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

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!

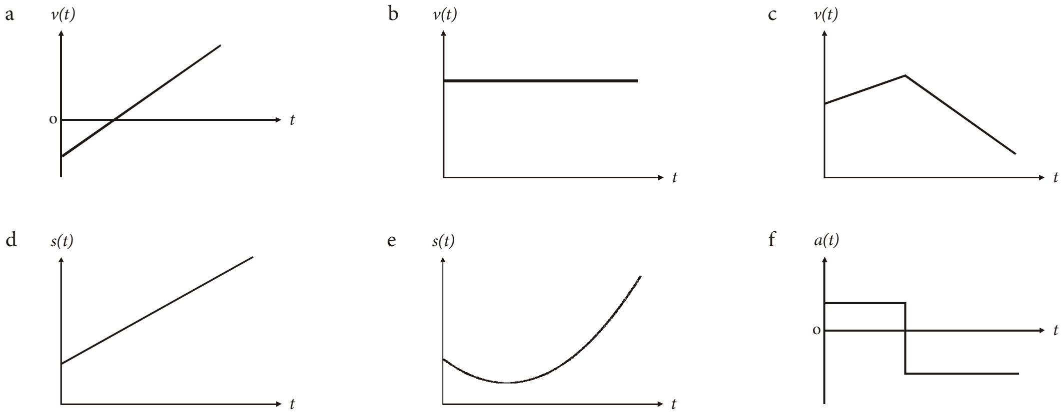
Points:	/ 101

A1 Free neutrons decay with a half-life of some 10 minutes. What fraction of free neutrons decays in an hour?

3 P

A2 Among the diagrams a to f there are always two describing the same motion. Match the three pairs. (*s(t)* is the displacement, *v(t)* the velocity and *a(t)* the acceleration of the motion.)

2 P



A3 In an ac household appliance the current lags behind the voltage by 2.5 ms. Calculate the phase shift.

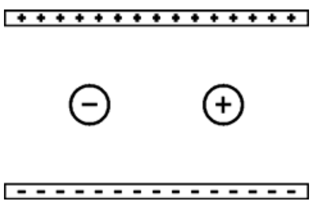
3 P

A4 A tennis ball flying at 84 km/h hits the back of a lorry moving at 52 km/h in the same direction. Determine the ball's speed and direction (relative to the ground) after the totally elastic collision.

4 P

A5 Draw the field lines for an arrangement of two parallel plates and two point charges (see figure).

3 P



A6 Briefly describe a device that can be used to detect radioactive radiation.

3 P

A7 Mark the correct statements with a cross:

3 P

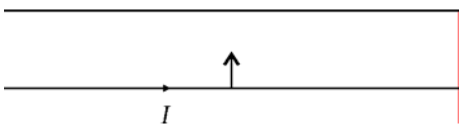
- ☐ The electrostatic force between a charged and a neutral object is always attractive.
- ☐ When one of two point charges is doubled and the other one halved, the force between them does not change.
- ☐ The path of a charged particle in a homogeneous electric field is a circular arc.
- ☐ When the distance between two point charges is increased by a factor ten, the force decreases to 1 % of its initial value.

A8 The gas cartridges used in the "Soda Club ®" appliance contain 450 g carbon dioxide (CO_2). Calculate the number of molecules in a full cartridge.

4 P

A9 A current-carrying wire moves towards a second wire (see figure). Determine the direction of the current induced in the second wire. Give reasons for your answer.

3 P

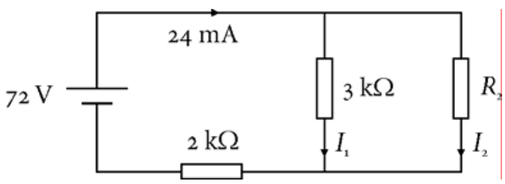


A10 A 35 cm long thread breaks when the pull is greater than 50 N. When it is used to hold a steel ball on a circular path, it breaks at a frequency of 15 Hz. Calculate the ball's mass.

