Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2013

PHYSICS AND CHEMISTRY – HIGHER LEVEL

MONDAY, 17 JUNE – MORNING, 9:30 to 12:30

Six questions to be answered.

Answer any **three** questions from **Section I** and any **three** questions from **Section II**.

All questions carry equal marks.

However, in each section, one additional mark will be given to each of the first two questions for which the highest marks are obtained.

N.B. Relevant data are listed in the *Formulae and Tables* booklet, which is available from the superintendent. Take the acceleration due to gravity, $g = 9.8 \text{ m s}^{-2}$.

SECTION I – PHYSICS (200 marks)

1. Answer **eleven** of the following items (*a*), (*b*), (*c*), etc. All the items carry equal marks.
Keep your answers short.

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

(*b*) Distinguish between a vector and a scalar.

(*c*) Define the unit of power, i.e. the *watt*.

(*d*) Identify the wave phenomena shown at **A** and at **B** in **Figure 1**.

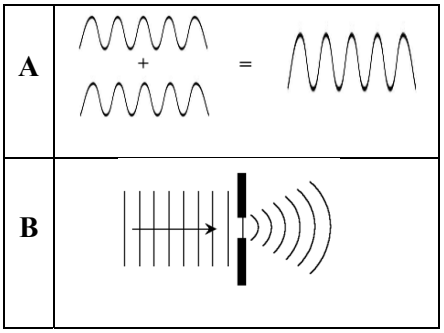

Figure 1

(*e*) Describe what happens in the *photoelectric effect*.

(*f*) What is a transverse wave?

(*g*) Calculate the energy of a photon of ultraviolet radiation that has a frequency of 1.2×10^{15} Hz.

(*h*) State *Boyle's law*.

(*i*) What is a thermometric property? Give an example.

(*j*) What is the purpose of the fuse in the plug shown in **Figure 2**?

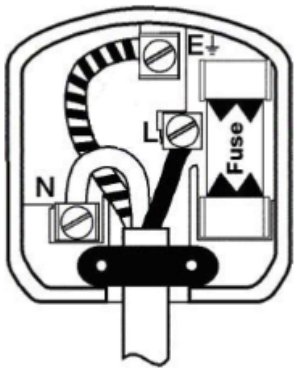

Figure 2

(*k*) What is *electromagnetic induction*?

(*l*) State the principle on which the operation of the moving-coil galvanometer is based.

(*m*) **Figure 3** represents an alternating current. Copy the diagram into your answerbook and label the axes.

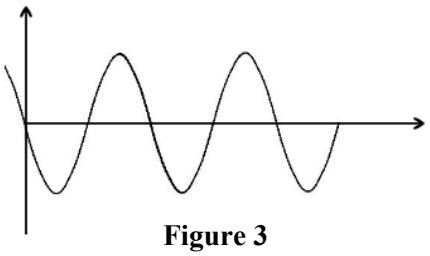

Figure 3

(*n*) What is meant by *radioactivity*?

(*o*) Give two properties of a beta particle.

(11 × 6)

2. (*a*) Define (i) momentum, (ii) potential energy. (12)

(*b*) State the law of conservation of energy. (6)

(*c*) List the energy conversions that occur

(i) while a hailstone is falling
(ii) when a hailstone strikes the ground
(iii) as a hailstone bounces up from the ground. (9)

(*d*) Describe, with the aid of a labelled diagram, a laboratory experiment to measure velocity. (12)

(*e*) Calculate

(i) the change in momentum when a large raindrop of mass 0.065 g travelling vertically with a velocity of 9 m s^{-1} strikes the ground and comes to rest

(ii) the change in momentum when a hailstone of mass 0.065 g travelling vertically with a velocity of 12 m s^{-1} strikes the ground and rebounds with an initial upwards velocity of 2 m s^{-1}

(iii) the force exerted on the ground by the hailstone if it remains in contact with the ground for 0.08 s

(iv) the maximum height reached by the hailstone after the bounce.

