Matura Exams 2011

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

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!

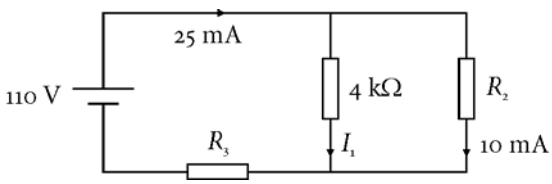
Points:	/ 82

A1 Calculate the mass of a housefly by making reasonable assumptions about its size and density.

4 P

A2 Determine the missing quantities in the electric circuit.

5 P



$I_1 =$

$R_2 =$

$R_3 =$

A3 The microscopic kinetic energy of a gas with initial temperature 25 °C is increased by 10 %. Calculate its final temperature.

3 P

A4 For each of the following pairs of values choose an appropriate comparison operator (<, = or >). If the values cannot be compared (e.g. because the units do not match), use the unequal sign (≠).

6 P

a) $3.5 \cdot 10^5$ VAs   35 kJ   b) 71 μℓ $(4\text{ mm})^3$ c) 1.8 mN   1.8 g · m/s

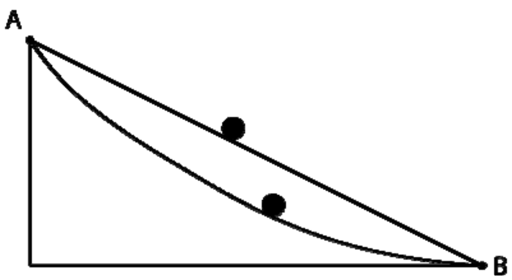
d) 44 ns $4.4 \cdot 10^{-10}$ s   e) 150 m   15 bar   f) 85 dB "+" 80 dB   88 dB

A5 Calculate the wavelength of a whistling sound with frequency 850 Hz.

3 P

A6 The time it takes the ball to get from A to B is shorter on the curved track than on the straight one although the distance is greater. Give a qualitative explanation for this observation.

2 P

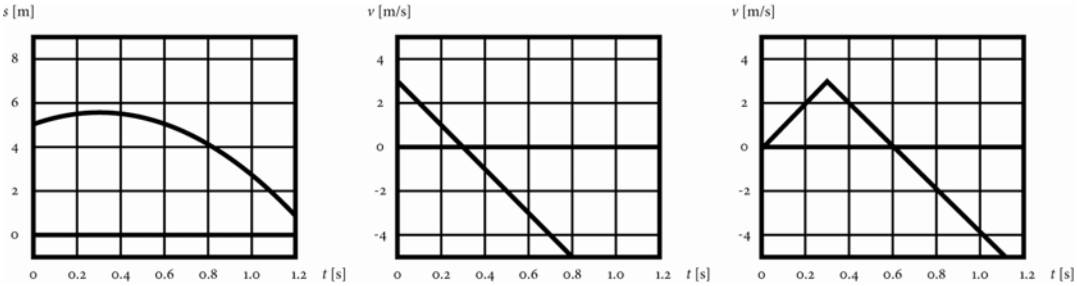


A7 The radioactive isotope $^{238}_{92}U$ emits α radiation. How many protons and neutrons are in the daughter nucleus?

3 P

A8 A linear motion of an object is described by the displacement vs. time diagram on the left. Which of the two velocity vs. time diagrams describes the same motion? Describe the other motion in words.

3 P

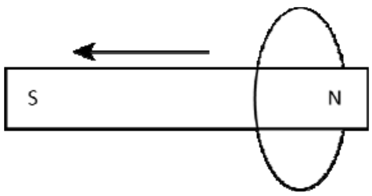


A9 Name four examples of electromagnetic radiation and order them by increasing frequency.

4 P

A10 A bar magnet is moved through a loop of wire (see figure). Determine the direction of the current induced in the wire. Justify your answer carefully.

3 P



A11 A hot metal object with mass 800 g is put in a cup containing 400 g of cold water. The metal's temperature decreases by 240 °C while the water's increases by 15 °C. Calculate the metal's specific heat constant.

3 P

A12 Derive a formal expression for the kinetic energy of an object as a function of its mass and momentum.

3 P

A13 When a cork plate with mass 150 g is placed in a vessel with alcohol, 40 % of its total height are immersed in the liquid. Calculate the additional force required to fully immerse the plate.