4 P

A11 Determine the missing quantities in the electric circuit.

4 P



I_1 =

I_2 =

R_2 =

A12 Draw the displacement vs. time diagram for a damped oscillation with a linear envelope. Mark the point on the time axis where the oscillation energy has decreased to one half of its initial value.

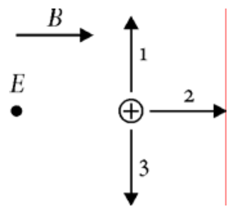
5 P

A13 A crane lifts a load with mass 350 kg vertically upwards. Towards the end of the motion the load is slowed down with a deceleration 2 m/s^2. Calculate the force the crane exerts on the load.

4 P

A14 The drawing shows three possible directions (1, 2, and 3) for the velocity v of a positively charged particle moving through a uniform electric field E (directed out of the screen) and a uniform magnetic field B (from left to right). In which direction is the magnitude of the net force (i.e. the combined magnetic and electric forces) greatest? Give reasons for your choice.

4 P



A15 Calculate the heat energy it takes to prepare a cup of tea. Make reasonable assumptions for the quantities used in your calculation.

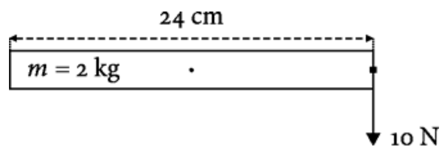
4 P

A16 Two quantities a and b are measured with absolute errors Δa and Δb, respectively. Calculate the absolute error of the derived quantity $c = \left(\frac{a}{2 \cdot b}\right)^{3/2}$.

4 P

A17 A wooden stick with length 24 cm and mass 2 kg is pulled downwards with 10 N at its right end. Determine the position where it has to be suspended to be in equilibrium.

3 P



A18 A mass is suspended on a spring. When oscillating with an amplitude of 5.4 cm its maximum speed is 36 cm/s. Calculate the oscillation period.

3 P

A19 The voltage across a resistor is increased by 20 %. Calculate the percentage change in power dissipated in the resistor.

3 P

A20 For each of the following pairs of values choose an appropriate comparison operator (<, = or >). If the values can not be compared (e.g. because the units do not match), use the unequal sign (≠).

3 P

a) 1.5 μm/s $5 \cdot 10^{-5}$ km/h   b) 1.5 kg   15 dℓ   c) 53 g/cℓ $5.3 \cdot 10^{3}$ kg/m³

d) 5 kWh $1.8 \cdot 10^{6}$ J   e) 150 kPa   1.5 bar   f) - 120 °C   120 K

A21 The periods (T_A,T_B,T_C) and the major semi-axes (a_A, a_B, a_C) of three planets A, B and C fulfill the relations $T_A : T_B = 4 : 1$ and $a_A : a_C = 2 : 1$. Which planet is closest to the sun? Give reasons for your answer.

3 P

A22 Two forces with magnitudes 7 N and 3 N act on the same object. Which of the following values are possible for the resultant force?

2 P

☐ 3 N   ☐ 4 N   ☐ 6 N   ☐ 10 N   ☐ 13 N

A23 When the temperature is increased by ΔT, the length of an aluminium rod increases by a factor m. Find an algebraic expression for the rod's extension (as a multiple of its initial length) when the temperature is increased by $2 \cdot \Delta T$.

2 P

A24 Mark the correct statements with a cross:

3 P

- ☐ Pressure waves in stone are always transverse.
- ☐ The total sound intensity level of two sources with levels 62 dB and 68 dB is greater than 100 dB.
- ☐ The interval between 100 Hz and 300 Hz corresponds to two octaves.
- ☐ The speed of sound in air increases when the temperature is increased.

A25 A stone is thrown away at an angle α to the horizontal. After 1.4 s it reaches the apex (highest point) of its trajectory, where its speed is 7 m/s. Determine the magnitude of α with the help of a construction.

4 P

A26 The equivalent resistance of two resistors connected in parallel is 1.5 kΩ. The first resistor has a resistance of 2.0 kΩ. Calculate the second resistor's resistance.

