



**Coimisiún na Scrúduithe Stáit
State Examinations Commission**

LEAVING CERTIFICATE EXAMINATION, 2016

PHYSICS – HIGHER LEVEL

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

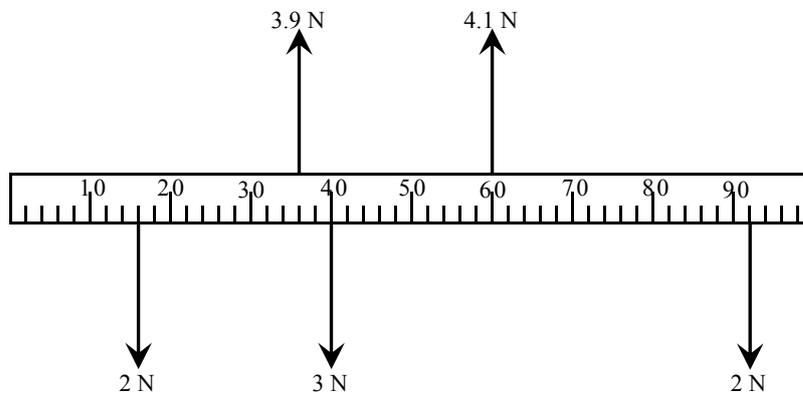
Answer **three** questions from **Section A** and **five** questions from **Section B**.

SECTION A (120 marks)

Answer **three** questions from this section.

Each question carries 40 marks.

1. In an experiment to verify the laws of equilibrium, the centre of gravity and the weight of a metre stick were found. The centre of gravity of the stick was at the 50.2 cm mark and its weight was 1.1 N. A number of forces were then applied to the metre stick, as shown in the diagram. The metre stick was horizontal and stationary.



Explain how

- the centre of gravity was found
- the weight of the metre stick was found
- the upward forces and downward forces were determined.

Give one possible reason why the centre of gravity is not at the 50.0 cm mark. (16)

Use the data given to calculate

- the net force acting on the metre stick
- the sum of the moments about the 40 cm mark of the metre stick.

Explain how your calculations verify the laws of equilibrium. (24)

2. A student investigated the variation of f , the fundamental frequency of a stretched string, with its length l . The string was kept at a constant tension of 8.5 N.

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

Indicate on your diagram the measured length of the string. (12)

The following data were recorded.

f (Hz)	256	288	320	341	384	427	480	512
l (cm)	51.3	42.6	39.2	37.7	34.5	30.3	26.0	25.0

Draw a suitable graph to illustrate the relationship between f and l .

State the relationship and explain how the graph verifies it. (18)

Use your graph to calculate

- (i) the length of the string at a frequency of 192 Hz
(ii) the mass per unit length of the string. (10)

3. In an experiment to measure the wavelength of monochromatic light, the angles θ between a central bright image ($n = 0$) and the first and second order images to the left and right were measured.

A source of monochromatic light and a diffraction grating of 500 lines per mm were used.

Describe, with the aid of a labelled diagram, how the data were obtained. (15)

The following data were recorded.

n	2 (left)	1 (left)	1 (right)	2 (right)
θ (degrees)	36.2	17.2	17.1	36.1

Use the data to calculate

- (i) the wavelength of the light
(ii) the maximum number of images that could be observed. (18)

Explain what would happen to the positions of the images if

- (i) the wavelength of the light was decreased
(ii) the diffraction grating was replaced with a diffraction grating of 300 lines per mm. (7)

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

The following data were recorded:

resistance of wire	= 29.1 Ω
length of wire	= 95.1 cm
diameter of wire	= 0.21 mm

Describe how the data were collected.

How did the student ensure that the wire was of uniform diameter? (12)

Use the data to calculate the resistivity of nichrome. (10)

The student then used a piece of this nichrome wire in an experiment to investigate the variation of the resistance of the piece of wire with its temperature.

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

The student drew a graph to show the relationship between resistance and temperature.

Draw a sketch of the graph. Describe this relationship. (18)

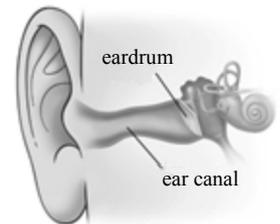
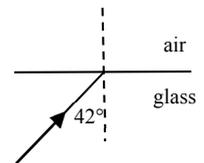
SECTION B (280 marks)

Answer **five** questions from this section.

Each question carries 56 marks.

