Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2006

PHYSICS – HIGHER LEVEL

MONDAY, 19 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.

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1. In investigating the relationship between the period and the length of a simple pendulum, a pendulum was set up so that it could swing freely about a fixed point. The length l of the pendulum and the time t taken for 25 oscillations were recorded. This procedure was repeated for different values of the length.

The table shows the recorded data.

l/cm	40.0	50.0	60.0	70.0	80.0	90.0	100.0
t/s	31.3	35.4	39.1	43.0	45.5	48.2	50.1

The pendulum used consisted of a small heavy bob attached to a length of inextensible string.
Explain

(i) why a small heavy bob was used;
(ii) why the string was inextensible. (9)

Describe how the pendulum was set up so that it swung freely about a fixed point.
Give one other precaution taken when allowing the pendulum to swing. (7)

Draw a suitable graph to investigate the relationship between the period of the simple pendulum and its length. What is this relationship? Justify your answer. (24)

2. In an experiment to measure the wavelength of monochromatic light, a narrow beam of the light fell normally on a diffraction grating. The grating had 300 lines per millimetre. A diffraction pattern was produced. The angle between the second order image to the left and the second order image to the right of the central bright image in the pattern was measured. The angle measured was 40.6^{o}.

Describe, with the aid of a labelled diagram, how the data was obtained. (9)

How was a narrow beam of light produced? (6)

Use the data to calculate the wavelength of the monochromatic light. (15)

Explain how using a diffraction grating of 500 lines per mm leads to a more accurate result. (6)

Give another way of improving the accuracy of this experiment. (4)

3. A cylindrical column of air closed at one end and three different tuning forks were used in an experiment to measure the speed of sound in air. A tuning fork of frequency f was set vibrating and held over the column of air.
The length of the column of air was adjusted until it was vibrating at its first harmonic and its length l was then measured. This procedure was repeated for each tuning fork.
Finally, the diameter of the column of air was measured.

The following data was recorded.

f/Hz	512	480	426
l/cm	16.0	17.2	19.4
Diameter of column of air = 2.05 cm			

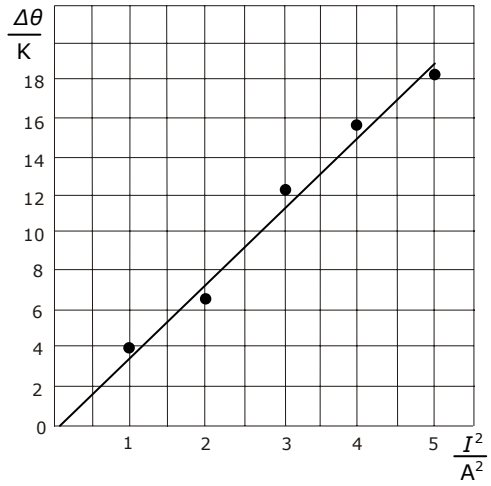
Describe

(i) how the length of the column of air was adjusted;
(ii) how the frequency of the column of air was measured;
(iii) how the diameter of the column of air was measured. (16)

How was it known that the air column was vibrating at its **first** harmonic? (9)

Using all of the data, calculate the speed of sound in air. (15)

4. In an experiment to verify Joule's law a student passed a current through a heating coil in a calorimeter containing a fixed mass of water and measured the rise in temperature $\Delta\theta$ for a series of different values of the current I. The student allowed the current to flow for three minutes in each case.



Describe, with the aid of a labelled diagram, how the student arranged the apparatus. (12)
Why was a fixed mass of water used throughout the experiment? (6)
The student drew a graph, as shown. Explain how this graph verifies Joule's law. (7)

Given that the mass of water in the calorimeter was 90 g in each case, and assuming that all of the electrical energy supplied was absorbed by the water, use the graph to determine the resistance of the heating coil. The specific heat capacity of water is 4200 J kg^{-1} K^{-1}. (15)

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) State Newton's third law of motion. (7)

(b) Why is it easier to turn a nut using a longer spanner than a shorter one? (7)