3 P

A27 The weight driving an old pendulum clock moves downwards by 36 cm in 24 h. Its mass is 240 g. Calculate the mechanical power available to drive the clock.

3 P

A28 When a 40 cm long steel rod is struck with a hammer, a sound with fundamental frequency 7.5 kHz can be heard. Calculate the speed of sound in steel.

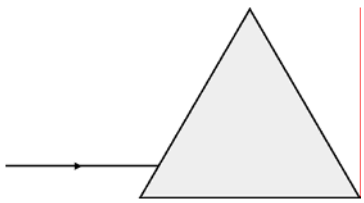
3 P

A29 A 12 cm long spring is used as a solenoid. For a given current the magnitude of the magnetic field in the spring is 2.5 mT. Calculate the magnitude of the field, when the spring has been stretched to 15 cm.

3 P

A30 Sketch the path of the light ray through the glass object and back into the air. Respect total internal reflection wherever applicable.

3 P



A31 A fisherman throws some stones from his boat into the lake. How does this affect the lake's surface level? Give reasons for your answer.

3 P

Matura Exams 2007

Physics

Class 4a

Part B: Problems

First Name: ....

Last Name: ....

Time: 120 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 can not 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 solving a particular problem.

Good luck!

Problem:	B1	B2	B3	Total
Score:	/29	/34	/21	/84

B1 Tungsten* Filament

Time: 40'

A company† selling tungsten parts lists the values displayed in the table below for this material's resistivity at different temperatures:

ϑ [°C]	20	227	727	1'727	2'727	3'227
ρ [n$\Omega \cdot$ m]	55	105	243	557	904	1'085

The "spiral-wounded" filament of a modern light bulb consists of a thin tungsten wire. For a 230 V/100 W light bulb, the wire has a total length of 1.000 m and a diameter of 43.7 µm. The glowing filament has a temperature of some 2'700 °C.

6 P a) Calculate the filament's resistance. Compare the result to the value you can expect from its voltage and power rating.

3 P b) Calculate the electric power dissipated by the filament immediately after the lamp has been switched on, i.e. when the wire is still at room temperature.

6 P Assume that the electric power is constant and that it is completely used to increase the filament's temperature. How long does it take to heat the filament to its final temperature?

6 P c) What effect is responsible for the fact that the temperature does not increase infinitely?

Qualitatively discuss the energy flows during the heating up of the filament and sketch temperature and electric current vs. time.

d) Another source‡ claims that the resistivity can be calculated using a quadratic function of the temperature ϑ (in °C):

$$\rho(\vartheta) = \rho_0 \cdot (1 + \alpha \cdot \vartheta + \beta \cdot \vartheta^2),$$

with the parameters ρo = 48.0 nΩ · m, α = 4.8297 · 10-3 K-1 and β = 1.663 · 10-6 K-2.

5 P Use your calculator to calculate a quadratic fit to the measured data. Write down the parameters with correct units and compare them to the values above.

1 P In what temperature range do the two sources agree reasonably well?

2 P Which source seems to be more trustworthy and why?

* Tungsten is the generally used word for the chemical element wolfram.
† Midwest Tungsten Service, Willowbrook, IL 60527, USA; www.tungsten.com
‡ *CRC Handbook of Chemistry and Physics*, 75th edition, 1995

B2 Proton Cyclotron

Time: 50'

At Zurich University Hospital a proton cyclotron is used to produce radioactive substances for nuclear medicine. According to the datasheet this device produces a proton beam carrying a current of 75 µA at the proton energy 16.5 MeV.

3 P a) Calculate the speed of the protons leaving the cyclotron and express the result as a fraction of the speed of light.

7 P Calculate the number of protons hitting the target in every second and the power carried by the beam.

4 P Assuming they arrive one at a time determine the distance in space and time between two consecutive protons in the beam.

5 P b) Sketch the protons' trajectory in the cyclotron and indicate the directions of their motion and of the magnetic field.

