Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2026

PHYSICS – HIGHER LEVEL

WEDNESDAY, 17TH JUNE – MORNING, 9:30 TO 12:30

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

Do not hand this up.

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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.

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1. In an experiment to verify Boyle's law, a student measured the volume V of a fixed mass of gas at different values of the pressure p. The temperature was kept constant.

The following data were recorded.

p (kPa)	100	120	140	160	180	220
V (cm^3)	52	43	36	32	29	23

(*i*) (*a*) Draw a labelled diagram to show how the apparatus was arranged in this experiment.

(*b*) Describe the steps that the student could have used to determine the volume V and the pressure p readings.

(*ii*) How could the student have ensured that the temperature of the gas was kept constant?

(18)

(*iii*) Draw a suitable graph to show the relationship between the pressure and the volume of the gas.

(*iv*) Explain how your graph verifies Boyle's law.

(*v*) Sketch a graph to show the relationship between pV and p for the gas. (22)

2. A simple pendulum consisting of a light inextensible string and a small heavy bob was set up so that it could swing freely about a fixed point. The length l of the pendulum was measured and the pendulum was allowed to oscillate through a small angle. The time t for 25 oscillations was recorded. This procedure was repeated for different values of l.

The following data were recorded.

l (cm)	40.0	50.0	60.0	70.0	80.0	90.0
t (s)	32.0	35.4	38.8	42.5	44.8	47.5

(*i*) Suggest a reason why the student measured the time for 25 oscillations instead of just one oscillation.

(*ii*) Describe, with the aid of a labelled diagram, how

(*a*) the pendulum was set up so that it swung freely about a fixed point,

(*b*) the student determined the length of the pendulum.

(*iii*) Explain why

(*a*) the student used a small heavy bob,

(*b*) the student used a small angle. (18)

(i*v*) (*a*) Draw a suitable graph to show the relationship between the period and the length of the simple pendulum.

(*b*) State this relationship.

(*v*) Use your graph to calculate the acceleration due to gravity, g. (22)

3. In an experiment to measure the wavelength of a narrow beam of monochromatic light, the angle θ between the central bright image (n = 0) and the first and second order images on both the left and right sides were measured. A diffraction grating with 400 lines per mm was used.

The following data were recorded.

	left	left	centre	right	right
n	2	1	0	1	2
θ (degrees)	28.2	13.7	0	13.8	28.3

(*i*) (*a*) Draw a labelled diagram to show how the apparatus was arranged in this experiment.

(*b*) Describe the method the student used to obtain the data.

(*ii*) State one precaution the student should take when carrying out the experiment. (18)

(*iii*) Use all of the data to calculate an average value for the wavelength of the light.

(*iv*) Describe the effect that each of the following changes would have on the position of the bright images formed.

(*a*) A light source with a shorter wavelength is used.

(*b*) A diffraction grating with fewer lines per mm is used.

(*v*) Describe the pattern produced if a narrow beam of white light is used instead of the monochromatic light. (22)

4. In an experiment to measure the specific latent heat of vaporisation of water, a student used a copper calorimeter containing water. Before introducing dry steam to the water in the calorimeter, the water was cooled to a temperature below room temperature.

The following data were recorded.

mass of copper calorimeter (g)	64.6
initial mass of calorimeter + water (g)	144.7
final mass of calorimeter + water + condensed steam (g)	145.8
initial temperature of calorimeter and cooled water (°C)	13
final temperature of calorimeter and water (°C)	21

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

(*ii*) Why is it important to use dry steam in this experiment?

(*iii*) How was the steam dried?

(*iv*) Suggest a reason why the water in the calorimeter was initially cooled below room temperature.

(*v*) Why is the rise in temperature the least accurate value? (21)

(*vi*) Use the data given to calculate

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

(*b*) the mass of steam used,

(*c*) the specific latent heat of vaporisation of water. (19)

specific heat capacity of water = 4180 J kg^{-1} K^{-1}; specific heat capacity of copper = 385 J kg^{-1} K^{-1}

5. In an experiment to investigate how the resistance *R* of a metallic conductor varies with its temperature θ, a student measured the resistance of a wire at different temperatures.

