



**Coimisiún na Scrúduithe Stáit  
State Examinations Commission**

---

**LEAVING CERTIFICATE EXAMINATION, 2013**

---

**PHYSICS – HIGHER LEVEL**

---

**MONDAY, 17 JUNE – MORNING, 9:30 TO 12:30**

---

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

---

**N.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. The laws of equilibrium for a set of co-planar forces acting on a metre stick were investigated by a student. She first found the centre of gravity of the metre stick and then determined its weight as 1.3 N.

How did the student find the centre of gravity of the metre stick? The centre of gravity was at the 50.3 cm mark rather than the mid-point of the metre stick. Explain.

The metre stick was suspended from two spring balances graduated in newtons. The student made use of a set of three weights, which she hung from the metre stick. She adjusted them until the metre stick was at equilibrium. How did the student ensure that the system was at equilibrium?

Draw a diagram of the experimental arrangement that the student used. (18)

The student recorded the positions of the forces acting on the metre stick and the direction in which each force was acting.

Position of force on metre stick/cm	11.4	21.8	30.3	65.4	80.0
Force/N	2.0	3.0	5.7	4.6	4.0
Direction	downward	downward	upward	upward	downward

Taking the moments of the forces about the mid-point of the metre stick (50 cm mark), use the student's data to calculate

- (i) the total of the clockwise moments
- (ii) the total of the anti-clockwise moments.

Explain how these results verify the laws of equilibrium. (22)

2. In an experiment to verify Boyle's law, a student took the set of readings given in the table below.

$X$	120	160	200	240	280	320
$Y$	52	39.1	31.1	25.9	22.2	19.6

What physical quantities do  $X$  and  $Y$  represent? (6)

Name the units used when measuring these quantities. (4)

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

Describe the procedure he used to obtain these readings. (15)

Use the data in the table to draw an appropriate graph on graph paper.

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

3. The following is part of a student's report on an experiment to measure the focal length of a concave mirror.

"I started with the object 6 cm from the mirror but couldn't get an image to form on the screen. I moved the object back a few centimetres and tried again, but I couldn't get an image to form on the screen until the object was 24 cm from the mirror. From then on I moved the object back 8 cm each time and measured the corresponding image distances. I wrote my results in the table."

$u/cm$	24.0	32.0	40.0	48.0
$v/cm$	72.5	40.3	33.0	27.9

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

Give two precautions that should be taken when measuring the image distance. (6)

Explain why the student was unable to form an image on the screen when the object was close to the mirror. (6)

Use all of the data in the table to calculate a value for the focal length of the mirror. (15)

Describe how the student could have found an approximate value for the focal length of the mirror before starting the experiment. (4)

4. A student was asked to investigate the variation of current with potential difference for a thin metallic conductor. The student set up a circuit using appropriate equipment. The student recorded the values of the current  $I$  passing through the conductor for the corresponding values of potential difference  $V$ . The recorded data are shown in the table.

$V/V$	1.0	2.0	3.0	4.0	5.0	6.0
$I/A$	0.17	0.34	0.50	0.64	0.77	0.88

Draw and label the circuit diagram used by the student.

Name the device in the circuit that is used to vary the potential difference across the conductor.

Explain how the student used this device to vary the potential difference. (18)

Use the data in the table to draw a graph on graph paper to show the variation of current with potential difference. Use your graph to find the value of the resistance of the conductor when the current is 0.7 A. (15)

Explain the shape of your graph. (7)

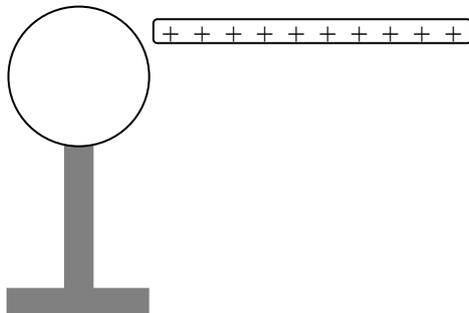
## SECTION B (280 marks)

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

---

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

- (a) What is the shortest stopping time for a car which is travelling at  $16 \text{ m s}^{-1}$  and has a maximum deceleration of  $2.5 \text{ m s}^{-2}$ ?
- (b) State the law of conservation of momentum.
- (c) Explain why heat does **not** travel through solids by means of convection.
- (d) Storage heaters are frequently used to heat buildings. State the principle that underlies the operation of an electrical storage heater.
- (e) If a diamond has a refractive index of 2.42, what is the speed of light in the diamond?
- (f) Define the volt.
- (g) A positively-charged rod is brought near to a neutral, conducting sphere that is on top of an insulating stand, as shown in the diagram. How would a student charge the sphere negatively by induction?