2 P Where and how is the protons' kinetic energy increased?

The magnitude of the magnetic field in the cyclotron is 0.63 T.

4 P c) Calculate the maximum radius of the protons' trajectory.

Hint: If you could not find a value in a), you may assume a proton speed of $5 \cdot 10^7$ m/s.

One of the substances produced in the target is Fluordeoxyglucose (FDG), which contains a radioactive Fluor 18 atom. Fluor 18 decays with a half-life of 1.8291 h, setting free 0.8737 MeV of energy per decay.

FDG is often used as a tracer in nuclear medicine to examine a patient's metabolism. The substance is therefore injected into the patient and, after some time, its distribution in her body can be determined by detecting the radioactive radiation.

As an example we will assume that a patient's initial activity is 370 MBq.

2 P d) Calculate the power emitted by the decaying Fluor atoms.

3 P e) By what fraction does the activity decrease during an examination that takes 45 minutes?

4 P f) Calculate the number of Fluor 18 atoms initially in the patient's body.

B3 Fullerene Diffraction

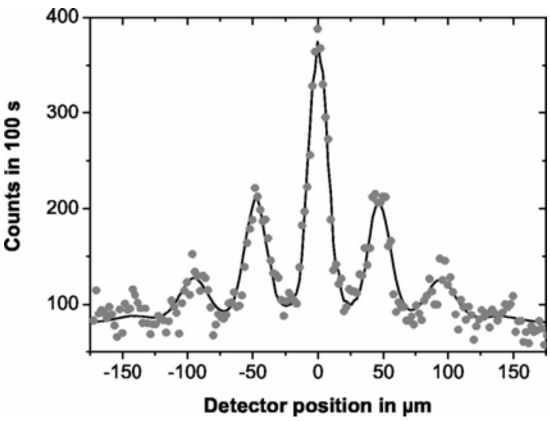
Time: 30'

One of the major discoveries of physics in the 20th century was that particles can behave like waves under certain circumstances. In 1924 Louis-Victor de Broglie found a relation for the wavelength corresponding to a beam of particles. It is given by the following expression:

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

where λ_B is the particles' so called *de Broglie wavelength*, $h = 6.626 \cdot 10^{-34}$ Js is *Planck's constant* and p is the particles' momentum.

The hypothesis was first confirmed in 1927 in a diffraction experiment with electrons. It has since been checked for a variety of different particles (protons, neutrons, atoms, …). One of the latest tests involved large molecules[§]. A source produced a beam of fullerene (C_{60}) molecules hitting a diffraction grating with a distance of 100 nm between the slits. A laser detector was used to analyse the diffraction pattern at a distance of 1.25 m from the grating. The figure below displays the results of this experiment.



3 p a) Using a sketch explain how the diffraction pattern of a double slit comes about, i.e. why there are places with maximum and minimum intensity, respectively.

1 p What is the main difference between the diffraction patterns of a double slit and of a grating?

7 p b) Using your knowledge of the diffraction of light and the information you can read from the figure, show that the expected wavelength is about 4 pm. Calculate the corresponding frequency.

1 p What type of electromagnetic radiation could be used to get the same diffraction pattern?

6 p c) The fullerene molecules used in the experiment had a speed of (117 ± 20) m/s. Calculate the corresponding de Broglie wavelength (with absolute error) and check whether the result is compatible with the value in b).

3 p d) How would the diffraction pattern change if the fullerene molecules were replaced by carbon atoms with the same speed? Give reasons for your answer.

[§] O. Nairz, M. Arndt, A. Zeilinger, *Quantum interference experiments with large molecules*, 2002

A1 Free neutrons decay with a half-life of some 10 minutes. What fraction of free neutrons decays in an hour?