The following data were recorded.

θ (°C)	10	20	30	40	50	60
R (mΩ)	29.5	30.7	31.9	33.1	34.3	35.5

(*i*) Draw a labelled diagram to show how the apparatus was arranged in this experiment.

(*ii*) Draw a suitable graph to show the variation of *R* with θ.

(*iii*) Use your graph to determine the resistance of the wire when its temperature is 25 °C. (21)

The wire has a length of 37 cm. The diameter of the wire is 0.5 mm.

(*iv*) Describe how the student measured the diameter of the wire.

(*v*) State one experimental precaution that should be taken when determining the length of the wire.

(*vi*) Calculate the resistivity of the wire at 25 °C. (19)

SECTION B (280 MARKS)

Answer **five** questions from this section.

Each question carries 56 marks.

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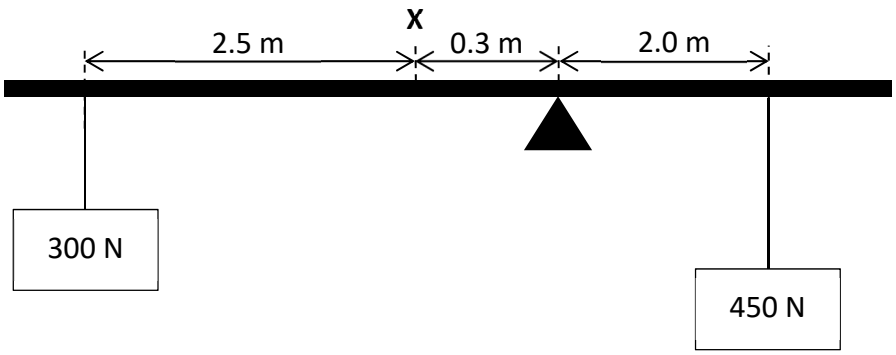
6. Answer any **eight** of the following parts, (*a*), (*b*), (*c*), etc.

(*a*) Draw a vector diagram to explain what is meant by friction.

(*b*) The diagram shows weights hanging from a uniform wooden plank at given distances. The plank is balanced on a triangular block as shown. It is in stationary equilibrium. **X** marks the centre of gravity of the plank. Calculate the mass of the plank.



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

(*c*) Describe an experiment to demonstrate Archimedes' principle.

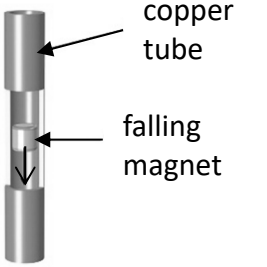
(*d*) The motion of a body undergoing simple harmonic motion is described by the equation $a = -\pi^2 s$. Calculate the period of its motion.

(*e*) Distinguish between heat and temperature.
Your answer should reference a distinguishing characteristic of each.

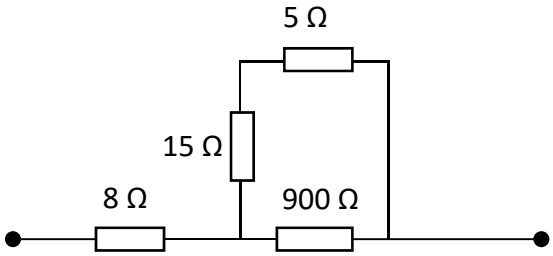
(*f*) 66 000 m^3 of water goes over the Victoria Falls every minute.
The water falls through a vertical height of 108 m.
Calculate the power generated by the water.

acceleration due to gravity = 9.8 m s^{-2};
density of water = 1.0 × 10^3 kg m^{-3}

(*g*) Explain why a strong magnet falling through a copper tube falls more slowly than a similar-sized piece of non-magnetised steel falling through the same copper tube.



(*h*) Calculate the effective resistance of the arrangement of the resistors shown below.



(*i*) State three factors that affect the amount of heat produced in a current-carrying conductor.

