Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2009

PHYSICS – HIGHER LEVEL

MONDAY 15 JUNE – MORNING 9:30 TO 12:30

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

SECTION A (120 marks)

Answer **three** questions from this section.
Each question carries 40 marks.

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1. In an experiment to measure the acceleration due to gravity, the time t for an object to fall from rest through a distance s was measured. The procedure was repeated for a series of values of the distance s. The table shows the recorded data.

s/cm	30	50	70	90	110	130	150
t/ms	247	310	377	435	473	514	540

Draw a labelled diagram of the apparatus used in the experiment.
Indicate the distance s on your diagram.
Describe how the time interval t was measured. (15)

Calculate a value for the acceleration due to gravity by drawing a suitable graph based on the recorded data. (21)

Give two ways of minimising the effect of air resistance in the experiment. (4)

2. A student was asked to measure the focal length of a converging lens. The student measured the image distance v for each of three different object distances u. The student recorded the following data.

u/cm	20.0	30.0	40.0
v/cm	65.2	33.3	25.1

Describe how the image distance was measured. (12)

Give two precautions that should be taken when measuring the image distance. (6)

Use all of the data to calculate the focal length of the converging lens. (15)

What difficulty would arise if the student placed the object 10 cm from the lens? (7)

3. A student investigated the variation of the fundamental frequency f of a stretched string with its tension T. The following is an extract of the student's account of the experiment.

> "I fixed the length of the string at 40 cm. I set a tuning fork of frequency 256 Hz vibrating and placed it by the string. I adjusted the tension of the string until resonance occurred. I recorded the tension in the string. I repeated the experiment using different tuning forks."

How was the tension measured? How did the student know that resonance occurred? (6)

The following data were recorded.

f/Hz	256	288	320	341	384	480	512
T/N	2.4	3.3	3.9	4.3	5.7	8.5	9.8

Draw a suitable graph to show the relationship between the fundamental frequency of a stretched string and its tension. State this relationship and explain how your graph verifies it. (21)

Use your graph to

(i) estimate the fundamental frequency of the string when its tension is 11 N;
(ii) calculate the mass per unit length of the string. (13)

4. In an experiment to measure the resistivity of nichrome, the resistance, the diameter and appropriate length of a sample of nichrome wire were measured.

The following data were recorded:

resistance of wire	= 7.9 Ω
length of wire	= 54.6 cm
average diameter of wire	= 0.31 mm

Describe the procedure used in measuring the length of the sample of wire. (6)

Describe the steps involved in finding the average diameter of the wire. (15)

Use the data to calculate the resistivity of nichrome. (15)

The experiment was repeated on a warmer day. What effect did this have on the measurements? (4)

SECTION B (280 marks)

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

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

(*a*) State Boyle's law. (7)

(*b*) The moon orbits the earth. What is the relationship between the period of the moon and the radius of its orbit? (7)

(*c*) Why is it necessary to have a standard thermometer? (7)

(*d*) The sound intensity level at a concert increases from 85 dB to 94 dB when the concert begins. By what factor has the sound intensity increased? (7)

(*e*) Draw a ray diagram to show the formation of an image in a convex mirror. (7)

(*f*) Define electric field strength. (7)

(*g*) When will an RCD (residual current device) disconnect a circuit? (7)

(*h*) What is the average emf induced in a coil of 20 turns when the magnetic flux cutting it decreases from 2.3 Wb to 1.4 Wb in 0.4 s? (7)

(*i*) How are X-rays produced? (7)

(*j*) Arrange the fundamental forces of nature in increasing order of strength. (7)

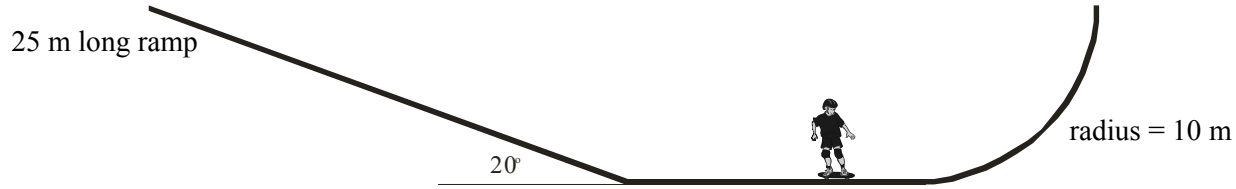
or

Draw the truth table for the AND gate. (7)

6. State Newton's laws of motion. (12)

Show that $F = ma$ is a special case of Newton's second law. (10)

A skateboarder with a total mass of 70 kg starts from rest at the top of a ramp and accelerates down it. The ramp is 25 m long and is at an angle of 20° to the horizontal. The skateboarder has a velocity of 12.2 m s^{-1} at the bottom of the ramp.



