Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate Examination, 2017

Physics – Higher Level

Monday, 19 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. A student investigated the relationship between the period and the length of a simple pendulum.

   The student measured the length l of the pendulum which was then allowed to swing about a fixed point and through a small angle. The time t for 40 oscillations was measured.

   This procedure was repeated for different lengths of the pendulum.

   The following data were recorded.

l (cm)	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0
t (s)	34.7	42.8	51.6	56.6	62.5	65.8	70.3	77.3

   Why did the student use a small angle?

   How did the student ensure that the pendulum was suspended from a fixed point?

   Between which points was the length of the pendulum measured?

   Which t value is most accurate? Explain your answer. (16)

   Draw a suitable graph to show the relationship between the length of a pendulum and its period.

   Use your graph to calculate g, the acceleration due to gravity. (24)

2. The variation of the fundamental frequency of a stretched string with its tension was investigated.

The length of the string and its mass per unit length were kept constant.

Draw a labelled diagram of the apparatus used.

Show on your diagram how (*i*) the tension and (*ii*) the length were measured.

How was the fundamental frequency determined? (22)

How would a student use the measurements taken in this experiment to draw a graph showing the relationship between frequency and tension?

Explain how the graph verifies this relationship.

For a string of constant length *l*, the mass per unit length μ can be determined using the slope *m* of the graph. Write an expression for μ in terms of *l* and *m*. (18)

3. In an experiment to determine the specific latent heat of fusion of ice, warm water and ice were mixed in a copper calorimeter. The following data were recorded.

Mass of calorimeter	= 61.8 g
Mass of calorimeter + warm water	= 110.2 g
Initial temperature of calorimeter + warm water	= 26.5 °C
Initial temperature of ice	= 0.0 °C
Mass of added ice	= 8.2 g
Final temperature of calorimeter + water + melted ice	= 12.0 °C

Describe how

    (*i*)   the mass of added ice was measured

    (*ii*)   it was ensured that the temperature of all the added ice was at 0.0 °C. (12)

State two ways in which the calorimeter could have been insulated during this experiment. (6)

Calculate the specific latent heat of fusion of ice.

State two characteristics of a thermometer suitable for use in this experiment. (22)

(*specific heat capacity of copper = 390 J kg^{-1} K^{-1}; specific heat capacity of water = 4180 J kg^{-1} K^{-1}*)

4. A student investigated the relationship between current *I* and potential difference *V* for a filament bulb.

Draw a circuit diagram for the apparatus used in this experiment. (12)

The following data were recorded.

V (V)	0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
I (mA)	0	11	23	33	44	51	57	63	68	72

Draw a suitable graph to illustrate the relationship between current and potential difference.

Use your graph to calculate the resistance of the filament (*i*) at 0.5 V and (*ii*) at 8.5 V. (18)
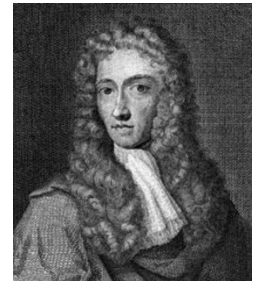
As the potential difference was increased, at what point did the resistance of the filament begin to change significantly?

Why does the resistance of a filament change with its potential difference? (10)

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*) State Boyle's law.

(*b*) Sphere A of mass 400 g is travelling horizontally with a speed of 6 m s^{-1} when it collides with sphere B of mass 150 g travelling in the opposite direction with a speed of 9 m s^{-1}. Sphere A comes to rest as a result of the collision. Calculate the new velocity of sphere B.
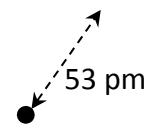

(*c*) What is the thermometric property (*i*) of a thermocouple and (*ii*) of a mercury thermometer?

(*d*) The diffraction effects of sound waves are noticeable in everyday life, whereas the diffraction effects of light waves are not. Explain why.

(*e*) Explain how point discharge occurs.

(*f*) What is the electric field strength 53 pm from a proton?

(*g*) What is meant by sound intensity?

(*h*) A certain RCD has a rating of 30 mA. What is the significance of this number?

(*i*) What is the function of the moderator in a fission reactor?