- (h) Explain what is meant by the statement: “Zinc has a threshold frequency of  $1.04 \times 10^{15} \text{ Hz}$ ”.
- (i) Give one benefit of switching from fossil fuels to nuclear power for the generation of electricity. Explain your answer.
- (j) Give an expression for the minimum frequency of a photon that can form an electron and a positron by pair production.

**or**

What event inside an LED causes the release of a photon?

(8 × 7)

6. (i) State Newton's law of universal gravitation. (6)
- (ii) Explain what is meant by angular velocity. Derive an equation for the angular velocity of an object in terms of its linear velocity when the object moves in a circle. (9)

The International Space Station (ISS), shown in the photograph, functions as a research laboratory and a location for testing of equipment required for trips to the moon and to Mars. The ISS orbits the earth at an altitude of  $4.13 \times 10^5$  m every 92 minutes 50 seconds.



- (iii) Calculate (a) the angular velocity, (b) the linear velocity, of the ISS. (12)
- (iv) Name the type of acceleration that the ISS experiences as it travels in a circular orbit around the earth. What force provides this acceleration? (6)
- (v) Calculate the attractive force between the earth and the ISS. Hence or otherwise, calculate the mass of the earth. (15)
- (vi) If the value of the acceleration due to gravity on the ISS is  $8.63 \text{ m s}^{-2}$ , why do occupants of the ISS experience apparent weightlessness? (3)
- (vii) A geostationary communications satellite orbits the earth at a much higher altitude than the ISS. What is the period of a geostationary communications satellite? (5)
- (mass of ISS =  $4.5 \times 10^5$  kg; radius of the earth =  $6.37 \times 10^6$  m)

7. What is meant by the term resonance? How would resonance be demonstrated in the laboratory? (15)

A set of wind chimes, as shown in the diagram, is made from different lengths of hollow metal tubing that are open at both ends. When the wind blows, the wind chimes are struck by a clapper and emit sounds.

The sound from one of the tubes was analysed. The following frequencies were identified in the sound: 550 Hz, 1100 Hz and 1651 Hz.

What name is given to this set of frequencies? (5)

Draw labelled diagrams to show how the tube produces each of these frequencies.

The length of the metal tube is 30 cm. Use any of the above frequencies to calculate a value for the speed of sound in air. (24)



A sample of wire, of length 12 m and mass 48 g, was being tested for use as a guitar string. A 64 cm length of the wire was fixed at both ends and plucked. The fundamental frequency of the sound produced was found to be 173 Hz. Calculate the tension in the wire. (12)

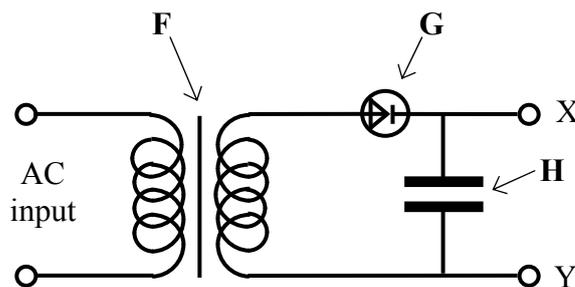
8. (a) The diagram shows a circuit used in a charger for a mobile phone.

Name the parts labelled **F**, **G** and **H**. (9)

Describe the function of **G** in this circuit. (6)

Sketch graphs to show how voltage varies with time for

- (i) the input voltage  
(ii) the output voltage,  $V_{XY}$ . (12)



The photograph shows the device **H** used in the circuit. Use the data printed on the device to calculate the maximum energy that it can store. (9)

- (b) Electricity generating companies transmit electricity over large distances at high voltage. Explain why high voltage is used. (6)

A 3 km length of aluminium wire is used to carry a current of 250 A. The wire has a circular cross-section of diameter 18 mm.

- (i) Calculate the resistance of the aluminium wire.  
(ii) Calculate how much electrical energy is converted to heat energy in the wire in ten minutes. (14)

(resistivity of aluminium =  $2.8 \times 10^{-8} \Omega \text{ m}$ )

9. Define the becquerel. (6)

Name one device used to detect ionising radiations. (3)

Compare alpha, beta, and gamma emissions using the following headings: (a) penetrating ability, (b) deflection in a magnetic field. (9)

The photograph shows one of the nuclear reactors at Chernobyl, where there was a fire in April 1986 that released large quantities of radioactive contaminants. Among the contaminants were iodine-131 and caesium-137, which are two of the unstable isotopes formed by the fission of uranium-235.



