2015. M36

Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2015

PHYSICS – HIGHER LEVEL

MONDAY, 15 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.

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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 of the gas was the same for each measurement. The following data were recorded.

V (cm^3)	80	120	160	200	240	280
p (kPa)	324	214	165	135	112	100

Describe, with the aid of a labelled diagram, how the student obtained the data. (12)

Draw a suitable graph to show the relationship between the pressure of the gas and its volume.

Explain how the graph verifies Boyle's law. (15)

Use your graph to estimate the pressure of the gas at a volume of 250 cm^3.

Why might the temperature of the gas have changed significantly during the experiment?

How did the student ensure that the temperature of the gas was the same for each measurement? (13)

2. In an experiment to measure the specific latent heat of vaporisation of water, cool water was placed in a polystyrene cup. Dry steam was then added to the water.
The following data were recorded.

Mass of polystyrene cup	= 1.2 g
Initial mass of polystyrene cup and water	= 84.6 g
Initial temperature of water	= 11 °C
Temperature of steam	= 100 °C
Final temperature of water	= 30 °C
Final mass of polystyrene cup and water	= 87.2 g

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

A student used these data to calculate the specific latent heat of vaporisation of water.

State two assumptions that the student made about the polystyrene cup when carrying out this calculation.

Use the data given above to calculate the specific latent heat of vaporisation of water. (22)

The student ensured that (*i*) the steam had been dried and (*ii*) the water that was initially in the cup had been cooled.

How did each of these steps improve the accuracy of the experiment? (9)

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

3. In an experiment to measure the wavelength of monochromatic light, a beam of light was incident normally on a diffraction grating. The diffraction grating had 80 lines per mm.

The angle ϕ between the first order image to the left and the first order image to the right was measured. This was repeated for higher order images.

The following data were recorded.

n	1	2	3	4
ϕ (degrees)	4.60	9.18	13.81	18.44

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

How were the first order images identified?

How was a beam of light produced? (15)

Which of the four ϕ angles is the most accurate? Suggest a reason for your answer. (6)

Calculate the wavelength of the monochromatic light. (15)

What would be the effect on the pattern produced if this diffraction grating was replaced with a diffraction grating of 500 lines per mm? (4)

4. In an experiment to measure the variation of the resistance R of a metallic conductor with its temperature θ, a student recorded the following data.

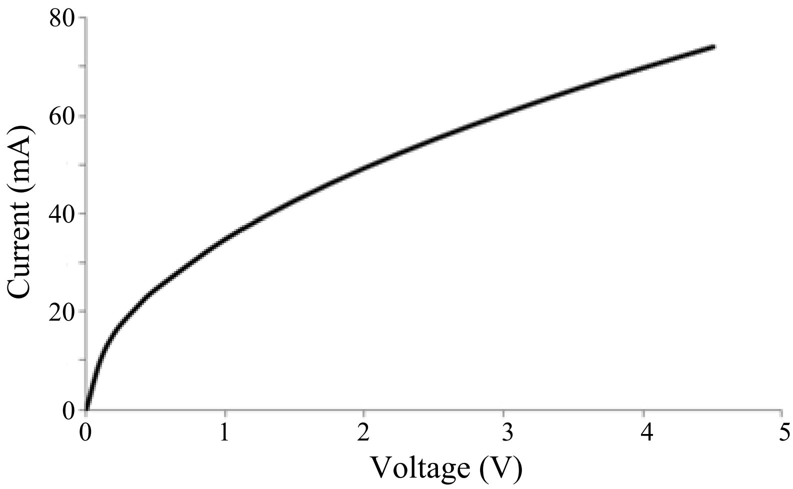
θ (°C)	15	20	30	40	50	60	80	100
R (Ω)	6.0	6.2	6.5	6.8	7.2	7.5	8.2	8.8

Using the recorded data, plot a graph to show the variation of the resistance of the metallic conductor with its temperature.

Use your graph to estimate

(*i*) the rate of change of resistance with respect to temperature for the metallic conductor
(*ii*) the resistance of the metallic conductor when it is immersed in melting ice. (20)

The student then completed an experiment to establish the relationship between current and voltage for the thin metallic filament of a bulb. Data were recorded and the following graph plotted.



Describe, with the aid of a circuit diagram, how the student carried out this second experiment.