(*j*) Carbon–12 (C–12) which is necessary for life on Earth can be formed from alpha particles in a process called the triple-alpha process. The process can be described by this simplified nuclear equation.

$$3{}^{4}_{2}\alpha \rightarrow {}^{12}_{6}C$$

alpha particle mass = 6.644656 × 10^{-27} kg; C–12 nucleus mass = 1.992101 × 10^{-26} kg

Calculate the energy released in this reaction.

(*k*) The energy of a photon of light is 3.75 × 10^{-19} J. Calculate the wavelength of the light.

(*l*) (*i*) State two reasons why it is difficult to detect a neutrino.

or

(*ii*) State two factors that affect the efficiency of a transformer.

(8 × 7)

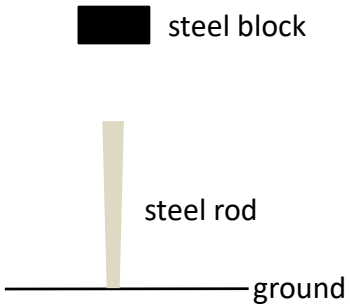
7. (*i*) Explain what is meant by

(*a*) momentum,

(*b*) force.

(*ii*) Use Newton's second law of motion to derive the relationship between force, mass and acceleration. (19)

A pile driver is used to sink steel rods, known as piles, into the ground. During the operation of a pile driver, a steel block of mass 500 kg is released from rest and falls through a height onto the top of a stationary steel rod.



(*iii*) The steel block falls for 1.01 s before striking the steel rod. Calculate the distance that the steel block has fallen.

After the steel block strikes the steel rod, the block bounces vertically upwards. The steel block rises by a maximum vertical displacement of 1.8 cm. The steel rod of mass 1500 kg is driven vertically downwards into the ground.

(*iv*) Calculate the upward velocity of the steel block immediately after the collision.

(*v*) Calculate the downward velocity of the steel rod immediately after the collision.

(*vi*) The steel rod takes 2 ms to come to rest. Calculate the average force exerted by the ground on the steel rod to bring it to rest. (27)

The pile driver generates a loud sound as the steel block strikes the steel rod. At a certain distance *d* from the pile driver, an observer can measure both the sound intensity and the sound intensity level due to the sound generated.

(*vii*) The observer moves to a distance 4*d* from the pile driver. Describe the effect on

(*a*) the sound intensity measured,

(*b*) the sound intensity level measured. (10)

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

8. Philosophers have struggled to explain exactly what light is and why it behaves as it does. The laws of reflection were known to ancient Greeks while the laws of refraction were discovered in 1621. These phenomena can be explained through the principles of geometric optics. Later, Dutch mathematician, Christiaan Huygens, proposed that light was a wave motion.

Let There Be Light by Alex Montwell and Ann Breslin

(*i*) Explain what is meant by reflection of light.

(*ii*) An object is placed in front of a concave mirror which has a focal length of 20 cm. An image that is half the size of the object is formed.
Calculate the position of the object.

(*iii*) Suggest a reason why a dentist may choose a concave mirror over a convex mirror when examining teeth. (15)

Lenses work due to the refraction of light.

(*iv*) Draw a ray diagram to show how a virtual image can be formed by a converging lens.

An underwater lamp is placed at a depth of 0.5 m in a pool of water. When the lamp is switched on at night, a circular disc of light becomes visible on the surface of the water.

(*v*) Explain why the region on the surface of the water surrounding the circular disc of light remains dark.

(*vi*) The diameter of the circular disc is 1.14 m. Calculate the refractive index of the water.

(*vii*) Using a labelled diagram explain why the underwater lamp does not appear to be at a depth of 0.5 m when viewed by an observer outside the pool. (32)

Light travels as a transverse wave.

(*viii*) Describe an experiment to demonstrate that light waves are transverse waves. (9)

9. The music produced by a violin and an organ is due to vibrations in the air caused by oscillations within the instruments themselves. For the violin the bow causes a string to oscillate, while for the organ air is blown into pipes to create vibrations. Both instruments generate stationary waves with resonance playing a key role. Each note has unique characteristics.