Suggest a reason why hailstones, striking bare skin, hurt more than raindrops do. (27)

3. (*a*) State the laws of reflection of light. (6)

(*b*) Distinguish between a real image and a virtual image, in terms of light rays. (6)

(*c*) Draw a ray diagram to show the formation of an image of an object by a convex mirror. (9)

(*d*) An experiment was carried out to measure the focal length of a convex mirror. A tall search pin was used to locate each image.

(i) Sketch the arrangement of the apparatus.
(ii) Explain why the images could not be located using a screen.
(iii) How was the tall search pin used to find the image positions?
(iv) What measurements were made in the experiment?
(v) How were these measurements used to determine the focal length of the mirror?
(vi) Mention one precaution taken to ensure an accurate result. (21)

Convex mirrors are sometimes used as rear-view door mirrors on cars as shown in **Figure 4**.

(*e*) Give one advantage and one disadvantage of using a convex mirror instead of a plane mirror as the exterior door mirror on a car. (6)

(*f*) A car door mirror has a focal length of 1.5 m. An ambulance is 21 m from the mirror. An image of the ambulance is formed by the mirror.

Calculate

(i) the image distance
(ii) the magnification. (18)

Figure 4

4. (*a*) The kinetic theory of gases explains the properties of the *ideal gas* in terms of the behaviour of its molecules. *Brownian motion* provides evidence for the kinetic theory.

State two of the assumptions of the kinetic theory of gases.

Define the ideal gas.

State two ways in which the behaviour of a real gas differs from the behaviour of the ideal gas.

Describe how you would demonstrate Brownian motion. (27)

(*b*) In 1787 Jacques Charles investigated the relationship between the volume and the temperature of a fixed mass of gas at constant pressure.

Sketch a labelled graph to show the relationship established by Charles.

How is the concept of absolute zero of temperature related to Charles' law? (15)

(*c*) A weather balloon like that shown in **Figure 5**, carrying a small instrument package that transmitted weather data, was filled with hydrogen gas. At ground level when the temperature was 5.0 °C, the balloon had a volume of 4.2 m^3. At night, when the temperature had dropped, the volume was 3.9 m^3. Assuming that the atmospheric pressure remained constant at 1×10^5 N m^{-2}, use Charles' law to deduce the night-time temperature at ground level.

Figure 5

Calculate the number of moles of hydrogen gas in the balloon.

When the balloon was released it ascended, expanding as it rose, to a height of about 30 km where it had a volume of 464 m^3. The temperature reading transmitted at this height was 230.7 K.

Calculate the pressure of the atmosphere at this height. (24)

5. (*a*) State Ohm's law.

Define *resistance*. (12)

Define the *ampere*, the unit of electrical current. (9)

(*b*) A student measured the temperature rise $\Delta\theta$ of a fixed mass of water in a certain time for a number of different currents I, using a heating coil immersed in the water.

Draw a labelled diagram of an apparatus that could have been used. (9)

The following data were recorded.

I/A	0.5	1.0	1.5	2.0	2.5	3.0	3.5
$\Delta\theta$/K	1.0	4.1	8.8	15.8	24.4	36.1	50.0

Use the data to draw a suitable graph to show the relationship between the rise in temperature of the water and the current. (15)

(*c*) In an 'instant' electric shower, the temperature of a fixed mass of water is raised over a short period of time.

Calculate the current in the heating coil of an 8.5 kW electric shower that is connected to the mains supply of 230 V when it is used at full power. (6)

Hence calculate the resistance of the heating coil. (6)

The temperature rise of the water when the shower is operating at full power is 30 ºC.

Deduce the temperature rise, assuming the same flow rate of water, when the shower is used at half power. (3)

State two effects of an electric current, other than heating. (6)

6. Answer any **two** of the following parts (*a*), (*b*), (*c*), (*d*). Each part carries 33 marks.

(*a*) Define weight.