Use the findings of the first experiment to explain the shape of the graph in the second experiment. (20)

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*) A hurler strikes a sliotar with an initial velocity of 41 m s^{-1} at an angle of 30° to the horizontal. How far does the ball travel horizontally in three seconds?

(*b*) Describe the movement of a particle that is undergoing simple harmonic motion.

(*c*) The refractive index of haematite is 3.2. What is its critical angle?

(*d*) What frequency would be detected by an observer when a source emitting a sound of frequency 512 Hz approaches at a velocity of 28 m s^{-1}?

(*e*) Calculate the energy from the Sun falling on a football pitch of dimensions 106 m × 68 m in 90 minutes.

(*f*) Write an expression for the charge stored on one plate of a parallel plate capacitor in terms of the potential difference between the plates, their common area, the distance between them and the permittivity of the dielectric.

(*g*) Define the ampere, the SI unit of current.

(*h*) Name the wire that contains the fuse in a three-pin plug. What colour is this wire?

(*i*) The first artificial transmutation of an atom was achieved by Rutherford in 1919. An alpha-particle collided with a nitrogen–14 nucleus to create an isotope of oxygen and a proton. Write a nuclear equation for this transmutation.

(*j*) Give the quark composition of (*i*) the proton and (*ii*) the anti-neutron.

or

Draw the symbol and truth table for a NOT gate.

(speed of sound in air = 340 m s^{-1}; solar constant = 1.36 kW m^{-2})

(8 × 7)

6. In the circular orbit of a satellite around the Earth, the required centripetal force is the gravitational force between the satellite and the Earth. The force can be determined using Newton's law of universal gravitation.

Explain what is meant by centripetal force.
State Newton's law of universal gravitation. (9)

Derive the relationship between the period of a satellite, the radius of its orbit and the mass of the Earth. (15)

A Global Positioning Systems (GPS) receiver can calculate its position on Earth to within a few metres. It picks up radio-wave signals from several of the 32 GPS satellites orbiting the Earth.

GPS satellites orbit the Earth in Medium Earth Orbit (MEO) with a period of 12 hours.

Calculate
- (*i*) the height of a GPS satellite above the Earth's surface
- (*ii*) the speed of a GPS satellite
- (*iii*) the minimum time it takes a GPS signal to travel from the satellite to a receiver on the surface of the Earth. (24)

Explain why GPS satellites are not classed as geostationary satellites. (4)

Radio-waves, such as those used by GPS satellites, have the lowest frequency of all electromagnetic radiation types. What type of electromagnetic radiation has the next lowest frequency? (4)

(mass of Earth = 5.97×10^{24} kg; radius of Earth = 6371 km)

7. X-rays have two important uses in medicine: imaging and radiation therapy.

Describe, with the aid of a labelled diagram of an X-ray tube, how X-rays are produced. (14)

A potential difference of 50 kV is applied across an X-ray tube.
Calculate
- (*i*) the maximum velocity of an electron in the tube
- (*ii*) the minimum wavelength of the X-rays produced by the tube. (18)

The large atoms found in bones (e.g. calcium and phosphorus) absorb X-ray photons. The small atoms found in soft tissue (e.g. carbon and hydrogen) do not absorb X-ray photons. This is why bones cast shadows on an X-ray film.

The X-ray photons absorbed by large atoms can cause the photoelectric effect to occur.
What is the photoelectric effect?

Describe a laboratory experiment to demonstrate the photoelectric effect.

Albert Einstein received a Nobel Prize in 1921 for his explanation of the photoelectric effect.
Outline Einstein's explanation of the photoelectric effect. (24)

8. Define electric field strength. (6)

Both Van de Graaff generators and gold leaf electroscopes are used to investigate static electricity in the laboratory.

Draw a labelled diagram of a gold leaf electroscope.
Describe how it can be given a negative charge by induction. (20)

A Van de Graaff generator can be used to demonstrate point discharge.

Explain, with the aid of a labelled diagram, how point discharge occurs.
Describe an experiment to demonstrate point discharge. (18)

The polished spherical dome of a Van de Graaff generator has a diameter of 40 cm and a charge of +3.8 μC.

What is the electric field strength at a point 4 cm from the surface of the dome? (12)

9. Musical instruments produce stationary (standing) waves.

Resonance also occurs in many instruments.