Calculate

(i) the average acceleration of the skateboarder on the ramp.
(ii) the component of the skateboarder's weight that is parallel to the ramp.
(iii) the force of friction acting on the skateboarder on the ramp. (18)

The skateboarder then maintains a speed of 10.5 m s^{-1} until he enters a circular ramp of radius 10 m.

What is the initial centripetal force acting on him?

What is the maximum height that the skateboarder can reach? (12)

Sketch a velocity-time graph to illustrate his motion. (4)

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

7. When light shines on a compact disc it acts as a diffraction grating causing <u>diffraction</u> and <u>dispersion</u> of the light. Explain the underlined terms. (12)

Derive the diffraction grating formula. . (12)

An interference pattern is formed on a screen when green light from a laser passes normally through a diffraction grating. The grating has 80 lines per mm and the distance from the grating to the screen is 90 cm. The distance between the third order images is 23.8 cm.

Calculate

(i) the wavelength of the green light;
(ii) the maximum number of images that are formed on the screen. (21)

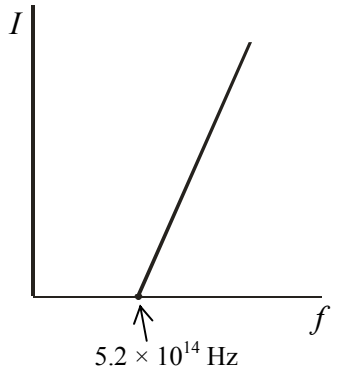
The laser is replaced with a source of white light and a series of spectra are formed on the screen.

Explain

(iii) how the diffraction grating produces a spectrum;
(iv) why a spectrum is **not** formed at the central (zero order) image. (11)

8. What is a photon? (6)

An investigation was carried out to establish the relationship between the current flowing in a photocell and the frequency of the light incident on it. The graph illustrates the relationship.



Draw a labelled diagram of the structure of a photocell. (12)

Using the graph, calculate the work function of the metal.

What is the maximum speed of an emitted electron when light of wavelength 550 nm is incident on the photocell?

Explain why a current does not flow in the photocell when the frequency of the light is less than 5.2×10^{14} Hz. (21)

The relationship between the current flowing in a photocell and the intensity of the light incident on the photocell was then investigated. Readings were taken and a graph was drawn to show the relationship.

Draw a sketch of the graph obtained. How was the intensity of the light varied?

What conclusion about the nature of light can be drawn from these investigations? (17)

(Planck constant = 6.6×10^{-34} J s; speed of light = 3.0×10^{8} m s^{-1};
charge on electron = 1.6×10^{-19} C; mass of electron = 9.1×10^{-31} kg)

9. Define (i) potential difference, (ii) capacitance. (12)

A capacitor stores energy.
Describe an experiment to demonstrate that a capacitor stores energy. (14)

The ability of a capacitor to store energy is the basis of a defibrillator. During a heart attack the chambers of the heart fail to pump blood because their muscle fibres contract and relax randomly. To save the victim, the heart muscle must be shocked to re-establish its normal rhythm. A defibrillator is used to shock the heart muscle.

A 64 μF capacitor in a defibrillator is charged to a potential difference of 2500 V.
The capacitor is discharged through electrodes attached to the chest of a heart attack victim.

Calculate

(i) the charge stored on each plate of the capacitor;

(ii) the energy stored in the capacitor;

(iii) the average current that flows through the victim when the capacitor discharges in a time of 10 ms;

(iv) the average power generated as the capacitor discharges. (30)

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

(*a*) In 1932 Cockcroft and Walton succeeded in splitting lithium nuclei by bombarding them with artificially accelerated protons using a linear accelerator.
Each time a lithium nucleus was split a pair of alpha particles was produced.