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

- (a) A cyclist's average power output when climbing a mountain is 280 W. He completes the climb in 18 minutes. How much energy does he use?
- (b) A sprinter starts from rest and accelerates uniformly for 3 seconds until she reaches a velocity of 10 m s^{-1} . She then runs at a constant velocity for 6 seconds before decelerating. Sketch a velocity-time graph of her motion.
- (c) In your answer book copy the diagram on the right, which shows a light ray incident on the interface between glass and air. In your diagram, sketch (i) the refracted ray, (ii) the weak reflected ray. The critical angle of the glass is 42° .
- (d) What is meant by the polarisation of a wave?
- (e) The ear canal acts as a cylindrical pipe closed at one end. It is of average length 2.3 cm. The speed of sound in air is 340 m s^{-1} . What is the fundamental frequency of the ear canal?
- (f) State and define the SI unit of capacitance.
- (g) Why is it more economical to transmit electrical energy at high-voltage?
- (h) When does the photoelectric effect occur?
- (i) The magnets in the Large Hadron Collider (LHC) operate at a temperature of 1.92 K, which is colder than deep space. What is the value of this temperature in degrees Celsius ($^\circ\text{C}$)?
- (j) Experiments in the LHC in 2016 have suggested the existence of pentaquarks, hadrons that consist of five quarks. What terms are used for hadrons that consist of (i) two quarks, (ii) three quarks?



or

Draw a labelled diagram of an electromagnetic relay.

(8 × 7)

6. A mass at the end of a spring obeys Hooke's law. The mass can be made to oscillate vertically, so that it executes simple harmonic motion.

Explain the underlined term.

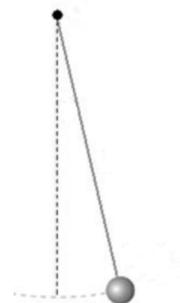
State Hooke's law.

Use Hooke's law to show that the mass executes simple harmonic motion. (14)

A simple pendulum also executes simple harmonic motion. The time taken for each oscillation of a certain simple pendulum on the Earth's surface is 2 s. The weight of its bob is 3.5 N. The bob travels along a curved path. It travels a distance of 18 cm during each oscillation.

Calculate

- (i) the length of the pendulum
- (ii) the maximum angular displacement of the pendulum.



Draw a diagram to show the forces acting on the bob when it is at its maximum displacement.

Calculate the restoring force at this point. At what point during its movement does the bob have its greatest angular velocity? (30)

The period of a simple pendulum varies with its height above the surface of the Earth. At what height will the period of a simple pendulum be 2% more than the period of a simple pendulum of the same length at the Earth's surface? Show your work clearly. (12)

(acceleration due to gravity at the Earth's surface = 9.8 m s^{-2} ; radius of Earth = 6371 km)

7. At a lecture in Cork in 1843, James Joule, while describing his work on heat and temperature, suggested the principle of conservation of energy. Later in the nineteenth century, the work of Joule and Lord Kelvin led to the invention of the heat pump.

Distinguish between heat and temperature. State the principle of conservation of energy. (10)

As part of his presentation, Joule proposed that the temperature of the water at the bottom of the Niagara Falls would be $0.12 \text{ }^\circ\text{C}$ greater than that at the top, due to gravitational potential energy being converted into heat energy. Calculate the height of the Niagara Falls.

In reality the increase in temperature will be much smaller. Suggest a reason for this. (12)

In a heat pump, a fluid is used to transfer energy from a cold body to a warmer body.

Describe the operation of a heat pump and explain how a heat pump can be used to reduce the temperature of a cold region, for example the interior of a refrigerator.

State two desirable physical properties of the fluid used in a heat pump. (18)

The fluid in the heat pump of a refrigerator has a specific latent heat of vaporisation of 4.6 MJ kg^{-1} . The internal volume of the refrigerator is 0.6 m^3 . The heat pump removes 12 kJ of energy from the air in the refrigerator as the fluid evaporates.

Calculate

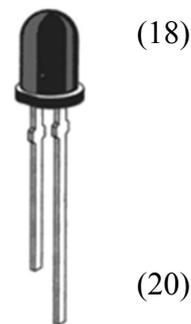
- (i) the mass of fluid that has evaporated
- (ii) the fall in temperature of the air in the refrigerator. (16)

(specific heat capacity of water = $4200 \text{ J kg}^{-1} \text{ K}^{-1}$; acceleration due to gravity = 9.8 m s^{-2} ;
density of air = 1.23 kg m^{-3} ; specific heat capacity of air = $1005 \text{ J kg}^{-1} \text{ K}^{-1}$)

8. What is a semiconductor?

Distinguish between intrinsic and extrinsic conduction in a semiconductor.