(*j*) Explain why the gravitational force can be ignored for sub-atomic particles.
or
How can a galvanometer be converted into a voltmeter?

(8 × 7)

6. In a bungee jump, Henry falls while attached to an elastic cord.
When the cord stops Henry's fall, he then oscillates up and down.
During the bungee jump, gravitational potential energy is converted into kinetic energy and then into elastic potential energy.

State the principle of conservation of energy.

Derive the expression $v^2=u^2+2as$ for uniform accelerated motion.

The cord is 32 m long and Henry, of mass 60 kg, falls from rest
while attached. Calculate his speed when he has fallen 16 m. (21)

A stretched elastic cord obeys Hooke's law and the weight
attached to the cord oscillates with simple harmonic motion.

State Hooke's law. What is meant by simple harmonic motion?

The elastic constant of the cord is 250 N m^{-1}. Calculate the length the cord
would have if Henry was suspended at rest. (15)

After the end of the fall, Henry oscillates with simple harmonic motion.
The maximum displacement from his rest position is 1.2 metres.

Calculate (*i*) his maximum acceleration as he oscillates and (*ii*) his period of oscillation.

Draw a diagram to show the forces acting on Henry when he is at his lowest point. (20)

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

7. Colour filters and polarising filters can be used to enhance photographs.

We see objects because light reflects from them. What is reflection?

What primary colours of light (*i*) are absorbed and (*ii*) are reflected
when white light shines on a red book?

What colour would the red book appear to be if colour filters were used so that the book
was illuminated (*iii*) with green light and (*iv*) with red light? (15)

What is polarisation? Describe how polarisation can be demonstrated in the laboratory.

Give an application of stress polarisation. (18)

Speed cameras use the Doppler effect to calculate the speed of vehicles.
Describe, with the aid of a labelled diagram, how the Doppler effect occurs.

A source that is emitting a sound wave of a certain frequency is approaching an observer.
The frequency observed is 15% more than the frequency of the sound wave emitted.
What is the speed of the source? (23)

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

8. Distinguish between resistance and resistivity.

What is the effect on the resistance of a length of wire if the diameter of the wire is increased by a factor of three? (14)

In the circuit diagram shown, the a.c. supply has an rms voltage of 12 V.
The variable resistor is set at 500 Ω.
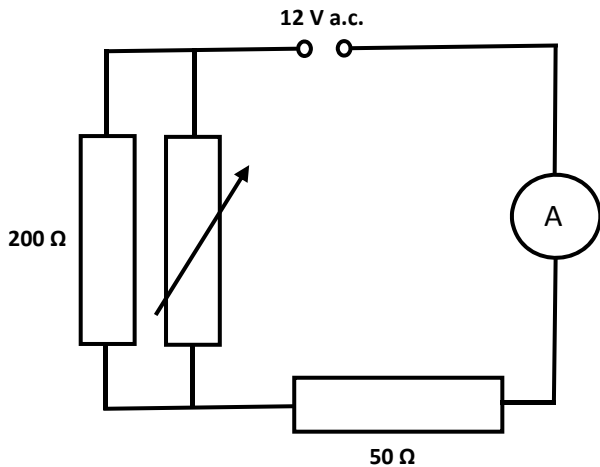
What is meant by rms?

What is meant by a.c.?

Calculate

(*i*) the effective resistance of the circuit

(*ii*) the current flowing in the 200 Ω resistor.
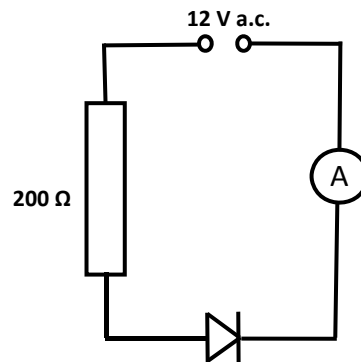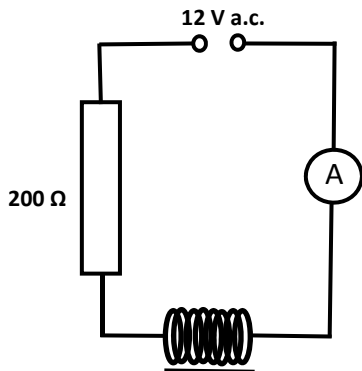
The variable resistor is then removed.