What is the weight of a 0.2 kg apple? (6)

Describe a laboratory experiment to measure the acceleration due to gravity, *g*. (15)

State *Newton's law of universal gravitation*. (6)

Calculate the gravitational force between the 0.2 kg apple and the earth. The mass of the earth is 6.0×10^{24} kg and its radius is 6.4×10^{6} m. (6)

(*b*) Define (i) critical angle, (ii) total internal reflection. (12)

Two rays of light labelled **A** and **B**, travelling through air, enter a semi-circular block of glass as shown in **Figure 6**. The path of ray **A** in the glass and as it emerges into air is also shown.

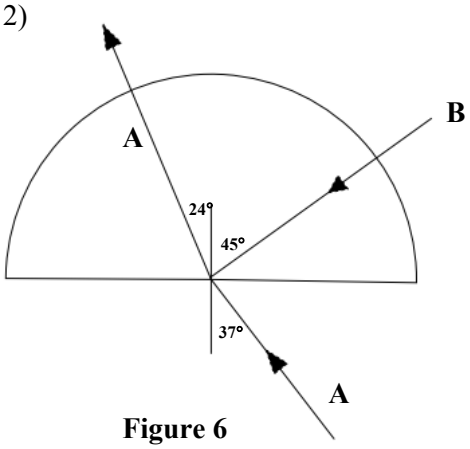

Figure 6

Calculate

(i) the refractive index of the glass
(ii) the critical angle for the glass
(iii) the speed of light in the glass.

Copy the diagram into your answerbook and complete the pathway followed by ray **B** showing clearly where ray **B** emerges from the glass block. (21)

(*c*) Define *capacitance*. (6)

Describe an experiment to show how the capacitance of a parallel-plate capacitor depends on the common area of the plates. (9)

The switch in the circuit shown in **Figure 7** was initially in position **B**. The switch was moved from position **B** to position **A**, connecting the 9 μF parallel-plate capacitor to the 12 V battery.

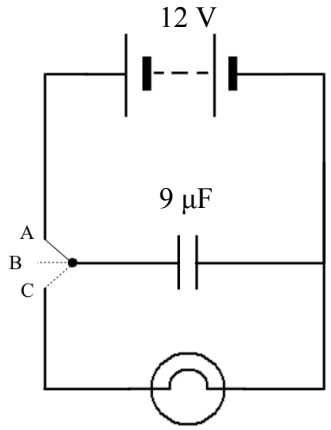

Figure 7

What charge was stored in the capacitor? (6)

Draw the electric field pattern around a charged capacitor. (6)

When the switch was then moved to position **C**, the bulb glowed briefly.

Explain. (6)

(*d*) The sun and other stars obtain their energy from nuclear fusion reactions.
Distinguish between nuclear fusion reactions and nuclear fission reactions. (12)

The following fusion reaction occurs in the sun.

$$\mathbf{{}^{1}_{1}H} + \mathbf{{}^{2}_{1}H} \rightarrow \mathbf{{}^{3}_{2}He} + \text{energy}$$

Using the relevant data listed on page 83 of the *Formulae and Tables* booklet, calculate the energy released by this reaction when one helium–3 nucleus is produced. (15)

Controlled nuclear fusion has not yet been achieved.

Give one potential advantage that nuclear fusion would have over nuclear fission for energy production. (3)

Give an example of an uncontrolled nuclear fusion reaction that has already been developed on earth. (3)

SECTION II – CHEMISTRY (200 marks)

7. Answer **eleven** of the following items, (*a*), (*b*), (*c*), etc. All the items carry equal marks.
Keep your answers short.

(*a*) Identify the metal associated with (i) a yellow colour, (ii) a lilac colour, when metal salts are heated strongly in a Bunsen flame.

(*b*) Define the *relative atomic mass* of an element.

(*c*) What information about an electron in an atom is given by (i) the principal quantum number, (ii) the fourth quantum number?

(*d*) Give a reason why (i) the first ionisation energy values show a general increase, (ii) atomic radii decrease, across the periods in the periodic table of the elements.

