Matura Exams 2007

Physics

Class 4a

Part A: Short Questions

First Name: .....

Last Name: .....

Time: 60 minutes

Aids: pen and pencil, ruler and set square, set of compasses, monolingual English dictionary

Write the solutions to the questions on the problem sheets. The reverse sides may be used for longer calculations or sketches.

Express numerical results as rounded decimal numbers (except in ratios).

Good luck!

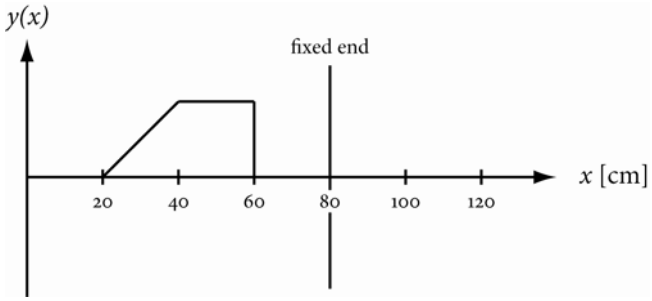
Points:	/ 81

A1 A wooden block placed in a tank filled with glycerine sinks to two thirds of its height. Calculate the force required to push it completely under water.

4 P

A2 The diagram below describes the shape of a wave at $t = 0$. The wave travels to the right at 20 cm/s, where it is reflected at a fixed end. Draw the shape of the wave at $t = 2.5$ s.

4 P



A3 An engine with efficiency 30 % delivers 75 kW of power for two hours. Calculate the input energy.

4 P

A4 When a vertically suspended rod is horizontally displaced by a distance x, it experiences the restoring force given by the formula below. Explain why this corresponds to a simple harmonic motion and find a formal expression for the period of the rod.

4 P

$$F_x \cong -\frac{3}{2} \cdot \frac{m \cdot g \cdot x}{\ell}$$

A5 Give an example for a) an unpolarised and b) a totally polarised wave.

2 P

A6 In the following pairs of numbers, add the appropriate operator (>, =, <). If a comparison is not possible (e.g. because of different units), use the unequal sign (≠).

6 P

a) 2.5 g/ℓ 2.5 kg/m³ b) 350 VA 0.35 Nm/ms c) 7.5 kW/h 10 MJ

d) 68 pF $6.8 \cdot 10^{-13}$ F e) 150 kg 1.5 hℓ f) 970 mbar 970 kPa

A7 In an ac circuit with frequency 60 Hz, the current lags behind the voltage by 2.5 ms. Calculate the phase shift.

3 P

A8 Which one is faster: A 1 MeV electron or a 20 MeV proton? Give reasons for your answer.

3 P

A9 Mark the correct statements with a cross:

4 P

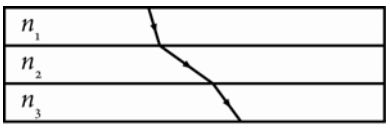
- ☐ The interval heard between 200 Hz and 400 Hz is the same as between 400 Hz and 600 Hz.
- ☐ Sound waves in air are always longitudinal.
- ☐ Two noises with 85 dB and 75 dB, respectively, together have an intensity level of less than 88 dB.
- ☐ Closing one end of a tube moves its fundamental frequency up by one octave.
- ☐ The speed of sound in air increases when the temperature rises.

A10 A cup of hot coffee cools down to room temperature. Making reasonable estimates for the required quantities, calculate the average cooling power.

5 P

A11 A light ray travels through three layers of different transparent media (see figure). Arrange the refractive indices n_1, n_2 and n_3 in increasing order. Give reasons for your solution.

3 P



A12 On a smooth surface, a bug of mass 10.2 mg can pull with a force of 13 mN. Calculate the maximum acceleration the bug can achieve.

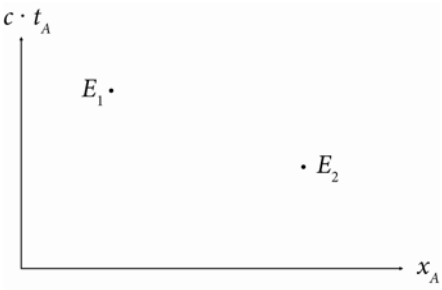
3 P

A13 Mobile phones designed for the UMTS network transmit at some 2 GHz. Calculate the length of an appropriate antenna.