What effect will this have on the current flowing in the 50 Ω resistor?

Explain your answer. (30)

In further investigations, the 50 Ω resistor was then replaced with
(*i*) a coil of resistance 50 Ω and (*ii*) a diode, as shown.

In each of the investigations, what effect did the replacement have on the current flowing?
Justify your answer in each case. (12)

9. Describe Rutherford's experiment to investigate the structure of the atom. What conclusions about the nature of the atom did Rutherford make? (15)
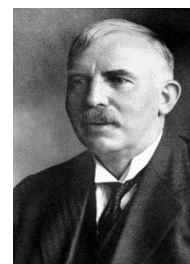
One of his students, Niels Bohr, further developed Rutherford's model of the atom. The Bohr model helps us identify different elements using emission line spectra.

Explain, using the Bohr model, how line spectra are formed. (12)

Draw a labelled diagram of a spectrometer and describe how a spectrometer and diffraction grating can be used to observe (*i*) a line spectrum and (*ii*) a continuous spectrum. (18)

Sodium emits visible light with a wavelength of 589 nm. This light is passed through a diffraction grating of 300 lines per mm. Calculate the angular separation between the first line to the left of the central image and the first line to the right of the central image. (11)

10. What are X-rays?

Electrons are produced and used in an X-ray tube.

How are the electrons produced? Where in the tube does this take place? (12)

A certain X-ray tube is designed to emit X-rays with wavelengths as small as 0.02 nm.

Calculate

    (*i*)   the energy of an X-ray photon of wavelength 0.02 nm

    (*ii*)   the maximum velocity of an electron in the tube

    (*iii*) the voltage applied to the electrons. (21)

Electrons are also produced and used in a photocell.

Draw a labelled diagram of a photocell.

Describe how a photocell conducts current.

A current of 2 μA is flowing in a photocell. How many electrons are generated in the photocell during each minute? (23)

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

Telecommunications have been among the most influential technologies in history. Communications across the Atlantic demonstrate the progress that has been made in this field. The invention of the telegraph in 1837 enabled the first transmission of signals using electrical methods. The telegraph made use of the principle that a current-carrying conductor experiences a force in a magnetic field and it used intermittent currents to transfer signals.

The first successful transatlantic cable connected Valentia Island, Kerry with Newfoundland, Canada in 1866. Many new electrical devices were used in the enterprise, including the Wheatstone bridge, which measured variations of resistance to locate breaks in the cable. The time taken to transmit messages across the Atlantic had been reduced from weeks to seconds.

In 1962 the first television signal was transmitted via the *Telstar* communications satellite, using microwaves. The satellite was in Medium Earth orbit and it allowed signals to be transmitted from Maine, USA to Brittany, France for 20 minutes during each 2.6 hour orbit.

In the late 20th century, communication of signals using optical fibres became a reality, with several cables laid across the Atlantic. In 2015 the *Hibernia Express* optical cable was completed. It connects Cork and London to Halifax and New York and carries a signal from London to New York in 29 milliseconds. The movement of data across the Atlantic has never been quicker.
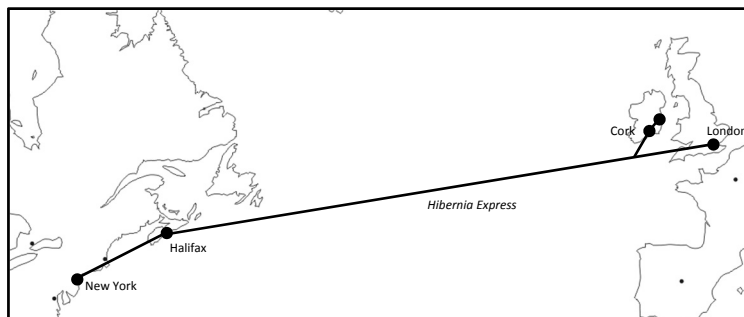
(Adapted from *Telecommunications History and Highlights*, Robert Colburn)

(*a*) Draw a labelled diagram of an arrangement of apparatus that could be used to demonstrate the principle that a current-carrying conductor experiences a force in a magnetic field.