(*e*) Explain, in terms of bonding, how metals can conduct electricity.

(*f*) Select from the following the molecules that have a dipole moment.

BF_3 **CO_2** **H_2O** **NH_3** **BeH_2** **CH_4**

(*g*) The toxic chemical stibnite (antimony sulfide, **Sb_2S_3**) was used as an eye cosmetic in ancient times, as shown in **Figure 8**. Calculate the percentage by mass of the element antimony in stibnite.
[**S** = 32; **Sb** = 122]

Figure 8

(*h*) What is meant by the *valency* of an element?

(*i*) Identify (i) the conjugate acid of **$H_2PO_4^-$** (ii) the conjugate base of **HF**.

(*j*) Give an example of (i) a basic oxide, (ii) an amphoteric oxide.

(*k*) Define *heat of solution*.

(*l*) In connecting a Liebig condenser to a cold water tap, which nozzle **A** or **B**, as shown in **Figure 9**, should be used?

(*m*) What is a *functional group* in organic chemistry?

(*n*) Why is ultraviolet light essential if methane and chlorine are to react?

(*o*) Draw the molecular structure of methyl ethanoate.

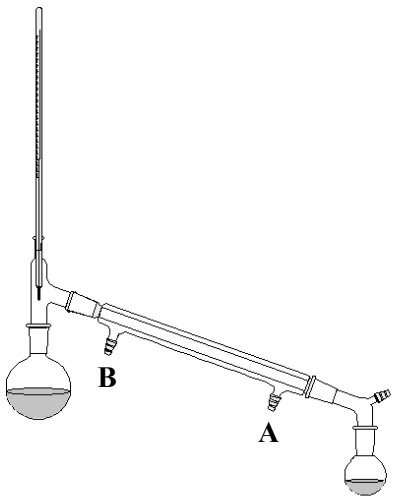

Figure 9

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8. Substances, whether solid, liquid or gaseous, are composed of particles which may be ions, atoms or molecules.

Figure 10

(*a*) **Figure 10** shows crystals of table salt, or sodium chloride, which is an ionic compound. Draw a dot and cross diagram to show how a sodium atom and a chlorine atom react to form sodium chloride. (12)

Describe the arrangement of ions within a crystal of sodium chloride. (9)

(*b*) Use electronegativity values to predict the type of bonding that occurs in a water molecule.

Use electron pair repulsion theory to predict the shape of the water molecule.

State the bond angle in the water molecule.

Name the type of bonding that holds water molecules together in ice and that is broken when ice melts as shown in **Figure 11**.

Explain how this type of bond between water molecules is formed. (21)

Figure 11

(*c*) Explain

(i) why sodium chloride crystals are water soluble

(ii) the conduction of electricity by aqueous sodium chloride solution. (12)

(*d*) A crystal of diamond, the hardest known substance, is shown in **Figure 12**.

Name the category of crystal to which diamond belongs.

What particles occupy the lattice points in a diamond?

Explain the hardness of diamond. (12)

Figure 12

9. (*a*) Define an acid in terms of the Brønsted-Lowry theory.

Distinguish between a strong acid and a weak acid in terms of the Brønsted-Lowry theory.

Give an example of a weak acid. (12)

(*b*) Define pH.

Calculate the pH of a solution of

(i) 0.1 M **HCl**

(ii) 0.1 M $\mathbf{H_2SO_4}$ (9)

A student titrated an acidic solution of *approximate* concentration 0.1 M and known to be *either* **HCl** *or* $\mathbf{H_2SO_4}$ against 25.0 cm^3 portions of a standard sodium carbonate solution that had a concentration of exactly 0.05 M. The two possible titration reactions are as follows.

$$\mathbf{Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2}$$

$$\mathbf{Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + H_2O + CO_2}$$

(*c*) Name one indicator suitable for both of these titrations.

Justify your choice of indicator.