4 P

A14 The diagram shows two events E_1 und E_2 in the rest system of observer A. Construct the world line of an observer B for whom the two events are simultaneous.

3 P

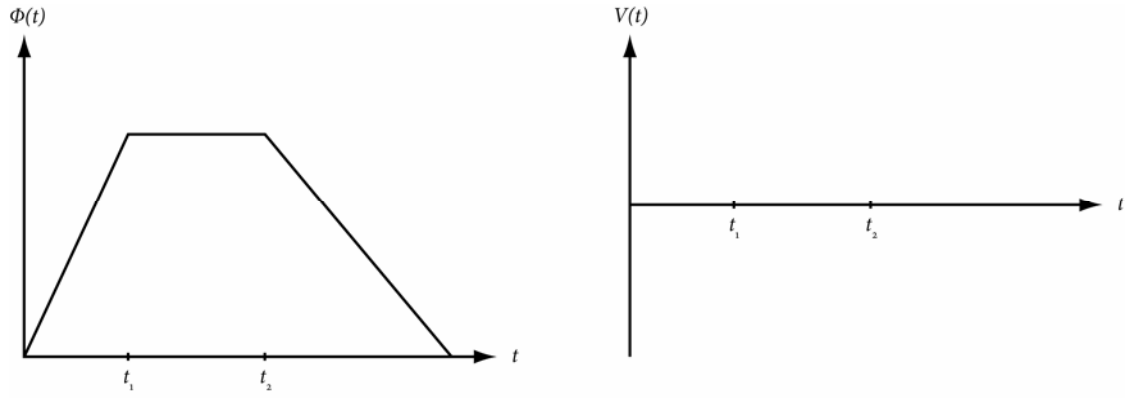


A15 The radioactive isotope Na-24 has a half life of 15 h. How long does it take until 99.9 % of the initial number of active nuclei have decayed?

3 P

A16 The magnetic flux through a coil is displayed in the left diagram below. In the right diagram, sketch the induced voltage measured at the ends of the coil.

3 P



A17 Calculate the force acting on the cover of a pressure cooker with radius 20 cm at 0.2 bar of overpressure.

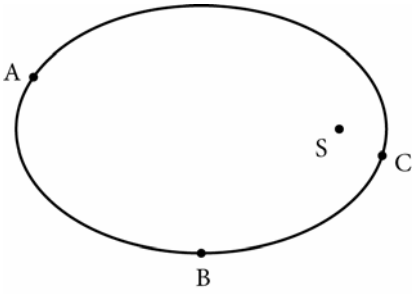
4 P

A18 The surface temperature of a wire is increased from 225 °C to 725 °C. By what factor is the emitted heat radiation changed accordingly?

3 P

A19 The figure shows the orbit of a comet around the sun S. Draw the velocity and acceleration vectors for the comet in points A, B and C. The lengths of the arrows should be in the correct order.

4 P

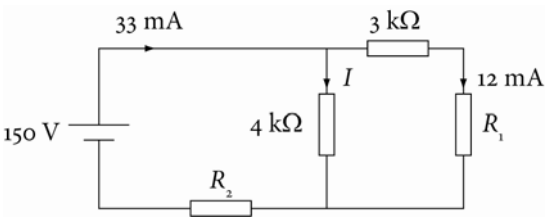


A20 Sketch the displacement vs. time graph for a lightly damped oscillation with an exponential envelope.

4 P

A21 Determine the missing quantities (I, R_1 and R_2) in the circuit.

5 P



A22 Of three electrically charged objects A, B and C, object A attracts B and B attracts C. What can you tell about the force between A and C? Give reasons for your answer.

3 P

Matura Exams 2007

Physics

Class 4a

Part B: Problems

First Name: .....

Last Name: .....

Time: 135 minutes

Aids: DMK/DPK "Formeln und Tafeln"
Graphical calculator TI 89
Brochure "Matura Exam in Physics"
Formula sheet: one page (two sides) A4, handwritten
Monolingual English dictionary

Start a new sheet of paper for every problem.

Always include formal solutions and numerical values of constants in your calculations. Round numerical results to a reasonable number of significant figures. Use appropriate units and/or powers of ten.

Formulae that cannot be found in "Formeln und Tafeln" have to be formally derived.

Answer qualitative questions in complete English sentences.

The time indications give you a guideline on how long you should dwell on a particular problem.

Good luck!