Explain how a pure semiconductor can be converted into (i) a p-type and (ii) an n-type semiconductor.

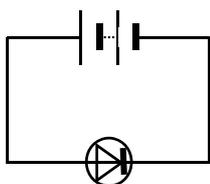


A semiconductor p-n junction acts a diode.

Describe, with the aid of a labelled diagram, how a depletion layer is formed at the p-n junction. What is a depletion layer?

Indicate on your diagram the sections of the p-n junction that are positively charged, negatively charged and neutral.

(20)



A diode will be damaged if too large a current flows through it when it is connected in forward bias.

Explain how a diode might be protected from having too large a current flowing through it when it is connected across a battery, as in the diagram.

What would be the effect on the current flowing in this diode if the terminals of the battery were reversed? Explain your answer.

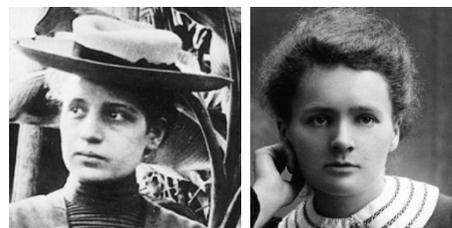
A diode can be used as a rectifier. What is the function of a rectifier?

What property of a diode makes it useful in a rectifier circuit?

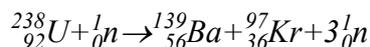
(18)

9. Lise Meitner and Marie Curie are the only women scientists to have elements named after them.

In the case of Meitner this was for her work on fission and in the case of Curie it was for her discovery of radium and her work on radioactivity. Explain the underlined terms. (12)



The following is the nuclear equation of a fission reaction explained by Meitner.



Calculate the energy released during this reaction.

How many of the neutrons emitted in a fission reaction must, on average, cause a further fission so that the reaction is self-sustaining and safe? Explain your answer.

The neutrons emitted are sometimes passed through a moderator. Explain the function of the moderator. (24)

Radium-225 is a radioactive isotope that decays into an isotope of actinium.

Write a nuclear equation for the decay of radium-225.

Radium-225 has a half-life of 14.9 days.

Calculate the number of radium-225 nuclei in a sample that has an activity of 5600 Bq. (20)

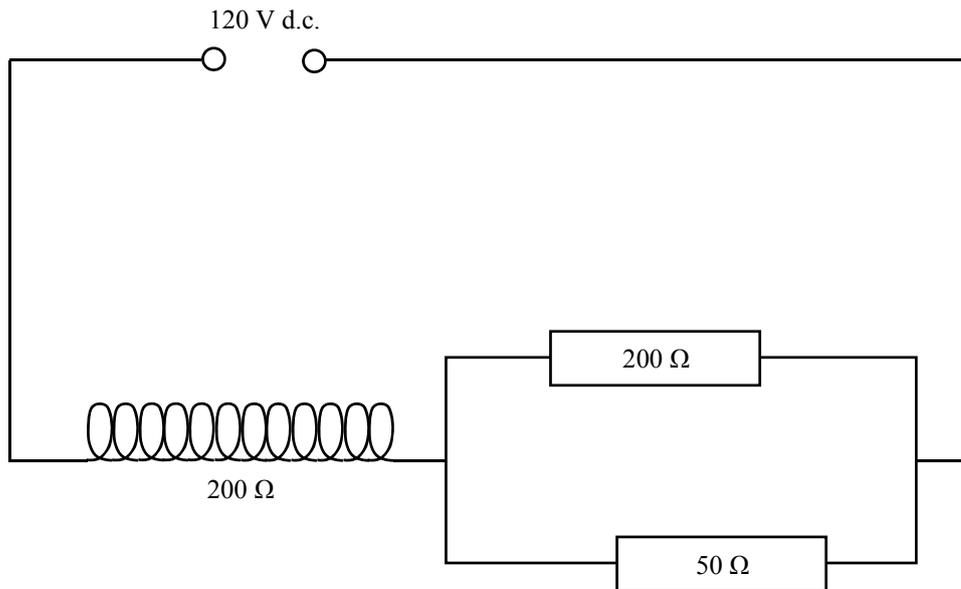
$$\begin{aligned} (\text{Nuclear masses: } U-238 &= 3.9529 \times 10^{-25} \text{ kg; } Ba-139 = 2.3066 \times 10^{-25} \text{ kg;} \\ Kr-97 &= 1.6099 \times 10^{-25} \text{ kg}) \end{aligned}$$

10. State Faraday's law of electromagnetic induction.
Describe an experiment to demonstrate this law. (15)

Derive an expression for the effective resistance of two resistors in parallel. (11)

A coil consists of 150 turns of wire and has a total resistance of $200\ \Omega$.