State the colour change observed at the end point. (12)

(*d*) Describe the correct procedure for rinsing, filling and emptying a pipette during the titration. (12)

(*e*) One rough and two accurate titrations were carried out and the following volumes of acidic solution were recorded: 24.9 cm^3, 24.6 cm^3 and 24.5 cm^3.

Determine, by calculation, whether the acid used was **HCl** or $\mathbf{H_2SO_4}$.

Calculate, correct to three significant figures, the concentration of the acid in terms of (i) moles per litre, (ii) grams per litre. (18)

How could the student measure accurately the pH of the acid to confirm the identity of the acid? (3)

10. (*a*) Arrange the following metals in order of *decreasing* reactivity according to the electrochemical series.

silver **iron** **aluminium** **zinc** **sodium**

Which of these metals may be found free in nature? (9)

(*b*) What do the electron configurations of the transition metals have in common?
Which of the metals listed above are transition metals?
List two properties that are common to transition metals. (18)

(*c*) Explain why iron corrodes more rapidly than aluminium.
How does galvanising with zinc protect iron from corrosion? (12)

(*d*) Write a balanced chemical equation for the reaction between sodium and water. (6)

(*e*) Give two observations made when a zinc rod and a copper rod are dipped into dilute sulfuric acid solution and joined as shown in **Figure 13**.
Give a reason for one of these observations. (9)

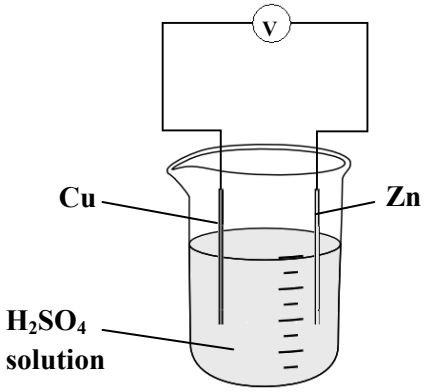

Figure 13

(*f*) Define (i) oxidation, (ii) reduction, in terms of electron transfer.
Identify the reducing agent in each of the following reactions that involve silver.

$$2Ag + S \rightarrow Ag_2S$$

$$3Ag_2S + 2Al \rightarrow 6Ag + Al_2S_3$$

(12)

11. (*a*) What is a *homologous series* of organic compounds? (6)

(*b*) What is a hydrocarbon?
Explain the term *unsaturated* hydrocarbon. (12)

(*c*) Draw the structure of the ethyne molecule.
Name the homologous series to which ethyne belongs. (6)

The arrangement shown in **Figure 14** is used in the preparation of the unsaturated hydrocarbon ethyne from liquid **A** and solid **B**.

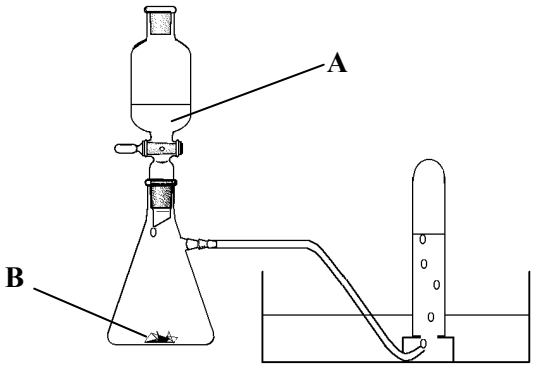

Figure 14

(*d*) Identify liquid **A** and solid **B** and write a balanced equation for the reaction to prepare ethyne. (12)

(*e*) Describe the flame observed when a test tube of ethyne is burned in air. (6)

(*f*) Describe a test to verify that ethyne is unsaturated. (9)

(*g*) Give a major use for ethyne gas. (3)

Ethyne gas can be converted into other useful organic compounds including **X**, **Y** and **Z**, as shown in **Figure 15**.