(c) The average value for the solar constant in Ireland is 1.2×10^2 W m^{-2}. What is the average energy falling normally on an area of 5 m^2 of ground in Ireland in 1 minute? (7)

(d) A sound wave is diffracted as it passes through a doorway but a light wave is not. Explain why. (7)

(e) What is the Doppler effect? (7)

(f) An RCD is rated 30 mA. Explain the significance of this current. (7)

(g) Why is Coulomb's law an example of the inverse square law? (7)

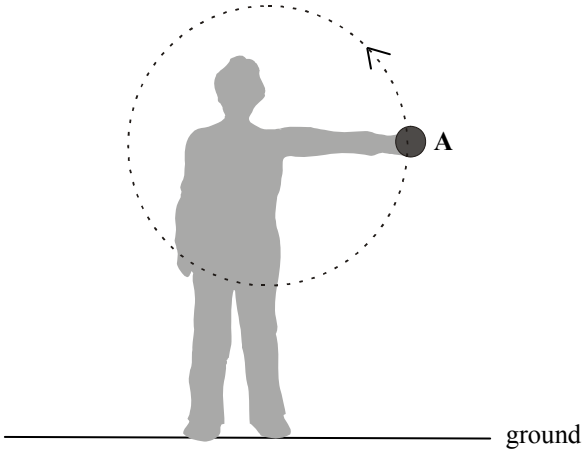
(h) Sketch a graph to show the variation of current with potential difference for a semiconductor diode in forward bias. (7)

(i) Describe the Bohr model of the atom. (7)

(j) Name the three negatively charged leptons.
or
How can a galvanometer be converted into a voltmeter? (7)

6. Define (i) velocity, (ii) angular velocity. (12)

Derive the relationship between the velocity of a particle travelling in uniform circular motion and its angular velocity. (12)



A student swings a ball in a circle of radius 70 cm in the vertical plane as shown. The angular velocity of the ball is 10 rad s^{-1}.

What is the velocity of the ball? How long does the ball take to complete one revolution? (9)

Draw a diagram to show the forces acting on the ball when it is at position A. (6)

The student releases the ball when is it at A, which is 130 cm above the ground, and the ball travels vertically upwards.
Calculate

(i) the maximum height, above the ground, the ball will reach;
(ii) the time taken for the ball to hit the ground after its release from A.

(17)

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

7. What is meant by the refraction of light? (6)

A converging lens is used as a magnifying glass.
Draw a ray diagram to show how an erect image is formed by a magnifying glass. (12)

A diverging lens cannot be used as a magnifying glass.
Explain why. (5)

The converging lens has a focal length of 8 cm. Determine the two positions that an object can be placed to produce an image that is four times the size of the object? (15)

The power of an eye when looking at a distant object should be 60 m^{-1}. A person with defective vision has a minimum power of 64 m^{-1}.

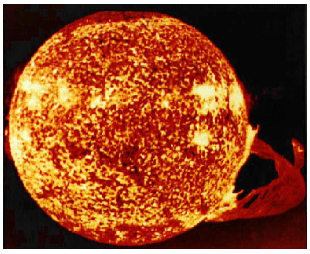
Calculate the focal length of the lens required to correct this defect. (12)

What type of lens is used? Name the defect. (6)

8. Distinguish between fission and fusion. (12)

The core of our sun is extremely hot and acts as a fusion reactor. Why are large temperatures required for fusion to occur? (5)

In the sun a series of different fusion reactions take place. In one of the reactions, 2 isotopes of helium, each with a mass number of 3, combine to form another isotope of helium with the release of 2 protons.
Write an equation for this nuclear reaction. (12)


picture of sun from skylab

Controlled nuclear fusion has been achieved on earth using the following reaction.

$$ {}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \longrightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} $$

What condition is necessary for this reaction to take place on earth?
Calculate the energy released during this reaction. (18)

Give one benefit of a terrestrial fusion reactor under each of the following headings:
(i) fuel;
(ii) energy;
(iii) pollution. (9)

(speed of light = 2.998×10^{-8} m s^{-1}; mass of hydrogen-2 nucleus = 3.342×10^{-27} kg ; mass of hydrogen-3 nucleus = 5.004×10^{-27} kg; mass of helium nucleus = 6.644×10^{-27} kg; mass of neutron = 1.674×10^{-27} kg)