3 P

A14 Tick the correct statements:

4 P

- ☐ The speed of light in vacuum depends on the wavelength.
- ☐ Gamma rays are transverse waves.
- ☐ The intensity of unpolarised light decreases when passing a polarisation filter.
- ☐ The electric and magnetic parts of a standing electromagnetic wave are in phase.

A15 A car driving at constant speed experiences a resultant force. Explain how this is possible.

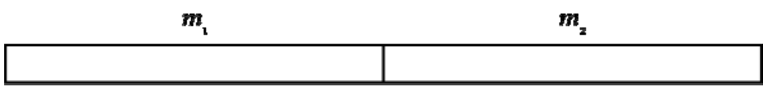
2 P

A16 Calculate the mass of 5.5 mol of oxygen gas.

2 P

A17 Two bars of the same length are connected as shown in the figure. The ratio of their masses is $m_1 : m_2 = 3 : 1$. Construct the centre of mass of this arrangement.

3 P



A18 The tip of a pendulum oscillates with a period of 1.5 s and an amplitude of 12 cm. Calculate the tip's speed when it passes the equilibrium position.

3 P

A19 Describe a method to determine the mass of an electron.

3 P

A20

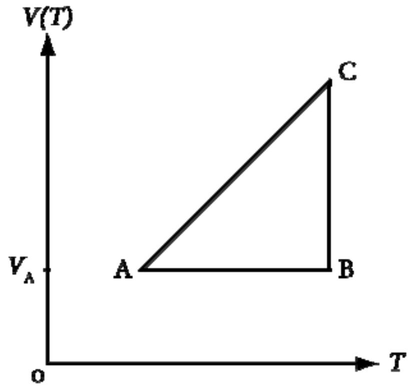
4 P

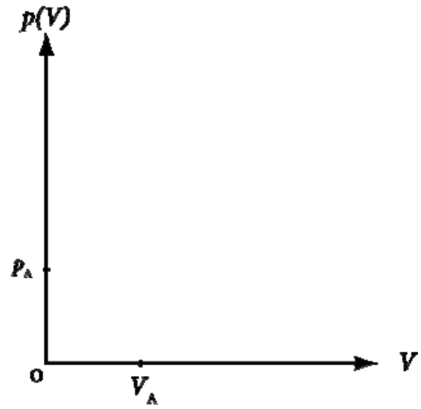
The speed of a stone thrown vertically upwards has slowed down to 8 m/s after 0.4 s. Calculate its initial speed and the distance it has travelled in these 0.4 s.

A21

3 P

An ideal gas undergoes a cyclic process A → B → C → A as displayed in the volume vs. temperature diagram on the left. The pressure in state A is pA. Draw the pressure vs. volume diagram for the same process.





A22

6 P

The electrostatic force between two alpha particles at some distance is 15 pN. What would be the force if the alpha particles were replaced by electrons? By what factor would the particles' acceleration change?

A23

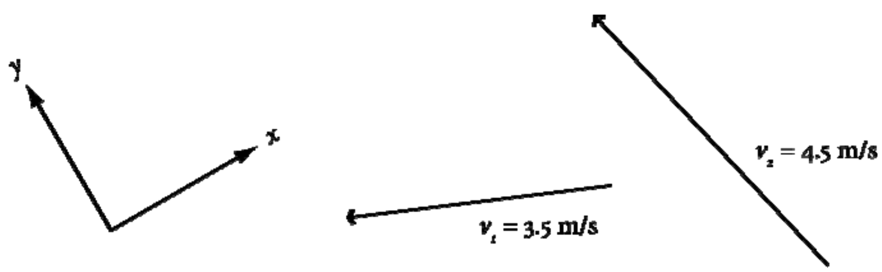
3 P

The interval between 500 Hz and 1'000 Hz is divided into two identical intervals. Calculate the frequency of the central tone.

A24

4 P

Graphically add the two velocity vectors. Determine the magnitude and the components (with respect to the given x and y directions) of the resultant vector.



Matura Exams 2011

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:	/23	/20	/26	/32	/101

B1 Indianapolis 500

Time: 20'

The famous Indianapolis 500-Mile Race is an American automobile race held annually at the Indianapolis Motor Speedway. The 2.5 miles long race track contains four 90° turns, each 402 m long. The turns are banked, i.e. slightly inclined (see figure 1b).