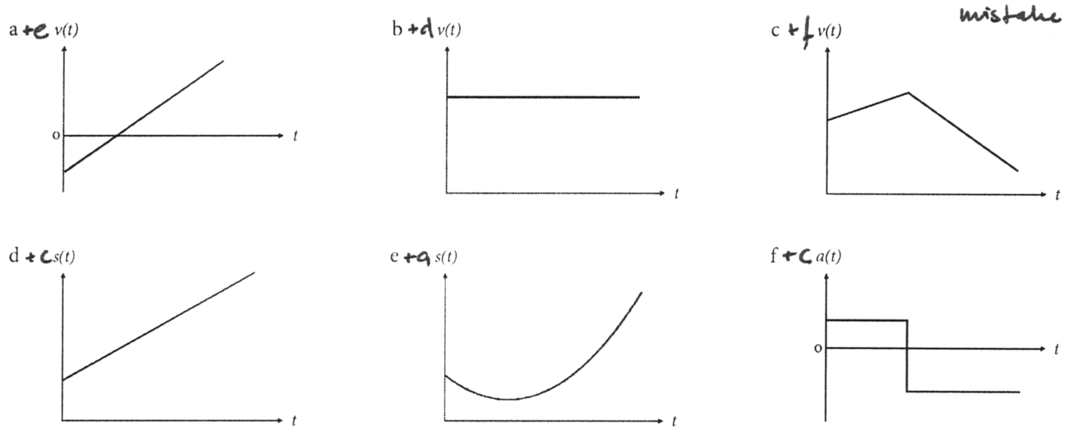
3 P

$N' = N\cdot\left(\frac{1}{2}\right)^{1/6}$ (1) $= \frac{N}{64}$ (1) $\Rightarrow$ $\underline{\frac{63}{64}}$ decay (1)

A2 Among the diagrams a to f there are always two describing the same motion. Match the three pairs. (*s(t)* is the displacement, *v(t)* the velocity and *a(t)* the acceleration of the motion.)

2 P

mistake (-1)



A3 In an ac household appliance the current lags behind the voltage by 2.5 ms. Calculate the phase shift.

3 P

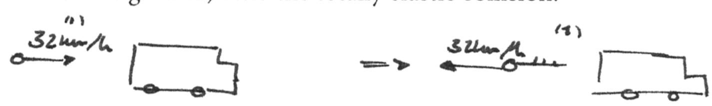
$\Delta\varphi = 2\pi\cdot\frac{\Delta t}{T} = 2\pi\cdot\Delta t\cdot f$ (1) $= 2\pi\cdot 2.5\,\text{ms}\cdot 50\,\text{Hz}$ (1)

$= \underline{0.75\ \text{rad}}$ (1)

A4 A tennis ball flying at 84 km/h hits the back of a lorry moving at 52 km/h in the same direction. Determine the ball's speed and direction (relative to the ground) after the totally elastic collision.

4 P

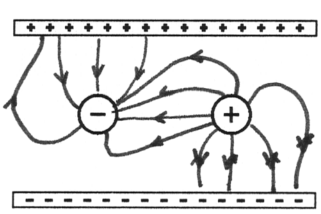
lorry's frame:



$\Rightarrow$ 20 km/h (1) in direction of lorry (1)

A5 Draw the field lines for an arrangement of two parallel plates and two point charges (see figure).

3 P



qualitatively correct (2)
directions (1)

A6 Briefly describe a device that can be used to detect radioactive radiation.

3 P

ionisation (1)

description (2)

A7 Mark the correct statements with a cross:

3 P

- ☒ The electrostatic force between a charged and a neutral object is always attractive.
- ☒ When one of two point charges is doubled and the other one halved, the force between them does not change.
- ☐ The path of a charged particle in a homogeneous electric field is a circular arc.
- ☒ When the distance between two point charges is increased by a factor ten, the force decreases to 1 % of its initial value.

A8 The gas cartridges used in the "Soda Club ®" appliance contain 450 g carbon dioxide (CO_2). Calculate the number of molecules in a full cartridge.