It is connected in series with a 120 V d.c. power supply and a parallel combination of a $200\ \Omega$ and a $50\ \Omega$ resistor, as shown.



Calculate the current in

- (i) the coil
- (ii) the $50\ \Omega$ resistor. (15)

The d.c. supply is then replaced with an a.c. supply.

It takes 3 ms for the magnetic flux cutting the coil to increase by 4.5×10^{-4} Wb.

The average voltage of the a.c. supply during this time period is 120 V.

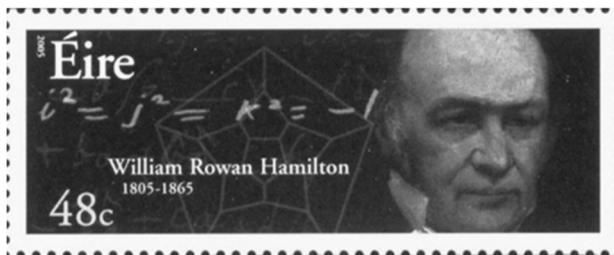
Calculate

- (i) the average emf induced in the coil during the 3 ms time period
- (ii) the average current in the coil during this period. (15)

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

The story of theories of light nicely demonstrates the ways in which theories are used as science evolves. Some ideas are discarded while others are retained as approximations that are appropriate in certain circumstances.

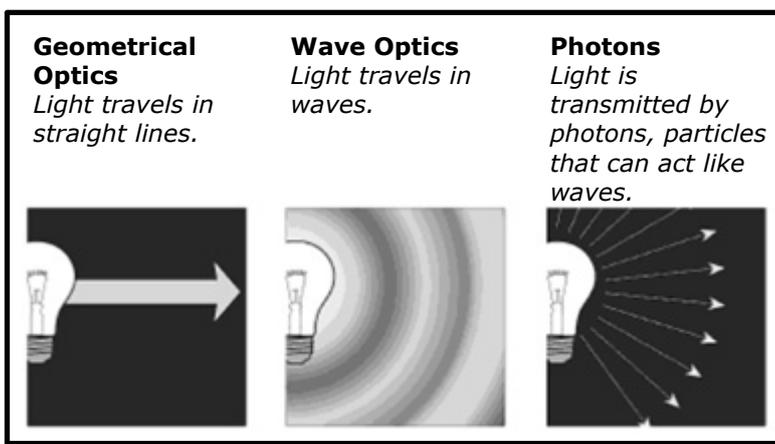
Geometrical optics hit its heyday in the nineteenth century when the Irish mathematician William Rowan Hamilton made a mathematical prediction about conical refraction that was later verified by his friend and colleague Humphrey Lloyd.



Geometrical optics, though clearly an approximation, is nonetheless a good description for a wave with wavelengths small enough for interference effects to be irrelevant. Ray diagrams can be used to explain refraction and reflection as well as in the fields of photography, medicine and astronomy.

Isaac Newton had developed a 'corpuscular' theory that was inconsistent with the wave theory of light developed by his rival Robert Hooke and by Christian Huygens. Thomas Young measured light interference, providing a clear verification that light had the properties of a wave.

However, later developments in quantum theory demonstrated that Newton was also correct in some sense. Quantum mechanics now tells us that light is indeed composed of individual particles called photons that are responsible for communicating the electromagnetic force. Quantum mechanics gives us our most fundamental description of what light is and how it interacts with matter.



