiment to demonstrate Faraday's law. (9)

A hollow copper pipe and a hollow glass pipe, with identical dimensions, were arranged as shown in the diagram. A student measured the time it took a strong magnet to fall through each cylinder. It took much longer for the magnet to fall through the copper pipe. Explain why. (13)



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