2018. M36

Coimisiún na Scrúduithe Stáit

State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2018

PHYSICS – HIGHER LEVEL

WEDNESDAY, 20 JUNE – MORNING, 9:30 TO 12:30

Answer **three** questions from **Section A** and **five** questions from **Section 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. In an experiment to verify the principle of conservation of momentum, body A was set in motion with a velocity u. It collided with body B, which was initially at rest. Bodies A and B then moved with a common velocity v. The following data were recorded.

Mass of body A	= 360.7 g
Mass of body B	= 340.9 g
Distance travelled by A for 0.12 s before the collision	= 161 mm
Distance travelled by A and B for 0.12 s after the collision	= 83 mm

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

External forces were minimised in the experiment.
State the two principal external forces that were minimised. How were they minimised? (21)

Calculate velocities u and v.
Use the data to verify the principle of conservation of momentum.

Calculate the loss of kinetic energy in the bodies during the collision.
What form of energy could account for this loss of kinetic energy? (19)

2. A student measured the angle of incidence i and the angle of refraction r for a ray of light passing through a transparent block. She repeated this experiment for different values of i and used her data to investigate the relationship between the angle of incidence and the angle of refraction. The following data were recorded.

i (degrees)	20	30	40	50	60	70
r (degrees)	14	20	26	31	35	38

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

Draw a suitable graph to show the relationship between the angle of incidence and the angle of refraction. State this relationship and explain how your graph verifies it.

Use your graph to determine the refractive index of the material used. (24)

What would be observed if the incident ray was perpendicular to the block? (4)

3. A student used a narrow beam of monochromatic light and a diffraction grating to determine λ, the wavelength of the monochromatic light. The following data were recorded.

ϕ, the angle between the two first order images = 34.1°

The number of lines per mm on the diffraction grating = 500

Draw a labelled diagram of the apparatus that the student used in this experiment.
Describe how the angle between the two first order images was obtained. (15)

Calculate the wavelength of the beam of light. (12)

Describe the effect on the size of the angle ϕ, the angle between the two first order images, if the diffraction grating above was replaced with a diffraction grating of 80 lines per mm.
Hence determine which grating would give a more accurate value for λ.
Justify your answer.

What would the student observe if the source of monochromatic light was replaced with a source of white light? (13)

4. In an experiment to verify Joule's law, a constant current, I, was passed through a heating coil immersed in water. The current was allowed to flow for 3 minutes and the final temperature θ of the water was then measured.
This was repeated for a number of different currents.

In each case, the initial temperature of the water was 18 °C and the mass of the water was 90 g.
The following data were recorded.

I (A)	1.5	2.0	2.5	3.0	3.5	4.5	5.5
θ (°C)	20.0	22.0	24.0	27.5	30.5	38.0	49.5

Draw a diagram of the apparatus used in this experiment. (15)

Draw a suitable graph to verify Joule's law.
Calculate the slope of the graph and hence calculate the resistance of the heating coil. (25)

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

SECTION B (280 MARKS)

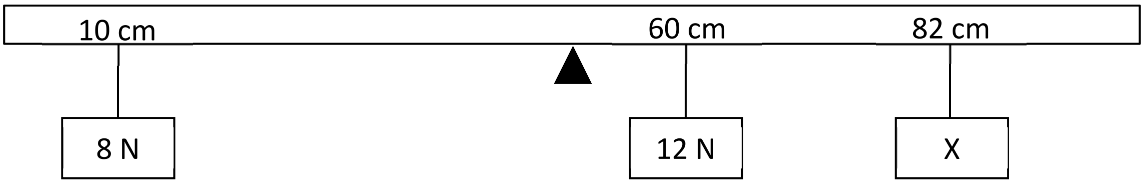
Answer **five** questions from this section.
Each question carries 56 marks.

---

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

(*a*) Draw a labelled diagram to show the forces acting on a skydiver falling with a constant velocity.

(*b*) A horizontal metre stick is in equilibrium when a weight of 8 N hangs from the 10 cm mark, a weight of 12 N hangs from the 60 cm mark and an unknown weight (X) hangs from the 82 cm mark. The metre stick is supported at its centre of gravity, 50 cm. Calculate X.



(*c*) Heat energy can be transferred by conduction, convection and radiation. Distinguish between the three methods of heat transfer.

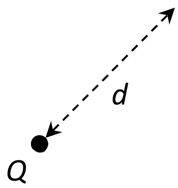
(*d*) A fire-engine travelling at a speed of 30 m s^{-1} emits a sound of frequency 2.3 kHz as it approaches an observer. Calculate the frequency observed.