(Adapted from *Knocking on Heaven's Door: How Physics and Scientific Thinking Illuminate the Universe and the Modern World*, Lisa Randall, Random House, 2011)

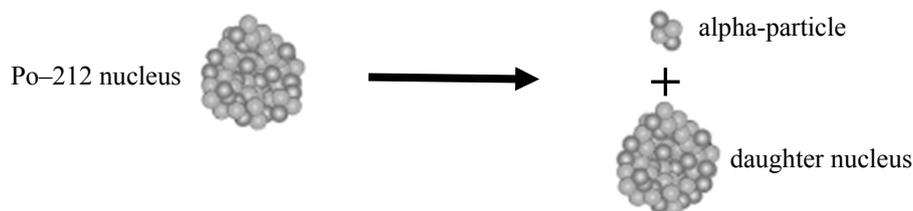
- (a) State the laws of refraction.
- (b) Draw a ray diagram to show the formation of a virtual image in a magnifying glass.
- (c) Explain what is meant by the term wavelength.
- (d) As part of his investigations into light, Newton dispersed light with a prism. List the colours observed by Newton, in order, starting with the colour that was refracted the least.
- (e) In Young's experiment to demonstrate the wave nature of light he needed two coherent sources of light. How might he have produced these sources?
- (f) Calculate the energy of a photon of green light, which has a wavelength of 510 nm.
- (g) Quantum mechanics is used to explain how electrons in atoms produce line emission spectra. Describe how these spectra are produced.
- (h) State two differences between photons and electrons.

(8 × 7)

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

(a) State the principle of conservation of momentum. (6)

A polonium-212 nucleus decays spontaneously while at rest, with the emission of an alpha-particle.

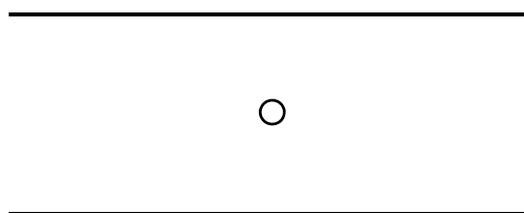


What daughter nucleus is produced during this alpha-decay?

The kinetic energy of the emitted alpha-particle is 8.9 MeV. Calculate its velocity.
Calculate the velocity of the daughter nucleus after the decay. (22)

(b) In 1909 Robert Millikan determined the charge on an electron by experiment.

A tiny drop of oil was placed between two horizontal plates, one directly above the other as shown. The oil drop was ionised by X-rays so that it became negatively charged. An electric field was applied between the plates until the drop no longer moved up or down.



Define electric field strength.

In your answer book, sketch the electric field pattern between two oppositely charged parallel plates.

Draw a diagram to show the forces acting on the drop of oil when it is stationary. (16)

The electric field strength between the plates was $3.6 \times 10^4 \text{ V m}^{-1}$ when the drop of oil was stationary, and the mass of the drop was $2.4 \times 10^{-15} \text{ kg}$.

Calculate the charge of the drop.

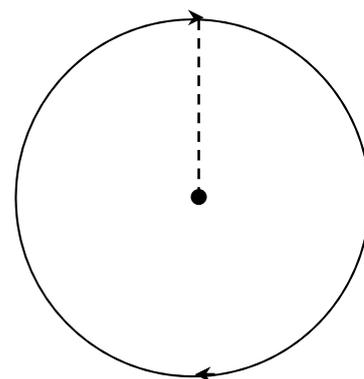
How many excess electrons are on this drop? (12)

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

(c) What is meant by the Doppler effect?

Define centripetal force.

(10)



A buzzer attached to a string of length 80 cm moves at a speed of 13 m s^{-1} in a vertical circle. The buzzer has a mass of 70 g and emits a note of frequency 1.1 kHz. An observer stands in the plane of motion of the buzzer, as shown in the diagram.

Calculate

(i) the maximum and minimum frequency of the note detected by an observer

(ii) the maximum and minimum tension in the string.

(18)

(speed of sound in air = 340 m s^{-1} ; acceleration due to gravity = 9.8 m s^{-2})

(d) Answer **either** part (i) **or** part (ii).

(i) The pair annihilation of an electron and a positron has been investigated for many years at CERN in Switzerland. Two gamma-ray photons are produced during this annihilation.

What is a positron?

Why are photons always produced in pairs during pair annihilation?

Write an equation for this annihilation.

Calculate the frequency of the gamma-radiation produced in this annihilation. (22)

The pair annihilation of a proton and an anti-proton is now being investigated at CERN.

Compare the energy produced in these two annihilations.

Explain your answer. (6)

(ii) Electric motors have a huge range of applications in the modern world.

Two types of motor are the d.c. motor and the induction motor.

Draw a labelled diagram of a d.c. motor.

Use your diagram to explain why the coil of a d.c. motor rotates when current flows through the coil. (15)

Describe how you would demonstrate the principle of operation of an induction motor.

State one advantage of an induction motor over a d.c. motor. (13)

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