Explain what happens during nuclear fission. (8)

Iodine-131 decays with the emission of a beta-particle and has a half-life of 8 days.

Write an equation for the beta-decay of iodine-131.

Estimate the fraction of the iodine-131 that remained after 40 days. (15)

Caesium-137 has a half-life of 30 years and it remains a significant contaminant in the region around Chernobyl. It is easily absorbed into the tissues of plants as they grow. Scientists collected a sample of berries growing near the abandoned power station. The activity of the sample was measured at 5000 Bq.

Calculate the decay constant of caesium-137. Hence calculate the number of caesium-137 atoms present in the sample. (You may assume that all of the activity was caused by caesium-137.) (15)

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

- (a) In 1932 J.D. Cockroft and E.T.S. Walton accelerated protons to energies of up to 700 keV and used them to bombard a lithium target. They observed the production of alpha-particles from the collisions between the accelerated protons and the lithium nuclei.

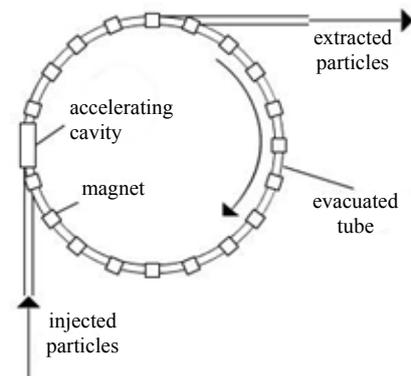
How did Cockroft and Walton accelerate the protons?

How did they detect the alpha-particles? (12)

Write the nuclear equation for the reaction that occurred and indicate the historical significance of their observation. (12)

Calculate the speed of a proton that has a kinetic energy of 700 keV. (12)

Many modern particle accelerators, such as the Large Hadron Collider (LHC) in CERN, have a circular design. The diagram shows a simplified design of a circular accelerator.



Why is the tube evacuated? (3)

What is the purpose of accelerating the particles to high velocities? (4)

What is the purpose of the magnets? (4)

Give an advantage of a circular accelerator over a linear accelerator. (3)

Can an accelerator of this design be used to accelerate neutrons? Explain your answer. (6)

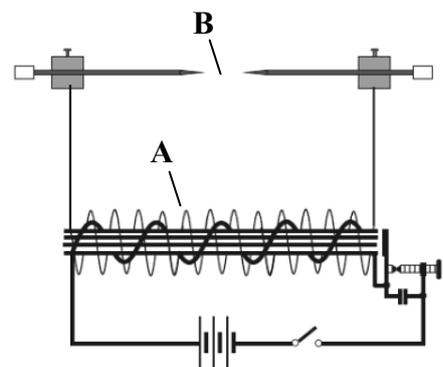
- (b) State the principle on which a moving-coil galvanometer is based. (6)

Draw labelled diagrams to show how a galvanometer may be converted to function as  
 (i) an ammeter  
 (ii) a voltmeter. (12)

A galvanometer with a resistance of  $100\ \Omega$  shows a full-scale deflection when a current of 2 mA passes through it. How can the galvanometer be converted to function as an ammeter reading up to 5 A? (15)

Name another device based on the same principle as the moving-coil galvanometer. (6)

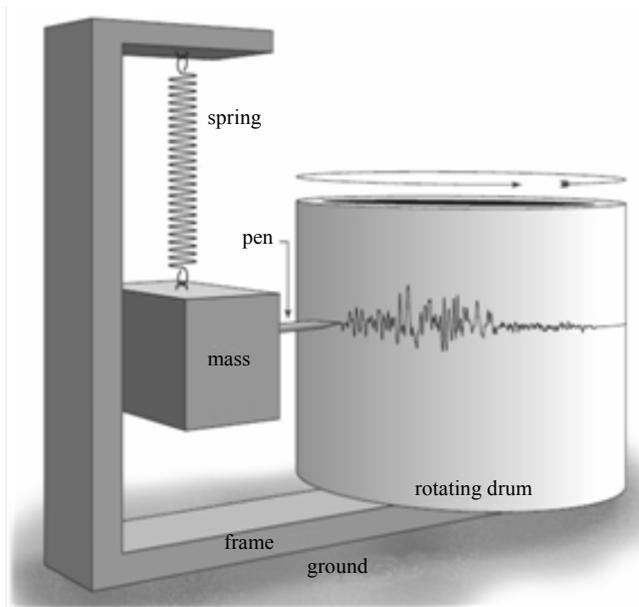
The induction coil was invented by Dr Nicholas Callan, an Irishman. The diagram shows an induction coil that is used to produce a very high voltage from a low voltage source.