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

(*e*) The refractive index of a material is 2.4. Calculate the speed of light in this material.

(*f*) Explain how electrons are (*i*) produced, (*ii*) accelerated in an X-ray tube.

(*g*) Write an expression for the electric field intensity E at a distance d from a charge Q.



(*h*) What are the charge carriers in (*i*) metals, (*ii*) gases, (*iii*) semiconductors?

(*i*) Calculate the effective resistance of a 5 Ω resistor and a 7 Ω resistor when they are connected in parallel.

(*j*) State (*i*) a physical quantity that is the same for a quark and its anti-quark and (*ii*) a physical quantity that is different for a quark and its anti-quark.

or

Draw the truth table for an AND gate.

(8 × 7)

6. The discus, long jump and pole vault are three of the ten events of the decathlon in track and field athletics. Sports biodynamics is the field of science that uses physics to study and model movement during athletic events.

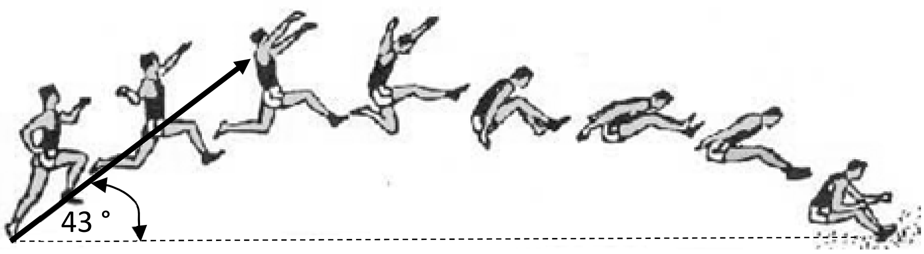
(*a*) During the discus event, Ashton swings a discus of mass 2.0 kg in uniform circular motion. The radius of orbit of the discus is 1.2 m and the discus has a velocity of 20.4 m s^{-1} when Ashton releases it.

(*i*) Derive an expression to show the relationship between the radius, velocity and angular velocity of an object moving in uniform circular motion.

(*ii*) Calculate the angular velocity of the discus immediately prior to its release.

(*iii*) Calculate the centripetal force acting on the discus just before Ashton releases it. In what direction does this force apply? (21)

(*b*) During the long jump, Ashton has a velocity of 10.9 m s^{-1} at an angle of 43° to the horizontal when he begins his jump.



He lands 1.03 seconds after he takes off.

Calculate

(*i*) his velocity in the horizontal direction,

(*ii*) the length of the jump. (12)

(*c*) During the pole vault event, Ashton has a horizontal speed of 9.2 m s^{-1} just before he jumps. He converts most of his kinetic energy into elastic potential energy in the pole and then into gravitational potential energy. At his maximum height he has a horizontal speed of 1.1 m s^{-1}.

(*i*) State the principle of conservation of energy.

(*ii*) What is meant by the centre of gravity of a body?

(*iii*) Ashton's centre of gravity when he is standing is 98 cm above the ground. During the vault, what is the maximum height above the ground to which he can raise his centre of gravity?

(*iv*) Draw a diagram to show any forces acting on Ashton when he is at his highest point, as shown in the photograph. (23)

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

7. Resonance is a phenomenon that is associated with musical instruments. What is resonance?

Describe an experiment to demonstrate resonance. (15)

A stretched string of a violin has a length of 328 mm and a mass of 0.126 g. The string emits a note of 660 Hz when it vibrates at its fundamental frequency.

Calculate

(*i*) the tension in the string,

(*ii*) the speed of sound in the string.

Draw a labelled diagram to represent the fundamental frequency of a stationary wave in a pipe that is closed at one end. (24)

Define sound intensity.

A source emits sound in all directions.

Describe the effect of doubling the distance from the source to an observer on

(*iii*) the sound intensity measured,

(*iv*) the sound intensity level measured. (17)

8. Explain the terms <u>nuclear fission</u> and <u>specific heat capacity</u>. (12)

Water can act as both a moderator and a coolant in a nuclear fission reactor.

What effect does a moderator have on the rate of fission?

How does a moderator have this effect?

In a nuclear reactor core, 5000 kg of water is heated so that its temperature increases by 70 K and it is converted into steam.

Calculate the energy absorbed by the water. (18)

In a fission reaction a neutron is absorbed by a uranium–235 nucleus. Barium–139 and krypton–94 nuclei are released as well as some neutrons.

Write a nuclear equation for this reaction.