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

(*ii*) Describe an experiment to demonstrate resonance. (15)

The fundamental frequency of a stretched string depends on the tension in the string as well as two other factors.

(*iii*) (*a*) Name these two factors.

(*b*) State the relationship between the fundamental frequency and each of these two factors.

(*iv*) A violin string is initially tuned to a fundamental frequency of 250 Hz under a tension of 10 N. Calculate the new tension required to adjust the fundamental frequency to 375 Hz assuming the tension is the only factor being changed.

(*v*) State one condition necessary for a stationary wave to form on a stretched string. (22)

In an organ the pipes can act as if they are open at both ends, or open at one end and closed at the other end.

(*vi*) Draw a labelled diagram to show the standing wave formed in a pipe that is open at one end and closed at the other end when it is vibrating at its third harmonic.

(*vii*) A pipe that is open at both ends has a length of 2.3 m and it generates a particular fundamental frequency. A second pipe that is open at one end and closed at the other end generates the same fundamental frequency.
Calculate the length of the second pipe.

(*viii*) Suggest a reason why the same musical note can have a different quality when played on different instruments. (19)

10. A parallel-plate capacitor consists of two metal plates separated by an insulating layer called a dielectric. It is designed to store separated electric charge, and so store energy.

(*i*) Explain what is meant by

(*a*) capacitance,

(*b*) potential difference.

(*ii*) Describe the movement of electrons when an uncharged parallel-plate capacitor is connected to a battery.

(*iii*) Describe a demonstration to show that a charged capacitor can store energy. (26)

A student carried out an experiment to verify the relationship between the capacitance C of a parallel-plate capacitor and the distance d between its plates. The area A of the plates was kept constant and a dielectric of permittivity ε was used, where $\varepsilon = 8.85 \times 10^{-12}$ F m^{-1}.

The student's results are shown in the following table.

d (m)	0.021	0.042	0.063	0.084	0.105	0.124
C (F)	9.69×10^{-12}	4.85×10^{-12}	3.23×10^{-12}	2.42×10^{-12}	1.94×10^{-12}	1.64×10^{-12}

(*iv*) Draw a suitable graph on graph paper to show the relationship between the C and d.

(*v*) Calculate the slope of the graph and use it to calculate A. (18)

The circuit diagram shows a 200 µF capacitor connected in series with a 40 kΩ resistor, a switch, and a 12 V battery. At a certain moment after the switch is closed, the current in the circuit is measured to be 130 µA.

(*vi*) Calculate

(*a*) the potential difference across the capacitor at that moment,

(*b*) the energy stored in the capacitor at that moment. (12)

11. (*i*) State two properties of an electron.

(*ii*) For a cathode ray tube, describe

(*a*) how the beam of electrons is generated,

(*b*) where the electrons are given a linear acceleration.

The principle involved in a cathode ray tube was used in devices like older colour televisions. Three beams of electrons were used to produce the primary colours on a screen.

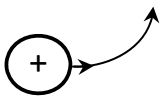
(*iii*) Explain how the primary colours of light can be combined to form

(*a*) a yellow colour,

(*b*) a white colour. (22)

(*iv*) Derive the formula $F = qvB$ for the force F acting on a particle with charge q moving with a velocity v perpendicular to a magnetic field of magnetic flux density B.

A positively charged particle enters a magnetic field with its direction of travel perpendicular to the field. The path of the positively charged particle just after it enters the magnetic field is shown below.



(*v*) Using Fleming's left-hand rule, or otherwise, determine the direction of the magnetic field.

An electron in a cathode ray tube starts from rest and is accelerated to a speed of 2.66×10^7 m s^{-1}.

(*vi*) Calculate the voltage in the tube.

An electron travels with a speed of 2.66×10^7 m s^{-1} and enters a uniform magnetic field with a magnetic flux density of 2 mT perpendicular to its direction of motion.

(*vii*) Calculate the force on the electron due to the magnetic field.