Explain the functions of the parts labelled A and B in the diagram. (12)

Give an application of the induction coil. (5)

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



A seismometer consists of a sensor that detects ground motion, attached to a recording system. A seismometer that is sensitive to up-down motions of the ground, as caused by an earthquake, can be understood by visualising a mass hanging on a spring as shown in the diagram. The frame and the drum move up and down as the seismic wave passes by, but the mass remains stationary.

If a recording system is installed, such as a rotating drum attached to the frame and a pen attached to the mass, this relative motion between the suspended mass and the ground can be recorded to produce a seismogram, as shown in the diagram.

Modern seismometers do not use a pen and drum. The relative motion between a magnet that is attached to the mass, and the frame, generates a potential difference that is recorded by a computer.

(Adapted from [www.iris.edu](http://www.iris.edu) Education and Outreach Series No.7: How does a Seismometer Work?)

- Seismic waves can be longitudinal or transverse. What is the main difference between them?
- An earthquake generates a seismic wave that takes 27 seconds to reach a recording station. If the wave travels at  $5 \text{ km s}^{-1}$  along the earth's surface, how far is the station from the centre of the earthquake?
- Draw a diagram to show the forces acting on the suspended mass when the seismometer is at rest.
- At rest, the tension in the spring is 49 N. What is the value, in kilograms, of the suspended mass?
- What type of motion does the frame have when it moves relative to the mass?
- During an earthquake the ground was observed at the recording station to move up and down as the seismic wave generated by the earthquake passed. Give an equation for the acceleration of the ground in terms of the periodic time of the wave motion and the displacement of the ground.
- If the period of the ground motion was recorded as 17 seconds and its amplitude was recorded as 0.8 cm, calculate the maximum ground acceleration at the recording station.
- In some modern seismometers a magnet is attached to the mass and a coil of wire is attached to the frame. During an earthquake, there is relative motion between the magnet and the coil. Explain why an emf is generated in the coil.

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

(8 × 7)

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

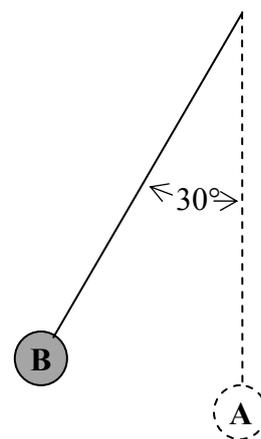
(a) State the law of conservation of energy. (4)

The pendulum in the diagram is 8 m long with a small bob of mass 6 kg at its end. It is displaced through an angle of  $30^\circ$  from the vertical (position **A**) and is then held in position **B**, as shown. Calculate the height through which the bob has been raised and the potential energy that it has gained. (9)

The bob is then released and allowed to swing freely. What is the maximum velocity it attains? (9)

When the moving bob is at position **A**, a force is applied which brings the bob to a stop in a distance of 5 mm. Calculate the force applied. (6)

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



(b) A narrow beam of light undergoes dispersion when it passes through either a prism or a diffraction grating.

What is meant by dispersion? (6)

Give two differences between what is observed when a narrow beam of light undergoes dispersion as it passes through a prism, and what is observed when a narrow beam of light undergoes dispersion as it passes through a diffraction grating. (6)

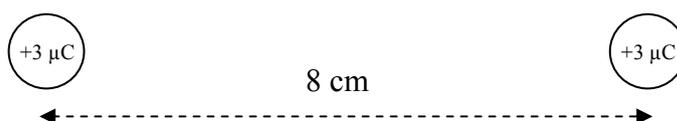
Give another example of light undergoing dispersion. (4)

Yellow light of wavelength 589 nm is produced in a low-pressure sodium vapour lamp. What causes the sodium atoms to emit this light? (3)

Calculate the highest order image that could be produced when a beam of light of this wavelength is incident perpendicularly on a diffraction grating that has 300 lines per mm. (9)

(c) Define the unit of charge, the coulomb. State Coulomb's law. (9)