The greatest average speed for the race was 185.981 miles/hour (Arie Luyendyk, 1990). [wikipedia.org]

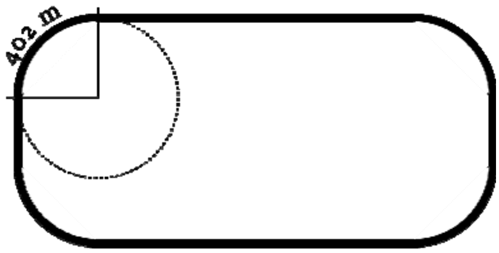


Figure 1a: Indianapolis Motor Speedway

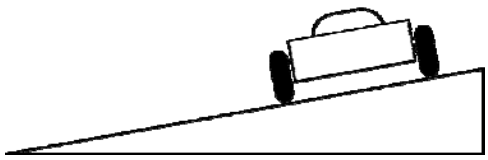


Figure 1b: Banked turn (sideview)

4 p a) Calculate the race time for the winner of 1990. What do you think of the quoted precision of the average speed?

8 p b) What is the power delivered by the motor to keep up the average speed against the air resistance? Express your result in PS. Why is the average power in a race even greater?

Hint: Make reasonable assumptions for the missing parameters in the calculation.

4 p c) Assuming a speed of 175 km/h in a turn, calculate the magnitude of the centripetal acceleration of the racing car.

7 p d) Draw the forces acting on the car in figure 1b. Which forces (or components of forces) add to the centripetal force? What parameters limit the maximum speed of the car in the turn? Explain how their value affects the maximum speed.

B2 Power Plant

Time: 30'

In a coal-fired power plant (see figure 2) anthracite (coal) is combusted in the *boiler*. The resulting heat is used to vaporise water, which then drives the *turbine* with the *generator* coupled to it. After passing the turbine the steam is condensed in the *condenser* and flows back to the boiler.

A specific power plant in Germany has an electric power output of 930 MW at an efficiency of 42.5 %.

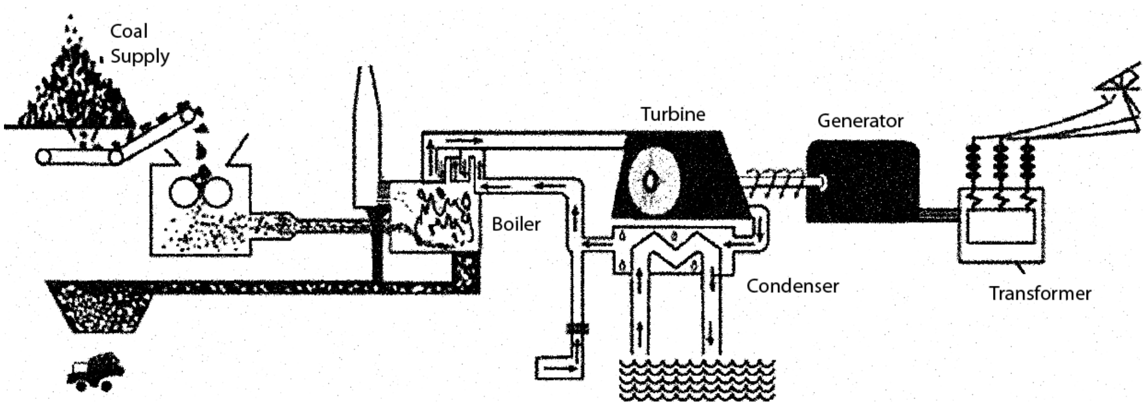


Figure 2: Parts of a coal-fired power plant

6 p a) Calculate the thermal input power. How much anthracite has to be provided per hour?

Some 670 kg steam leave the boiler every second. The steam arrives at the turbine with a temperature of 550 °C and a pressure of 260 bar.

6 p b) Calculate the volume per second arriving at the turbine.

3 p c) Considering the efficiency of the plant, what is the maximum temperature of the steam leaving the turbine?

2 p d) Explain how the generator transforms mechanical into electric energy. Which physical phenomenon is responsible for this task?

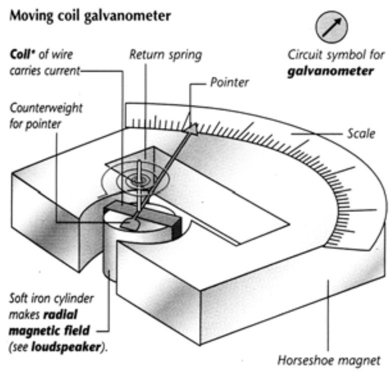
3 p e) Why is electric energy distributed over high voltage power lines? What are the advantages of ac voltage over dc voltage?