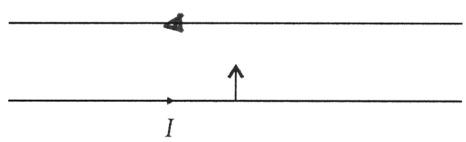
4 P

$$N = n \cdot N_A = \frac{m}{M_{CO_2}} \cdot N_A \ (1) = \frac{450\,g}{(1)\ 44\,g/mol} \cdot 6 \cdot 10^{23}\,mol^{-1} \ (1)$$

$$= \underline{6 \cdot 10^{24}} \ (1)$$

A9 A current-carrying wire moves towards a second wire (see figure). Determine the direction of the current induced in the second wire. Give reasons for your answer.

3 P



Lenz's law:
cause for induced current "stopped" (1)
⇒ repulsive force (1)
⇒ antiparallel currents (1)

A10 A 35 cm long thread breaks when the pull is greater than 50 N. When it is used to hold a steel ball on a circular path, it breaks at a frequency of 15 Hz. Calculate the ball's mass.

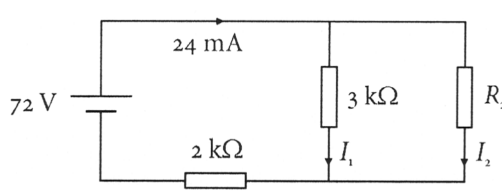
4 P

$$F_Z = m \cdot \omega^2 \cdot r \ (1) = m \cdot 4\pi^2 \cdot f^2 \cdot r \ (1)$$

$$\Rightarrow m = \frac{F_Z}{4\pi^2 \cdot f^2 \cdot r} \ (1) = \frac{50\,N}{4\pi^2 \cdot (15\,Hz)^2 \cdot 0.35\,m} = 0.017\,kg = \underline{17\,g} \ (1)$$

A11 Determine the missing quantities in the electric circuit.

4 P



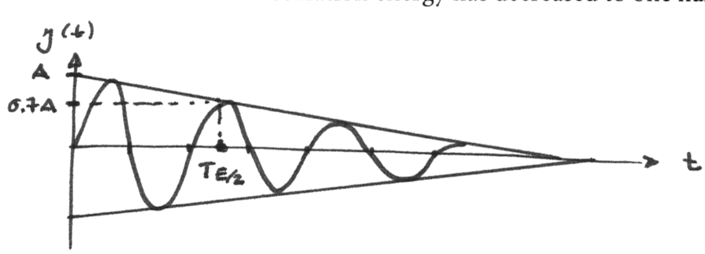
I_1 = 8 mA (1) $\left(\frac{24\,V}{3\,k\Omega}\right)$ (1)

I_2 = 16 mA (1) (24 mA − 8 mA)

R_2 = 1.5 kΩ (1) $\left(\frac{24\,V}{16\,mA}\right)$

A12 Draw the displacement vs. time diagram for a damped oscillation with a linear envelope. Mark the point on the time axis where the oscillation energy has decreased to one half of its initial value.

5 P



axis labels (1)
envelope (1)
constant period (1)
TE/2 (2)

A13 A crane lifts a load with mass 350 kg vertically upwards. Towards the end of the motion the load is slowed down with a deceleration 2 m/s². Calculate the force the crane then exerts on the load.

4 P

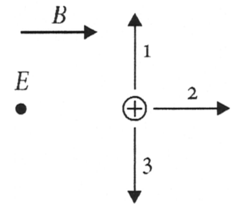
$F_{res} = F - F_G = m\cdot a$ (1)

$\Rightarrow F = m\cdot a + F_G = m\cdot(a+g)$ (1) $= 350\,kg\cdot(-2\,m/s^2 + 10\,m/s^2)$ (1)

$= \underline{2.8\,kN}$ (1)

A14 The drawing shows three possible directions (1, 2, and 3) for the velocity v of a positively charged particle moving through a uniform electric field E (directed out of the screen) and a uniform magnetic field B (from left to right). In which direction is the magnitude of the net force (i.e. the combined magnetic and electric forces) greatest? Give reasons for your choice.