(*viii*) Calculate the radius of curvature of the circular path followed by the electron. (34)

12. Radioactivity was first discovered by Henri Becquerel in 1896 when he observed that a uranium salt darkened a nearby photographic plate, even without exposure to sunlight. He concluded that uranium was emitting an unknown type of radiation. Subsequent research revealed that three distinct types of nuclear radiation can be emitted: alpha, beta, and gamma rays.

(*i*) Explain what is meant by each type of nuclear radiation: alpha, beta, and gamma.

(*ii*) Compare each type of radiation under the following headings:

(*a*) ionising ability,

(*b*) deflection in a magnetic field.

(*iii*) (*a*) Name one type of detector used to detect nuclear radiation.

(*b*) Describe the principle of operation of the detector. (24)

In a radioactive decay series thorium–232 (Th–232) decays to thorium–228 (Th–228).

(*iv*) Calculate how many

(*a*) alpha particles are emitted,

(*b*) beta particles are emitted.

An alpha particle emitted by Th–232 has a kinetic energy of 1.47×10^{-12} J and travels a distance through the air. As it moves, it produces ion pairs by colliding with molecules of the air.

(*v*) Given that the energy needed to create one ion pair is 5.6×10^{-18} J, calculate the maximum number of ion pairs that could be produced by the alpha particle due to its kinetic energy.

(*vi*) Explain what is meant by

(*a*) half-life,

(*b*) the becquerel (Bq).

Polonium was discovered by Marie and Pierre Curie in 1898.

A 210 g sample of polonium–210 contains 6.0×10^{23} nuclei. The decay constant of polonium–210 is 5.8134×10^{-8} s^{-1}.

(*vii*) Calculate the activity of a 3.0 mg sample of polonium–210.

(*viii*) Estimate by calculation how many nuclei of polonium–210 remain in the 3.0 mg sample after 276 days. (32)

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

Let's look at what your home could look like by 2030.

Imagine arriving at your home, greeted by sleek solar panels integrated into your roof, harnessing Ireland's sunlight and storing excess energy in state-of-the-art batteries. Solar panels generate DC and are known as photovoltaic (PV) modules. Solar PV systems are rated in kW and made from a variety of semiconductor materials e.g. silicon. In Ireland, the maximum intensity of solar radiation that reaches these solar panels is 1196 W m^{-2}.

Heat pumps quietly and efficiently regulate the temperature of your home. They extract heat from the air or ground (even in cold temperatures) and use it to warm your living spaces.

Imagine parking your electrical vehicle (EV) in your garage, where it seamlessly connects to your home's energy system. When electricity demand and prices are lower during off-peak, your EV charges automatically. Vehicle-to-grid (V2G) lets you use the car's battery to power your home, which uses AC, or sell electricity back to the grid.

The house of 2030 will feature very low U-values and average values of 0.1 W m^{-2} K^{-1} will guarantee exceptional thermal insulation and energy efficiency. This high level of insulation will reduce heat loss and help maintain a steady indoor temperature.

The lighting in your home will be more efficient and integrated into a smart home system. Ultra efficient LEDs will be the standard.

Adapted from Sustainable Energy Authority of Ireland

(*i*) Silicon is classed as a semiconductor. Explain what is meant by a semiconductor. (7)

(*ii*) A 10 W LED bulb gives out the same light as a 60 W filament bulb.

(*a*) What do the letters in the acronym LED stand for?

(*b*) Calculate how much energy is saved in one hour by using a 10 W LED bulb in place of a 60 W filament bulb. (7)

(*iii*) Sketch voltage-time graphs for

(*a*) the output from a solar panel,

(*b*) the input from the national grid, which is used in our homes. (7)

(*iv*) The lithium-ion battery in an electric car has a capacity of 75 kWh, which is sufficient to power a house during the night.

(*a*) Calculate how long would it take to give an electric car 75 kWh using a 7.2 kW home charger.

(*b*) What type of energy conversion takes place when the car powers the home?