Problem:	B1	B2	B3	B4	Total
Score:	/25	/25	/18	/20	/88

B1 Neon Bulb

Time: 40'

A simple neon bulb consists of two electrodes in a glass bulb filled with neon gas. As long as the voltage applied to the electrodes is below a characteristic *ignition voltage* V_i, the resulting current is very small. When the *striking voltage* is reached, the negative electrode starts glowing and the current increases significantly. The light disappears when the voltage drops below the bulb's *extinction voltage* V_e.

The diagram on the next page (figure 2) shows the measured current vs. voltage characteristic of a typical neon bulb in its lit state (Byland, 26 April 2007).

3 P a) The measurements suggest that the current vs. voltage characteristic of the neon bulb in its lit state can be approximated by a straight line. Derive a formal expression for the resistance as a function of the applied voltage. What is the asymptotic value you can expect for high voltages?

6 P Using the information read from the diagram, calculate the numerical value for this resistance and sketch the resistance vs. voltage diagram for the lit neon bulb.

5 P b) The neon bulb is to be run on 150 V with a current of 6.5 mA flowing through it. Find the resistance of an appropriate series resistor and calculate the power dissipated in the neon bulb.

c) The neon bulb (n. b.) is used in a circuit with a 125 V voltage supply, a 2.2 MΩ resistor and a 4.7 μF capacitor (see figure 1).

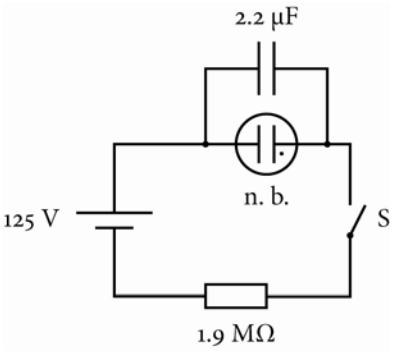


Fig. 1: Circuit diagram

6 P Calculate the time it takes after the switch S has been closed until the neon bulb lights up for the first time, i.e. until the capacitor has been charged to the ignition voltage. Hint: The current flowing through the unlit neon bulb can be neglected.

5 P Explain in words how the voltage across the capacitor changes when the neon bulb lights. Sketch the voltage across the capacitor versus time to illustrate your answer.

Diagram for problem B1:

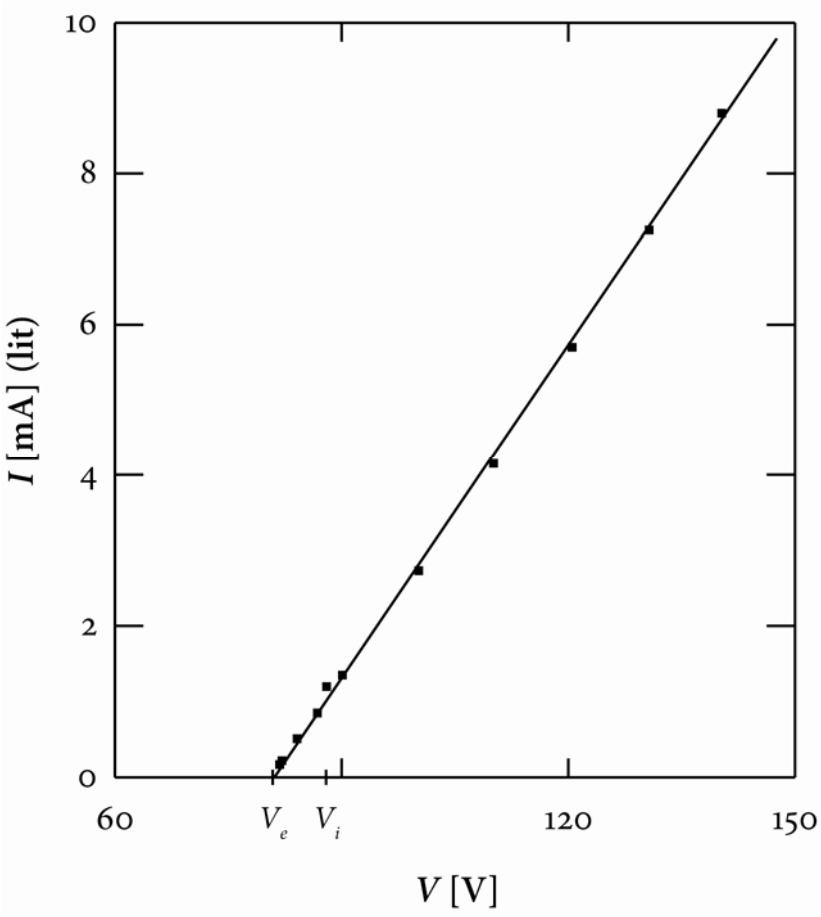


Fig. 2: Characteristic of a neon bulb with ignition voltage V_i and extinction voltage V_e