How were the protons accelerated? How were the alpha particles detected? (8)

Write a nuclear equation to represent the splitting of a lithium nucleus by a proton.
Calculate the energy released in this reaction. (21)

Most of the accelerated protons did not split a lithium nucleus. Explain why. (6)

Cockcroft and Walton's apparatus is now displayed at CERN in Switzerland, where very high energy protons are used in the Large Hadron Collider.

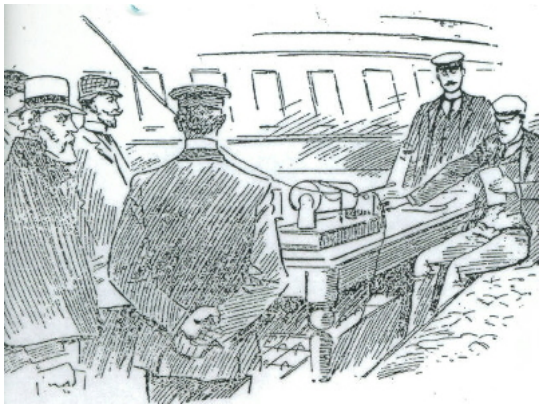
In the Large Hadron Collider, two beams of protons are accelerated to high energies in a circular accelerator. The two beams of protons then collide producing new particles. Each proton in the beams has a kinetic energy of 2.0 GeV.

Explain why new particles are formed.
What is the maximum net mass of the new particles created per collision? (15)

What is the advantage of using circular particle accelerators in particle physics? (6)

(mass of alpha particle = 6.6447×10^{-27} kg; mass of proton = 1.6726×10^{-27} kg; mass of lithium nucleus = 1.1646×10^{-26} kg; speed of light = 2.9979×10^{8} m s^{-1}; charge on electron = 1.6022×10^{-19} C)

(b) In July 1898, at Dun Laoghaire, Guglielmo Marconi used an induction coil to send radio waves from a ship. The induction coil works on the principle of electromagnetic induction and had been invented earlier in Maynooth. He was reporting on the annual Kingstown regatta, and it was the first time that radio waves had been used in journalism. Over two days Marconi sent over 700 messages to shore using Morse code. The messages were then transmitted by telephone to the Dublin office of the *Daily Express* newspaper.



What is electromagnetic induction? Who invented the induction coil? (9)

What is the function of an induction coil? (6)

In an induction coil, a primary coil with a few turns of thick wire and a secondary coil with many turns of thin wire are wrapped on the same soft-iron core.

Why are there a large number of turns in the secondary coil?

Explain why the primary coil has thick wire.

Why are both coils wrapped on the same soft-iron core? (15)

Radio waves are much less energetic than light waves. List two other types of electromagnetic waves with energy less than that of light waves.

Give one property that is common to all types of electromagnetic waves. (8)

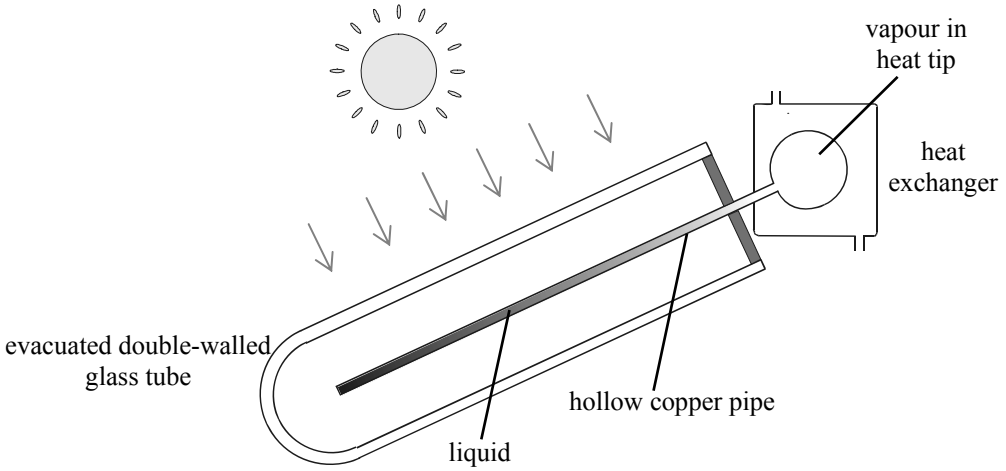
The telephone used to transmit the messages to Dublin contained a moving-coil loudspeaker. Describe, with the aid of a labelled diagram, how a loudspeaker operates. (18)

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

The sun is a major source of 'green' energy. In Ireland solar heating systems and geothermal systems are used to get energy from the sun.