9. What is an electric current? Define the ampere, the SI unit of current. (12)

Describe an experiment to demonstrate the principle on which the definition of the ampere is based. (15)

Sketch a graph to show the relationship between current and time for
(i) alternating current;
(ii) direct current. (9)

The peak voltage of the mains electricity is 325 V. Calculate the rms voltage of the mains? (6)

What is the resistance of the filament of a light bulb, rated 40 W, when it is connected to the mains? (9)

Explain why the resistance of the bulb is different when it is **not** connected to the mains. (5)

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

(a) During a nuclear interaction an antiproton collides with a proton. Pair annihilation takes place and two gamma ray photons of the same frequency are produced.

What is a photon? Calculate the frequency of a photon produced during the interaction. (12)

Why are two photons produced? Describe the motion of the photons after the interaction. (9)

How is charge conserved during this interaction? (6)

After the annihilation, pairs of negative and positive pions are produced. Explain why. (6)

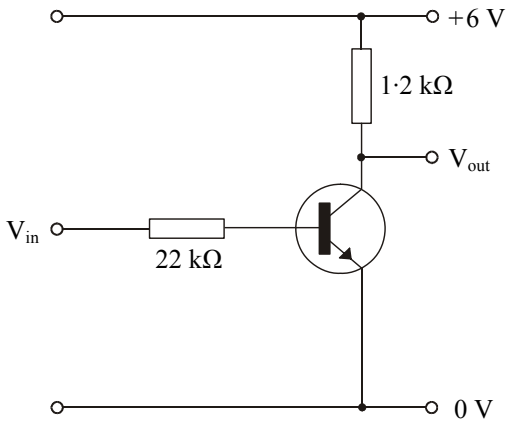
Pions are mesons that consist of up and down quarks and their antiquarks. Give the quark composition of (i) a positive pion, (ii) a negative pion. (9)

List the fundamental forces of nature that pions experience. (6)

A neutral pion is unstable with a decay constant of 2.5×10^{12} s^{-1}. What is the half-life of a neutral pion? (8)

(mass of proton= 1.673×10^{-27} kg; Planck constant = 6.626×10^{-34} J s; speed of light = 2.998×10^{8} m s^{-1})

(b) What is a transistor? Describe the structure of a bipolar transistor. (12)



The circuit diagram represents a voltage inverter.

What is the function of each resistor in the circuit? (6)

Explain why the output voltage is almost 0 V when the input voltage is 6 V. (12)

Calculate the collector current when the input voltage is 6V. (Assume that the output voltage is 0 V). (9)

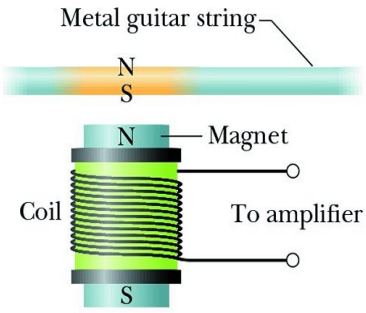
A voltage inverter is also a NOT gate.

Draw the symbol and truth table for a NOT gate. (12)

What is the significance of the work of George Boole in modern day electronics? (5)

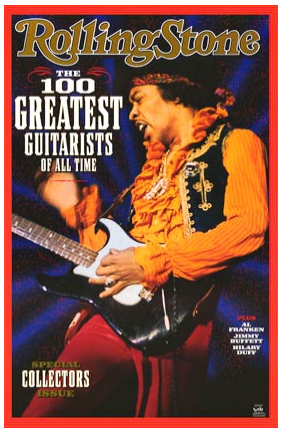
11. Read the following passage and answer the accompanying questions.

The growth of rock music in the 1960s was accompanied by a switch from acoustic guitars to electric guitars. The operation of each of these guitars is radically different.



The frequency of oscillation of the strings in both guitars can be adjusted by changing their tension. In the acoustic guitar the sound depends on the resonance produced in the hollow body of the instrument by the vibrations of the string. The electric guitar is a solid instrument and resonance does not occur.