B2 Current Loop

Time: 40'

It follows from first principles that the magnetic field on the axis of a circular current loop can be calculated using the formula

$$B(x) = \frac{\mu_0 \cdot I}{2} \cdot \frac{r^2}{(x^2 + r^2)^{3/2}},$$

where I is the current flowing through the loop, r the radius of the loop and x the position on the axis (see figure 3).

To confirm this theoretical result, the magnetic field of a ring shaped coil was measured using a hall probe whith a resolution of 10 μT (Byland, 26 April 2007). The coil had radius (10.0 ± 0.2) cm and ten turns, each of them carrying a current of (9.50 ± 0.02) A. The measured values are displayed in table 1.

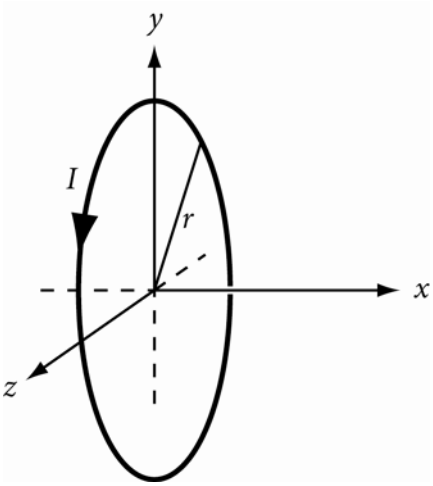


Fig. 3: Current loop

x [cm]	B [10^{-4} T]
0	5.8
2.0	5.3
4.0	4.7
6.0	3.6
8.0	2.8
10.0	2.0
12.0	1.3
16.0	0.8
20.0	0.5

Table 1: Measured data for the coil

8 P a) Calculate the magnetic field B_0 at the centre of the coil and its absolute error. Write the result properly rounded in the standard form ($B \pm \Delta B$) and check whether it is compatible with the measured value.

4 P b) Calculate the distance at which the magnitude of the magnetic field has dropped to one half of the value at the centre of the loop.

8 P c) With the substitution

$$\eta = \frac{r^2}{(x^2 + r^2)^{3/2}}$$

we expect a proportional relation between B and η. Prove this prediction by calculating the values of η from the measured data and fitting a straight line.

Briefly describe how you proceed. Write down the fit parameters (properly rounded and with correct units) and compare them to the expected values.

5 P d) An electron passes the centre of the coil in the positive z-direction with $3.7 \cdot 10^6$ m/s. Calculate the direction and the magnitude of the acceleration experienced by the electron at this position.

B3 Sound Oscillations

Time: 25'

Most realistic sound waves are not perfectly harmonic. All periodic signals can be expressed as a superposition of harmonic functions, nevertheless. As an example we will investigate a function of the form

$$\Delta p(t) = A \cdot \left(\sin(\omega \cdot t) + \eta \cdot \sin(2 \cdot \omega \cdot t)\right) \qquad (*)$$

A typical graph of this function is displayed in figure 4. We can interpret this as the pressure variation in air recorded by a microphone.

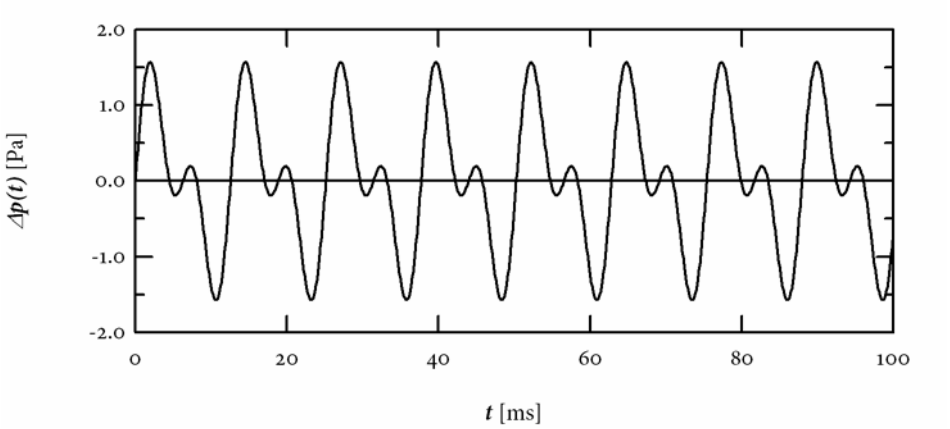


Fig. 4: Superposition of two harmonic functions

7 P a) Determine the period of the sound signal from the graph and calculate the fundamental frequency. Express the interval to the standard pitch (440 Hz) in terms of equally tempered half tones.