What are stationary waves? How are they produced?

What is resonance? Describe a laboratory experiment to demonstrate resonance. (24)

A guitar is a string instrument.

The frequency of a stretched string depends on the tension of the string and on two other factors.

What are the two other factors?

What effect does increasing the tension of the string from 36 N to 81 N have on the frequency of the string? (12)

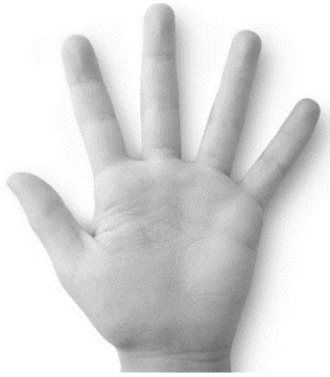
Explain, with the aid of labelled diagrams, why a pipe open at only one end produces half the number of harmonics as a pipe open at both ends.

A tin whistle consists of a pipe which is open at both ends. A particular tin whistle has a fundamental frequency of 587 Hz when all of the holes on it are covered.
How long is the pipe? (20)

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

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

(*a*) There are about a trillion neutrinos from the Sun passing through your hand every second.



Neutrinos are fundamental particles and are members of the lepton family.

Leptons are not subject to the strong nuclear force.

What is the principal force that neutrinos experience?

Electrons are also members of the lepton family. Name two other leptons.

Name one fundamental particle that is subject to the strong nuclear force. (12)

Pauli proposed that a neutrino is emitted during beta-decay.
Why did he make this proposal?

During beta-decay, a neutron decays with the emission of a proton, an electron and a neutrino.

Write a nuclear equation to represent beta-decay.

Calculate the energy released, in MeV, during beta-decay. (26)

An electron can be detected in a cloud chamber. However it is much more difficult to detect a neutrino. Explain why.

In a cloud chamber an electron travels perpendicular to the direction of a magnetic field of flux density 90 mT and it follows a circular path. Calculate the radius of the circle when the electron has a speed of 1.45×10^{8} m s^{-1}.

Describe the path of a neutrino in the same magnetic field. (18)

(*b*) Loudspeakers, d.c. motors and galvanometers are all based on the principle that a current-carrying conductor in a magnetic field experiences a force.

Describe a laboratory experiment to demonstrate this principle. (9)

Describe, with the aid of a labelled diagram, the principle of operation of the moving-coil loudspeaker. (12)

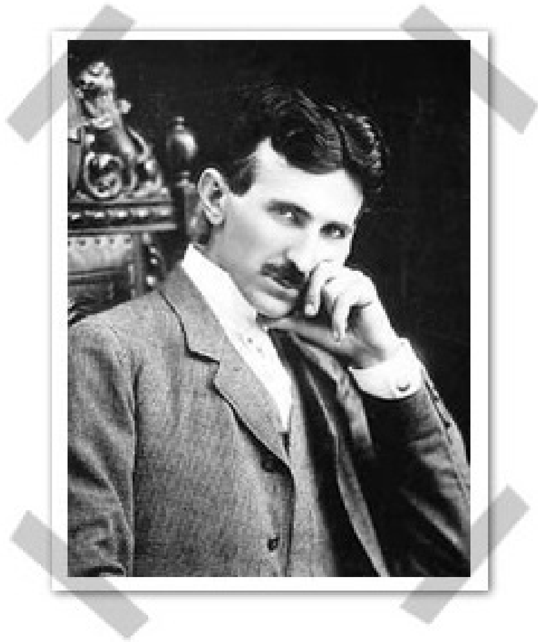
What is the principal energy conversion that takes place in a d.c. motor?

State the function of (*i*) the commutator and (*ii*) the carbon brushes in a d.c. motor.

The magnetic flux density of the field in a d.c. motor is 5.5 T and a current of 1.2 A flows in the coil. The coil is a square of side 8 cm and it has 500 turns. Calculate the maximum torque exerted by the motor. (21)

A galvanometer has an internal resistance of 90 Ω and a full-scale deflection of 10 mA. Explain how the galvanometer could be converted into a voltmeter of full-scale deflection 5 V. (14)

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



In the years since his death, Nikola Tesla (1856–1943) has enjoyed a curious legacy. On the one hand he is acknowledged for his contributions to alternating current and in 1960 "tesla" was adopted as the name of the unit of measure for magnetic flux density. On the other hand, thanks to the many colourful predictions he made about his inventions, Tesla has become a figure in popular culture.