Small bar magnets are placed under the steel strings of an electric guitar, as shown. Each magnet is placed inside a coil and it magnetises the steel guitar string immediately above it. When the string vibrates the magnetic flux cutting the coil changes, an emf is induced causing a varying current to flow in the coil. The signal is amplified and sent to a set of speakers.



Jimi Hendrix refined the electric guitar as an electronic instrument. He showed that further control over the music could be achieved by having coils of different turns.

(Adapted from Europhysics News (2001) Vol. 32 No. 4)

(a) How does resonance occur in an acoustic guitar? (7)

(b) What is the relationship between frequency and tension for a stretched string? (7)

(c) A stretched string of length 80 cm has a fundamental frequency of vibration of 400 Hz. What is the speed of the sound wave in the stretched string? (7)

(d) Why must the strings in the electric guitar be made of steel? (7)

(e) Define magnetic flux. (7)

(f) Why does the current produced in a coil of the electric guitar vary? (7)

(g) What is the effect on the sound produced when the number of turns in a coil is increased? (7)

(h) A coil has 5000 turns. What is the emf induced in the coil when the magnetic flux cutting the coil changes by 8×10^{-4} Wb in 0.1 s? (7)

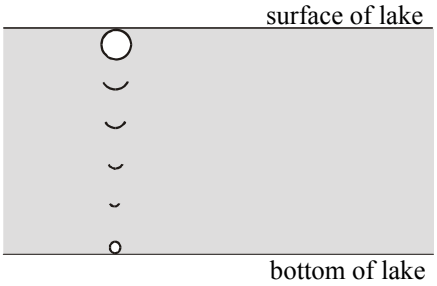
12. Answer any **two** of the following parts *(a), (b), (c), (d).*

(a) Define pressure. (6)

Is pressure a vector quantity or a scalar quantity? Justify your answer. (6)

State Boyle's law. (6)

A small bubble of gas rises from the bottom of a lake. The volume of the bubble increases threefold when it reaches the surface of the lake where the atmospheric pressure is 1.01×10^5 Pa. The temperature of the lake is 4 ^{o}C.



Calculate

(i) the pressure at the bottom of the lake;

(ii) the depth of the lake. (10)

(acceleration due to gravity = 9.8 m s^{-2}; density of water = 1.0×10^3 kg m^{-3})

(b) List the factors that affect the capacitance of a parallel plate capacitor. (6)

The plates of an air filled parallel plate capacitor have a common area of 40 cm^2 and are 1 cm apart. The capacitor is connected to a 12 V d.c. supply.

Calculate

(i) the capacitance of the capacitor;

(ii) the magnitude of the charge on each plate. (15)

What is the net charge on the capacitor?

Give a use for a capacitor. (7)

(permittivity of free space = 8.85×10^{-12} F m^{-1})

(c) Define (i) power, (ii) specific heat capacity. (9)

400 g of water at a temperature of 15 ^{o}C is placed in an electric kettle. The power rating of the kettle is 3.0 kW.

Calculate

(i) the energy required to raise the temperature of the water to 100 ^{o}C;

(ii) the energy supplied by the kettle per second;

(iii) the least amount of time it would take to heat the water to 100 ^{o}C. (15)

In reality, the time taken to heat the water will be greater. Explain why. (4)

(specific heat capacity of water = 4200 J kg^{-1} K^{-1})

(d) The first Nobel Prize in Physics was awarded in 1901 for the discovery of X-rays. What are X-rays? Who discovered them? (9)

In an X-ray tube electrons are emitted from a metal cathode and accelerated across the tube to hit a metal anode.

How are the electrons

(i) emitted from the cathode;

(ii) accelerated? (6)

Calculate the kinetic energy gained by an electron when it is accelerated through a potential difference of 50 kV in an X-ray tube.

Calculate the minimum wavelength of an X-ray emitted from the anode. (13)

(Planck constant = 6.6×10^{-34} J s; speed of light = 3.0×10^{8} m s^{-1};
charge on electron = 1.6×10^{-19} C)

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