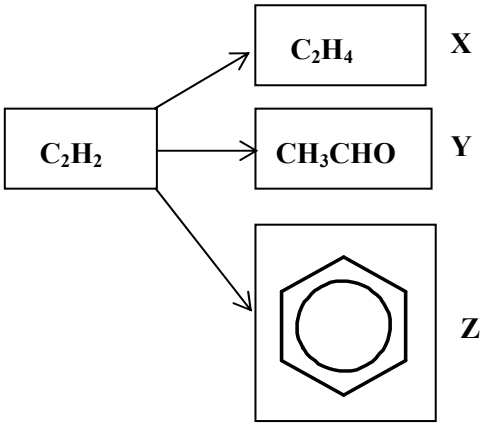

Figure 15

(*h*) Name the compounds **X**, **Y** and **Z**.
Name the reaction type when ethyne is converted to compound **X**. (12)

12. Answer any **three** of the following parts (*a*), (*b*), (*c*), (*d*). Each part carries 22 marks.

(*a*) Name the scientist, pictured in **Figure 16**, who first applied quantum theory to the energy of electrons in atoms.

Define (i) an atomic energy level, (ii) an atomic orbital.

Write the electron configuration (*s*, *p*) for a magnesium atom.

How many orbitals are occupied by electrons in a magnesium atom in its ground state?

Figure 16

(*b*) **Figure 17** shows an apparatus used in the electrolysis of acidified water using inert electrodes.

Which electrode, **A** or **B**, is the cathode?

What gas is collected above the cathode?

Write a balanced equation for the cathode reaction.

A current of 0.60 A was passed through the acidified water for 8 minutes. What volume of gas, measured at STP, was produced at the cathode?

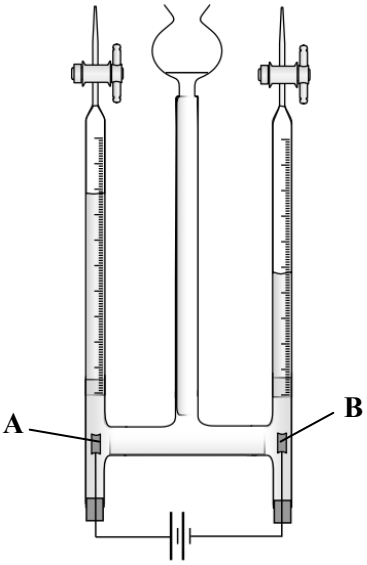

Figure 17

(*c*) The following balanced equation shows the reaction between a sodium hydroxide solution and aluminium metal.

$$\mathbf{2Al + 2NaOH + 2H_2O \rightarrow 2NaAlO_2 + 3H_2}$$

When 10.8 g of aluminium is added to excess dilute sodium hydroxide solution, calculate

(i) the number of moles of water that react
(ii) the mass of sodium aluminate ($\mathbf{NaAlO_2}$) produced
(iii) the number of hydrogen molecules formed.

Suggest a reason why a sodium hydroxide solution should not be stored in an aluminium container.

(*d*) State *Hess's law*.

Consider the following reactions.

$$\mathbf{C_{(s)} + O_{2\,(g)} \rightarrow CO_{2\,(g)} \qquad \Delta H = -393.5\ kJ\ mol^{-1}}$$
$$\mathbf{C_{(s)} + \tfrac{1}{2}O_{2\,(g)} \rightarrow CO_{(g)} \qquad \Delta H = -110.5\ kJ\ mol^{-1}}$$
$$\mathbf{\tfrac{1}{2}N_{2\,(g)} + \tfrac{1}{2}O_{2\,(g)} \rightarrow NO_{(g)} \qquad \Delta H = 91.3\ kJ\ mol^{-1}}$$

Use Hess's law and the heats of formation above to calculate the heat of reaction for the following conversion that occurs in the catalytic converter in a car exhaust system.

$$\mathbf{2NO_{(g)} + 2CO_{(g)} \rightarrow 2CO_{2\,(g)} + N_{2\,(g)}}$$

Although $\mathbf{CO_2}$ has a significant greenhouse effect, explain why the product gases of this reaction are considered environmentally less harmful than the reactant gases.

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