(*c*) Calculate the average current drawn if the V2G provides a peak AC voltage of 328 V to power a 2 kW electric kettle. (14)

(*v*) A single solar panel covers an area of 0.9 m^2. The efficiency of the solar panel is 25%. Calculate the maximum power generated by the solar panel in Ireland. (7)

(*vi*) State two desirable properties of a refrigerant fluid used in a heat pump. (7)

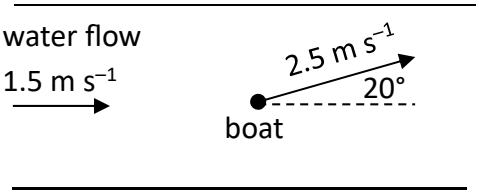
(*vii*) The temperature inside the home described is 21 °C and the temperature outside is 10 °C. Calculate the average rate of heat loss per square metre. (7)

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

(*a*) (*i*) Explain what is meant by a vector quantity.

(*ii*) Describe a laboratory experiment to find the resultant of two vectors. (15)

A river flows with a velocity of 1.5 m s^{-1} downstream. A boat propels itself with a velocity of 2.5 m s^{-1} at an angle of 20° to the flow of the water, as shown in the diagram.



(*iii*) (*a*) Resolve the velocity of the boat into parallel and perpendicular components relative to the water flow.

(*b*) Calculate the magnitude and the direction of the resultant velocity of the boat. (13)

(*b*) (*i*) Explain what is meant by

(*a*) angular velocity,

(*b*) frequency.

When a sound-emitting source moves towards a stationary observer, the frequency of the note appears to change.

(*ii*) State the name of this phenomenon. (13)

A whistle which is emitting a note of frequency 1.1 kHz is swung in a horizontal circle at the end of a string 1.3 m long with a constant angular velocity of 24 rad s^{-1}.

(*iii*) (*a*) Calculate the minimum frequency heard by a person standing some distance away.

(*b*) State the observed frequency at the centre of the circle. (15)

velocity of sound in air = 340 m s^{-1}

(*c*) (*i*) Describe how charge is distributed on a pear-shaped conductor.

(*ii*) Describe an experiment that demonstrates how charge is distributed over the surface of a pear-shaped conductor.

(*iii*) Explain why it is not possible to charge the dome of a Van de Graaff generator to a very high voltage when a pointed object is attached to it. (19)

A positive and a negative point charge are placed a distance apart in a vacuum, as shown in the diagram below. The electric field strength at **X** due to the positive charge is 2.3×10^3 N C^{-1}. The electric field strength at **X** due to negative charge is 4.5×10^3 N C^{-1}.

(*iv*) Draw a diagram to show the electric field due to the two charges.

(*v*) Calculate the electric field strength at **X**. (9)

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

Part (*a*)

The following reaction represents the pair annihilation of a proton p, and an anti-proton $\bar{p}$

$$p + \bar{p} \rightarrow 2\gamma$$

(*i*) Explain what is meant by anti-matter.

(*ii*) Explain how the quark model can be used to predict the charge of an anti-proton.

(*iii*) Express the minimum frequency *f* of the gamma rays emitted during this pair annihilation, in terms of the mass of a proton *m*, the speed of light *c*, and the Planck constant *h*. (16)

Two protons are at a distance of 1.5 fm from each other in a nucleus.

(*iv*) Given that, at this distance, the strong nuclear force between the two protons is 120 times stronger than the force due to their charge, calculate

(*a*) the strong nuclear force between the two protons,

(*b*) how many times stronger this strong nuclear force is than the gravitational force between the two protons. (12)

Part (*b*)

(*i*) Explain what is meant by a bi-polar transistor.

(*ii*) State the relationship between the base current, the collector current and the emitter current. (10)

(*iii*) (*a*) Draw a circuit diagram to show how a transistor can be used as a voltage amplifier.

(*b*) Label the input voltage and the output voltage in your circuit diagram.

(*iv*) State one example of a device that uses a voltage amplifier. (18)

Acknowledgements

Images

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Leaving Certificate Examination – Higher Level

Physics

Wednesday, 17 June

Morning, 9:30 – 12:30