Tesla was the champion of distributing electric power using alternating current rather than direct current. The problem with using direct current for electric lighting is that there is no easy way to transfer power from one d.c. circuit to another. Because the generator and the light bulbs must then be part of the same circuit, safety requires that the entire circuit uses low voltage and large current. Alternating current makes it easy to transfer power from one circuit to another, by electromagnetic induction in a device called a transformer.

The wires that carry the current a long distance are part of a high voltage, low current circuit and therefore waste little power.

As well as his work with alternating current, Tesla did pioneering work on the transmission of radio-waves and X-rays. In 1898 he demonstrated a radio-controlled boat.

The car manufacturing company, *Tesla Motors,* is also named in honour of Tesla. The *Tesla Roadster* uses an a.c. motor descended directly from Tesla's original 1882 design. It is the first production car to use lithium-ion cells and has a range of greater than 300 km.

(Adapted from *Tesla: Inventor of the Electrical Age*, W Bernard Carlson, Princeton University Press, 2013)

(*a*) Define the tesla.

(*b*) Sketch voltage-time graphs for (*i*) an a.c. supply and (*ii*) a d.c. supply.

(*c*) Explain the term *electromagnetic induction*.

(*d*) Why does a transformer not work with direct current?

(*e*) Why is it inefficient to use low voltage when transmitting electricity?

(*f*) The peak voltage of an a.c. supply is 321 V. Calculate the rms voltage.

(*g*) Explain why it is necessary to use rms values when comparing a.c. and d.c. electricity.

(*h*) Give one advantage and one disadvantage of electric cars.

(8 × 7)

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

(*a*) State Newton's second law of motion. (6)

A downhill skier of mass 71 kg started from rest and travelled a distance of 400 m on a downhill ski course. Her loss of elevation was 90 m.

What is the principal energy conversion that is taking place as the skier travels along the course? (4)

Ignoring friction, calculate her maximum velocity when she has travelled 400 m. (9)

She then ploughed into a snow drift and came to a stop in a time of 0.8 seconds.

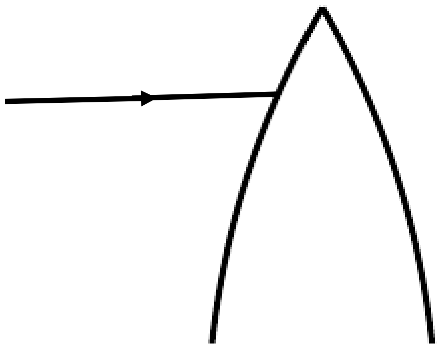
What is the force that she exerts on the snow drift?

What force does the snow drift exert on her? (9)

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

(*b*) When light passes through a lens, it is refracted at both faces of the lens.

Copy the diagram on the right into your answer book and complete the path of the light ray through the section of the lens. Include the normal at both faces. (6)



Draw a ray diagram to show the formation of a virtual image in a converging lens. (9)

A converging lens of focal length 20 cm and a diverging lens of focal length 8 cm are placed in contact.

Calculate the power of the combination. (9)

What eye defect can be corrected using converging lenses? (4)

(*c*) A thermometer uses a thermometric property to measure temperature. The thermometric property of a thermocouple thermometer is emf.

Explain the underlined terms. (9)

What is the SI unit of temperature? Give an advantage of using this unit in scientific measurements. (6)

Describe a laboratory experiment to demonstrate the principle of operation of a thermocouple. (9)

Give an advantage of using a thermocouple thermometer instead of a mercury-in-glass thermometer. (4)

(*d*) Radon is a radioactive gas which is present in some rocks. It can sometimes build up in houses and cause health concerns.

What is meant by the term *radioactive*? (6)

Name a detector of radiation and describe, with the aid of a labelled diagram, its principle of operation. (13)

Radon–210 decays by alpha-emission with a half-life of 144 minutes. A sample of the gas contains 4.5×10^{15} atoms of this isotope.

How many radon–210 atoms will remain after one day? (9)

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