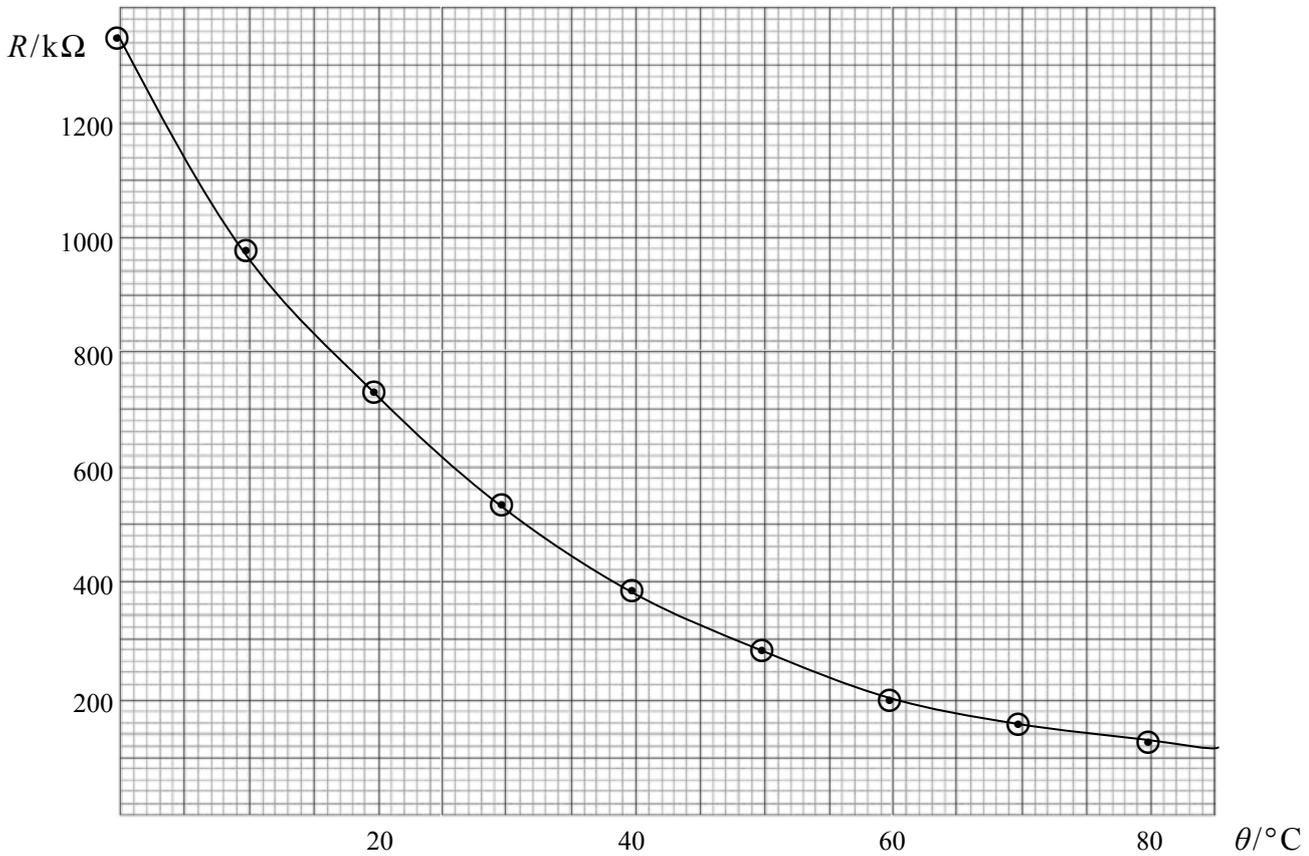
Calculate the force of repulsion between two small spheres when they are held 8 cm apart in a vacuum. Each sphere has a positive charge of  $+3 \mu\text{C}$ . (9)



Copy the diagram above and show on it the electric field generated by the charges. Mark on your diagram a place where the electric field strength is zero. (10)

(d) What is meant by the term thermometric property? (6)

This graph was obtained during an experiment where the resistance  $R$  of a thermistor was measured as its temperature  $\theta$  was raised from  $0\text{ }^{\circ}\text{C}$  to  $100\text{ }^{\circ}\text{C}$  (as measured by a mercury-in-glass thermometer).



The thermistor is used in a circuit to keep the water in a tank at a constant temperature. What is the temperature of the water when the resistance of the thermistor is  $420\text{ k}\Omega$ ? (6)

A thermocouple thermometer has emf values of  $0\text{ }\mu\text{V}$  at  $0\text{ }^{\circ}\text{C}$  and  $815\text{ }\mu\text{V}$  at  $100\text{ }^{\circ}\text{C}$ . When the thermocouple thermometer was placed in the tank of water, its emf was found to be  $319\text{ }\mu\text{V}$ . What is the temperature of the water in the tank as measured by the thermocouple thermometer? (9)

Why do the thermistor and the thermocouple thermometer give different temperature readings for the water in the tank? (7)

**Blank Page**