There are two main types of solar heating systems, flat-plate collectors and vacuum-tube collectors.

- A flat-plate collector is usually an aluminium box with a glass cover on top and a blackened plate on the bottom. A copper pipe is laid on the bottom of the box, like a hose on the ground; water is passed through the pipe and transfers the absorbed heat to the domestic hot water system.



- In a vacuum-tube collector, each tube consists of an evacuated double-walled silvered glass tube in which there is a hollow copper pipe containing a liquid. The liquid inside the copper pipe is vaporised and expands into the heat tip. There the vapour liquefies and the latent heat released is transferred, using a heat exchanger, to the domestic hot water system. The condensed liquid returns to the copper pipe and the cycle is repeated.

In a geothermal heating system a heat pump is used to extract solar energy stored in the ground and transfer it to the domestic hot water system.

(*a*) What is the maximum energy that can fall on an area of 8 m^2 in one hour if the solar constant is 1350 W m^{-2}? (7)

(*b*) Why is the bottom of a flat-plate collector blackened? (7)

(*c*) How much energy is required to raise the temperature of 500 litres of water from 20 $^{\circ}$C to 50 $^{\circ}$C? (7)

(*d*) The liquid in a vacuum-tube solar collector has a large specific latent heat of vaporisation. Explain why. (7)

(*e*) Name the three ways that heat could be lost from a vacuum-tube solar collector. (7)

(*f*) How is the sun's energy trapped in a vacuum-tube solar collector? (7)

(*g*) Describe, in terms of heat transfer, the operation of a heat pump. (7)

(*h*) Give an advantage of a geothermal heating system over a solar heating system. (7)

(specific heat capacity of water = 4200 J kg^{-1} K^{-1}; density of water = 1000 kg m^{-3}; 1 litre = 10^{-3} m^3)

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

(*a*) State Hooke's law. (6)

When a sphere of mass 500 g is attached to a spring of length 300 mm, the length of the spring increases to 330 mm.

Calculate the spring constant. (9)

The sphere is then pulled down until the spring's length has increased to 350 mm and is then released.

Describe the motion of the sphere when it is released. (4)

What is the maximum acceleration of the sphere? (9)

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

(*b*) A semiconductor diode is formed when small quantities of phosphorus and boron are added to adjacent layers of a crystal of silicon to increase its conduction.

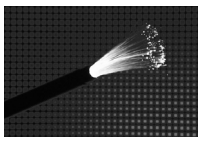
Explain how the presence of phosphorus and boron makes the silicon a better conductor. (6)

What happens at the boundary of the two adjacent layers? (9)

Describe what happens at the boundary when the semiconductor diode is (i) forward biased, (ii) reverse biased. (9)

Give a use of a semiconductor diode. (4)

(*c*) Information is transmitted over long distances using optical fibres in which a ray of light is guided along a fibre. Each fibre consists of a core of high quality glass with a refractive index of 1.55 and is coated with glass of a lower refractive index.



Explain, with the aid of a labelled diagram, how is a ray of light guided along a fibre. (9)

Why is each fibre coated with glass of lower refractive index? (6)

What is the speed of the light as it passes through the fibre? (7)

Light passing through optical fibres must travel through an enormous length of glass. Impurities in the glass reduce the power transmitted by half every 2 km. The initial power being transmitted by the light is 10 W.

What is the power being transmitted by the light after it has travelled 8 km through the fibre? (6)

(speed of light in air = 3.0×10^8 m s^{-1})

(*d*) Smoke detectors use a very small quantity of the element americium-241. This element does not exist in nature and was discovered during the Manhattan Project in 1944.

Alpha particles are produced by the americium-241 in a smoke detector.

(i) Give the structure of an alpha particle.

(ii) How are the alpha particles produced?

(iii) Why do these alpha particles not pose a health risk? (13)

Americium-241 has a decay constant of 5.1×10^{-11} s^{-1}.
Calculate its half life in years. (9)

Explain why americium-241 does not exist naturally. (6)

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