Calculate the energy released, in MeV, in this reaction. (21)

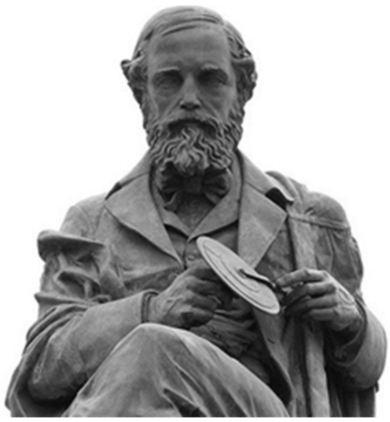
Nuclear fusion reactors could supply more energy than fission reactors. Explain why fusion reactors are not yet a practical source of energy on Earth. Give one other advantage that a fusion reactor would have over a fission reactor. (5)

(*specific heat capacity of water = 4180 J kg^{-1} K^{-1}*)

(*specific latent heat of vaporisation of water = 2.23 × 10^{6} J kg^{-1}*)

(*mass of barium–139 nucleus = 138.90884 u, mass of krypton–94 nucleus = 93.93436 u, mass of uranium–235 nucleus = 235.04393 u*)

9. James Clerk Maxwell, a Scottish physicist, is considered the greatest theoretical physicist of the nineteenth century.



Early in his career he investigated colour and light.

Maxwell created a colour triangle to illustrate the relationship between primary and secondary colours of light.

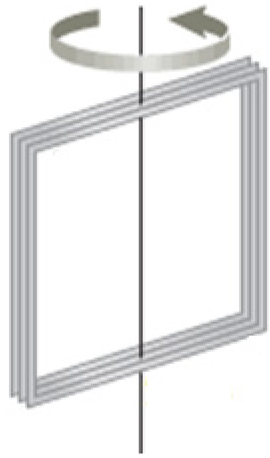
Using his triangle or otherwise (*i*) list the primary colours of light, (*ii*) name a pair of complementary colours of light. (9)

Maxwell later published equations that describe how electric charges and currents create electric and magnetic fields. He also described how a changing electric field can generate a changing magnetic field.

What is a magnetic field?

Draw labelled diagrams to show the magnetic field about (*iii*) a long straight current-carrying wire, (*iv*) a current-carrying solenoid. (12)

One of Maxwell's equations is equivalent to Faraday's law of electromagnetic induction.



State Faraday's law of electromagnetic induction.

Describe an experiment to demonstrate this law.

A square coil of 40 turns with a side of length 20 cm is perpendicular to a magnetic field of flux density 50 mT.

What is the average emf induced in the coil when it is rotated through 90° in ¼ of a second? (The axis of rotation connects the midpoints of opposite sides of the square, as shown.) (26)

Maxwell also showed that visible light is an electromagnetic wave and that some types of invisible waves belong in the electromagnetic spectrum too.

The eye is the sense organ that detects light. Where in the eye is light detected?

List two invisible parts of the electromagnetic spectrum that have a shorter wavelength than visible light. (9)

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

(*a*) Momentum, energy and charge are conserved in all nuclear reactions.

In beta-decay an unstable nucleus emits an electron.

In the early 20th century it was found that momentum and energy did not appear to be conserved during beta-decay. To solve this apparent problem, Wolfgang Pauli predicted the existence of an unknown particle, about which he said:

I have done a terrible thing. I have postulated a particle that cannot be detected.

Name the particle which Pauli predicted and explain how it solved the problem.

Write a nuclear equation for beta-decay.

Why did Pauli think that the particle could not be detected? (21)

The conservation laws also apply to pair annihilation.

Pair annihilation can be described using the following equation for an electron and a positron at rest.

$$e^{0}_{-1} + e^{0}_{1} \rightarrow 2\gamma$$

Why are two gamma-ray photons produced?

Explain how charge is conserved in the annihilation.

Calculate the maximum frequency of each emitted photon. (23)

Electrons are negatively charged leptons. List the two other negatively charged leptons.

List the three forces that these leptons can experience, in decreasing order of strength. (12)

(*b*) Sketch current-time graphs to compare alternating current and direct current.

A rectifier circuit converts alternating current to direct current.

Draw a circuit diagram of a half-wave rectifier circuit.

Sketch a graph to illustrate the output current from a half-wave rectifier. (18)

An induction coil is used to increase the magnitude of d.c. voltage.

Draw a labelled diagram of an induction coil.

Describe how the induction coil can be used to increase d.c. voltage. (18)

An induction coil is not used to increase a.c. voltage.

Name the device used to increase a.c. voltage.

Draw a labelled diagram of this device.