(*b*) Explain how this principle is used in the definition of the ampere.

(*c*) Draw a circuit diagram of a Wheatstone bridge.

(*d*) Why did *Telstar* not allow transatlantic signals to be transmitted constantly?

(*e*) Calculate the radius of orbit of *Telstar*.

(*f*) With the aid of a labelled diagram, explain how light is transmitted through optical fibres.

(*g*) Light travels a distance of 5500 km along the *Hibernia Express* between London and New York. Calculate the refractive index of the glass used in the cable.

(*h*) What particles are used for transatlantic communication (*i*) in telegraph cables, (*ii*) in satellite signals and (*iii*) in optical fibres?

(*mass of the Earth = 6.0×10^{24} kg*)

(8 × 7)

12. Answer any **two** of the following parts, (*a*), (*b*), (*c*), (*d*).
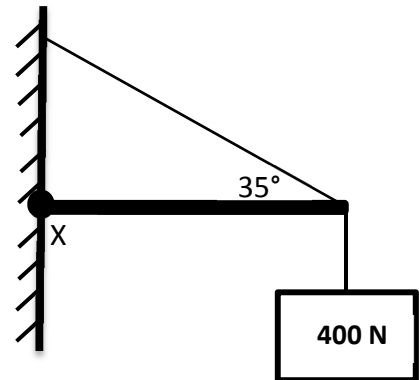
(*a*) State the laws of equilibrium. (9)

A sign weighing 400 N is suspended at the end
of a uniform horizontal rod. The rod touches the wall
at position X.

The rod weighs 330 N and is 1.2 m long.

A support cable makes an angle of 35° with the rod,
as shown in the diagram.

35°

X

400 N

Calculate the clockwise moment acting on the rod
(due to the weight of the sign and the weight of the rod)
about X.

Hence calculate the tension in the cable. (15)

A rotating object can be in equilibrium.

Explain how this can happen. (4)

(*b*) Potassium–40 is a significant source of radioactivity in the human body.
Bananas are a principle source of potassium in our diet.

Potassium–40 has a half-life of 1.25×10^9 years and it is a beta-emitter.

What is meant by radioactivity?

Name a device used to detect beta-radiation and explain its principle of
operation. (12)

The activity of a human body due to potassium–40 is 5400 Bq.

Write the nuclear equation for this decay.

Calculate the number of potassium–40 nuclei in this person. (16)

(c)   It has been recently suggested that the 17th century
Dutch artist Rembrandt used a concave mirror to help him
etch self-portraits by projecting an inverted image of himself
onto a copper sheet.

Draw a ray diagram to illustrate how Rembrandt used
a concave mirror in this way.   (10)

Rembrandt used a concave mirror of focal length 60 cm so that the
image on the copper sheet was only half the size of the object.

Calculate

     (*i*)   the distance from the sheet to the mirror and

     (*ii*)   the distance from the object to the mirror.

A concave mirror can also be used to produce an upright image.
Explain why this image was not of use to Rembrandt.   (18)

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

     (*i*)   In the Cockcroft and Walton experiment, accelerated protons
collided with lithium nuclei. In each collision a proton collided
with a lithium nucleus to produce two alpha-particles, as shown
in this commemorative coin.

Explain (*a*) how the protons were produced,
(*b*) how the protons were accelerated and (*c*) how the alpha-particles were detected.

Write the nuclear equation for this reaction.   (13)

For this reaction, calculate the loss in mass and hence
the energy released (in MeV).   (12)

Explain the historical significance of this experiment.   (3)

     (*ii*)   Draw a diagram to show the basic structure of the bi-polar
transistor.   (6)
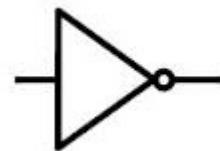
State the relationship between the three currents flowing
in a transistor circuit.   (6)

Draw the circuit diagram for a transistor circuit that can be used
as a voltage inverter (NOT gate).

Draw the truth table for a NOT gate.   (16)

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