B3 Moving Coil Galvanometer

Time: 35'

A *moving coil galvanometer* (see figure 4) is a well established device used to measure voltage and current in an electric circuit. It consists of a coil of wire placed in a radial magnetic field. The coil can rotate about an axis which is also connected to a spiral return spring (Sp). A pointer attached to the coil allows to read a value from the scale.

One of the galvanometers of the Rämibühl Physics Institute has a magnetic field with magnitude 170 mT and a coil (4.5 cm long and 2.2 cm wide) made of 25 turns of copper wire. Its maximum deflection is reached for a voltage of 150 mV and a current of 5 mA, respectively.



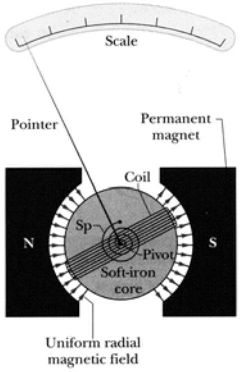


Figure 4: Galvanometer

5 P a) Explain how the galvanometer works. What is the role of the spring? Indicate the direction of the current flowing through the coil in the figure on the right hand.

2 P b) For full deflection of the pointer calculate the force acting on one side of the coil.

3 P c) Show that the torque M acting on the coil can be expressed as

$$M = n \cdot A \cdot B \cdot I \ ,$$

where n is the number of turns, A the area of the loop surrounded by the coil, B the magnitude of the magnetic field and I the current flowing through the coil. Why is a radial field for this application preferable to a homogeneous field?

6 P d) Calculate the resistance of the coil and the diameter of the coil's wires.

6 P e) How much energy is dissipated in the coil in one minute at maximum deflection? Calculate the temperature increase of the copper wire. Why does the temperature not exceed a certain maximum value?

4 P f) The galvanometer is supposed to be used as a voltmeter for voltages of up to 5 V. How can you modify it to allow for this? Calculate the resistance of the additional resistor.

B4 Damped Pendulum

Time: 50'

A pendulum consists of an aluminium rod with a mass at its lower end. The oscillation is damped through a tip moving through a vessel filled with water. In order to investigate the oscillation, a dc voltage of 10 V was applied to two electrodes at the edges of the vessel and 29 cm apart (see figure 3). The voltage between the tip of the pendulum and the centre of the vessel was recorded with a data logger. The resulting voltage vs. time diagram is displayed on the next page (figure 3b).

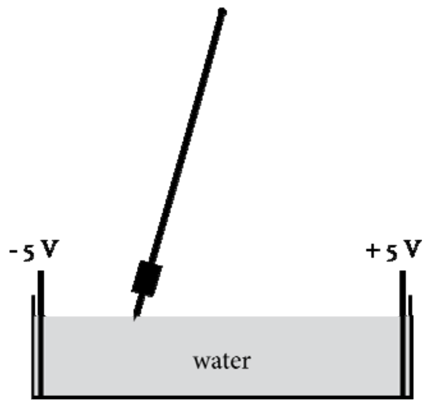


Figure 3a: Damped pendulum

3 p a) Draw the schematic diagram for the electric circuit used to measure the voltage.

Hint: Think of the water-filled vessel as a length of wire with a certain resistance.

7 p b) Determine the oscillation period from the diagram. Calculate the corresponding frequency and its error making a reasonable assumption about the precision of your reading. Write the result in the standard form with absolute error and correctly rounded.

6 p c) For small amplitudes the deflection angle φ fulfils the characteristic equation

$$J \cdot \ddot{\varphi}(t) = -k \cdot \varphi(t) ,$$

where $J = 0.0411$ kg m^2 is the pendulum's *moment of inertia* and $k = 0.539$ N m has the role of a spring constant.

Derive a formal expression for the oscillation frequency. Prove that it has the correct unit. Calculate the numerical value and compare it to the value found in b).

5 p d) Determine the speed of the pendulum tip when it returns to the equilibrium position for the 5^{th} time.

9 p e) As a reasonable hypothesis we assume that the envelope of the damped oscillation can be described by an exponential function. In order to test this hypothesis, graph the logarithm of the amplitude vs. time. Explain why a straight line in this representation corresponds to an exponential function. Determine the half life of the exponential decay from the parameters of the straight line fit.

2 p f) Describe the motion of a similar pendulum whose tip moves through honey instead of water.

Figure 3b: Damped oscillation