4 P b) Without any calculations, find realistic values and correct units for the parameters A and η in the given function (*). Give reasons for your assumptions.

c) The sound intensity J of a harmonic sound wave is given by the formula

$$J = \frac{p_{\max}{}^2}{2 \cdot v_s \cdot \rho},$$

where $p_{\max}$ is the amplitude of the pressure variation, v_s the speed of sound and ρ the density of the medium.

4 P Determine the sound intensity level (decibel level).

3 P Can the sound be heard? Give reasons for your answer.

B4 Diffraction with Electrons

Time: 30'

When quantum physics came up in the first half of the twentieth century, one of the fundamental discoveries was that massive particles also have properties of waves (*de Broglie hypothesis*). The corresponding wavelength is given by the relation

$$\lambda = \frac{h}{p},$$

where h is Planck's constant (see "Formeln und Tafeln") and p the momentum of the particle.

This relation was investigated by Carl Jönsson in 1961 in a diffraction experiment. He used a beam of electrons with a corresponding wavelength of some 5 pm on a double slit with a slit separation of about 1 µm. The diffraction pattern (see figure 5) was projected onto a screen 3.5 m beyond the slits.

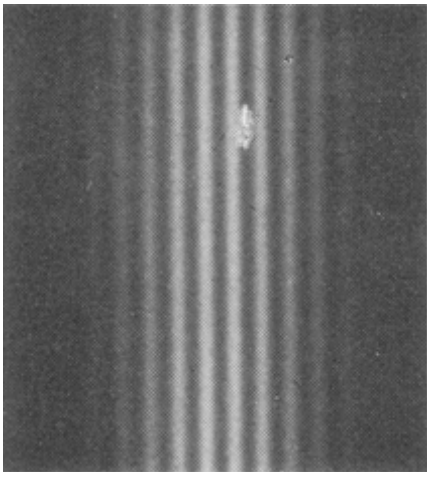


Fig. 5: Electron diffraction pattern from double slit

4 P a) Calculate the expected position of the first maximum on the screen.

4 P b) What are possible advantages and disadvantages of electron diffraction over diffraction with light? Can you think of a typical application of electron diffraction? Give reasons for your suggestion.

10 P c) Using the de Broglie relation, calculate the momentum of the electrons. Determine their (relativistic) total energy and their speed (as a fraction of the speed of light).

2 P Calculate the acceleration voltage used in the experiment.

Matura Exams 2007

Physics

Class 4a

Part C: Essay

First Name: .....

Last Name: .....

Time: 45 minutes

Aids: Copy of *The Forces of Matter* by Michael Faraday
Monolingual English dictionary

Good luck!

Correctness	Completeness	Structure	Style	Language	Total
/10	/15	/5	/5	/5	/40

The Forces of Matter

Choose one of the three topics below and write an essay of 250 – 300 words.

Although you are allowed to refer to the text, you are expected to present your own thoughts. Wherever possible try to illustrate your ideas with concrete physical examples.

Sketches are not allowed. Formal relations have to be explained in words.

The skills which are assessed are the correctness of the statements, completeness of your discussion, concise and logical structure, appropriate style and proper use of technical terms.

Topics:

1. Throughout the book, Faraday uses "force" and "power" as synonyms. Discuss the correct use of these terms from the point of view of physics in our own time. Give some examples where Faraday uses "force" or "power" in a sense that you would consider wrong.
2. In the second part of lecture V, Faraday compares the conductions of heat and electricity in matter. In a text addressed to Faraday, explain to him how these two phenomena work on a microscopic level. Illustrate your discussion by referring to some of Faraday's experiments.
3. One of Faraday's most important contributions to physics, his work on induced emf (*Faraday's law*) is not covered in the book. Imitating the style of the original lectures, write an imaginary "last lecture" about this topic.