Describe how this device can be used to increase a.c. voltage. (20)

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

The Irish Low Frequency Array, or I-LOFAR, is part of a €150 million network of radio telescope stations spread across seven European countries. It detects radio waves with wavelengths between 1.3 m and 30 m.

The system is used to study celestial objects such as the Sun, black holes, magnetic fields and emerging galaxies in the early universe.

I-LOFAR links into the international LOFAR network, which comprises thousands of antennae that record measurements at the lowest frequencies that can be observed from the Earth. This network comprises 51 stations and is the largest virtual radio telescope dish in the world; it has a diameter of 2000 km. Each station connects to a central core in the Netherlands via high-speed fibre optic cable.

I-LOFAR is run by a consortium of Irish astrophysicists, software engineers and data scientists. It is located at Birr Castle which has a long history in astronomy.

In 1845 the 3rd Earl of Rosse built the 15-metre long Leviathan, which was the biggest optical telescope in the world at the time and which remained so for 75 years. It was a reflecting telescope that contained a concave mirror with a focal length of 16 m.

An example of a modern telescope is the Hubble telescope, which is in low Earth orbit 570 km above the ground. It undergoes 15.1 orbits per day. Hubble's position allows it to take extremely high-resolution images.

Adapted from rte.ie and nasa.gov

(*a*) Calculate the minimum frequency of the radio waves detected by I-LOFAR.

(*b*) Draw a diagram of the magnetic field around the Earth.

(*c*) Explain how information is transmitted using optical fibres.

(*d*) Calculate the position of the image of a person standing 75 cm from the Leviathan mirror.

(*e*) Where, with respect to the concave mirror, will an image of the moon be formed? Justify your answer.

(*f*) A concave mirror can also be used as a microscope to magnify images. Draw a ray diagram to show the formation of an upright, magnified image in a concave mirror.

(*g*) Calculate the velocity of the Hubble telescope as it orbits the Earth.

(*h*) Name one optical phenomenon which reduced the effectiveness of the Leviathan and which is eliminated by the location of the Hubble telescope. How does the location of the Hubble telescope eliminate this problem?

(radius of the Earth = 6400 km)

(8 × 7)

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

(*a*) A simple pendulum can execute <u>simple harmonic motion</u>.
Explain the underlined term.

When does a simple pendulum execute simple harmonic motion?

What is the relationship between the period and the length of a simple pendulum? (12)

A stretched spring can also execute simple harmonic motion.
A spring has a natural length of 50 cm.
A mass of 60 g is hung from the spring and the mass is allowed to oscillate with simple harmonic motion.
It has a period of oscillation of 0.85 seconds.

Calculate

(*i*) the spring constant,

(*ii*) the length of the spring when the mass is at rest. (16)

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

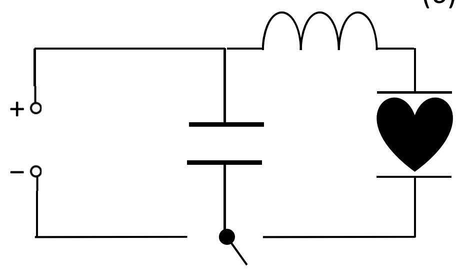
(*b*) The radioactivity of an isotope of radon was measured each day for a week and the following data were recorded.

Time (days)	0	1	2	3	4	5	6	7
Activity (MBq)	600	490	400	330	270	220	180	150

What is meant by radioactivity? (6)

On graph paper, draw a decay curve (a graph of activity against time).
Use the decay curve to determine the half-life of the isotope.
Calculate the number of nuclei in the sample at the beginning of the investigation. (22)

(*c*) Define capacitance and state its unit. (6)



A capacitor is an important component of a defibrillator. A simple defibrillator circuit is shown.

Each plate of a parallel plate capacitor in a defibrillator stores a charge of 0.11 C when a potential difference of 4.0 kV is applied across it.

Calculate the energy stored in the capacitor.

What is the net charge of the capacitor when it stores this energy?

The capacitor discharges in a time of 15 ms. Calculate the average current flowing as the capacitor discharges.

Draw a diagram of the electric field between the charged plates of a parallel plate capacitor. (22)

(*d*) A typical solar panel consists of a sandwich made of a p-n junction surrounded by a pair of conductors. When light falls on the solar panel, the photoelectric effect occurs and a current flows.

What is a p-n junction?

In 1921, Albert Einstein was awarded the Nobel Prize in Physics for his explanation of the photoelectric effect. Outline his explanation. (15)

The work function of iron is 4.7 eV. Calculate the maximum kinetic energy of an emitted electron when ultraviolet radiation of wavelength 200 nm is incident on iron. (13)

There is no examination material on this page.