4 P



$\vec{F}_e$ ⊙ (1)

$\Rightarrow$ maximum for $\vec{F}_B \parallel \vec{F}_e \Rightarrow \vec{F}_B$ ⊙ (1)

$\vec{F}_B$: 1 ⊗ ; 2 0 ; 3 ⊙ (1) $\longrightarrow$ greatest (1)

A15 Calculate the heat energy it takes to prepare a cup of tea. Make reasonable assumptions for the quantities used in your calculation.

4 P

$Q = c\cdot m\cdot \Delta\vartheta$ (1) $= 4\cdot 10^3\,J/kg\cdot K$ (1) $\cdot\, 0.2\,kg \cdot 80\,K$ (1)

$= \underline{64\,kJ}$ (1)

A16 Two quantities a and b are measured with absolute errors Δa and Δb, respectively. Calculate the absolute error of the derived quantity $c = \left(\frac{a}{2\cdot b}\right)^{3/2}$.

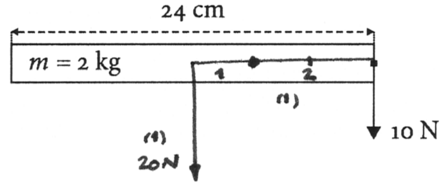
4 P

$r_c = \frac{3}{2}\cdot(r_a + r_b)$ (2) $= \frac{3}{2}\cdot\left(\frac{\Delta a}{a} + \frac{\Delta b}{b}\right)$ (1)

$\Rightarrow \Delta c = r_c\cdot c = \frac{3}{2}\cdot\left(\frac{\Delta a\cdot a^{1/2}}{(2\cdot b)^{3/2}} + \frac{\Delta b\cdot a^{3/2}}{2^{3/2}\cdot b^{5/2}}\right)$ (1)

A17 A wooden stick with length 24 cm and mass 2 kg is pulled downwards with 10 N at its right end. Determine the position where it has to be suspended to be in equilibrium.

3 P



$\Rightarrow$ 8 cm from right end (1)

A18 A mass is suspended on a spring. When oscillating with an amplitude of 5.4 cm its maximum speed is 36 cm/s. Calculate the oscillation period.

3 P

$v_{max} = A\cdot\omega$ (1)

$\Rightarrow T = \frac{2\pi}{\omega}$ (1) $= \frac{2\pi\cdot A}{v_{max}} = \frac{2\pi\cdot 5.4\,cm}{36\,cm/s} = \underline{0.9\,s}$ (1)

A19 The voltage across a resistor is increased by 20 %. Calculate the percentage change in power dissipated in the resistor.

3 P

$P = \frac{(\Delta V)^2}{R}$ (1) $\Rightarrow$ $\frac{P'}{P} = \left(\frac{\Delta V'}{\Delta V}\right)^2 = \left(\frac{120}{100}\right)^2 = 1.44$ (1)

$\Rightarrow$ $\underline{+44\,\%}$ (1)

A20 For each of the following pairs of values choose an appropriate comparison operator (<, = or >). If the values can not be compared (e.g. because the units do not match), use the unequal sign (≠).

3 P

a) 1.5 µm/s < $5 \cdot 10^{-5}$ km/h b) 1.5 kg ≠ 15 dℓ c) 53 g/cℓ = $5.3 \cdot 10^3$ kg/m³

d) 5 kWh > $1.8 \cdot 10^6$ J e) 150 kPa = 1.5 bar f) - 120 °C > 120 K

A21 The periods (T_A, T_B, T_C) and the radii (r_A, r_B, r_C) for three planets' circular orbits (A, B and C) fulfill the relations $T_A : T_B = 4 : 1$ and $r_A : r_C = 2 : 1$. Which planet is closest to the sun? Give reasons for your answer.

3 P

$T_A^2 : T_B^2 = 16 : 1$

$r_A^3 : r_C^3 = 8 : 1 = 16 : 2 = T_A^2 : T_C^2$ (2)

$\Rightarrow$ B is closest (1)

A22 Two forces with magnitudes 7 N and 3 N act on the same object. Which of the following values are possible for the resultant force?

2 P

mistake (-1)

☐ 3 N ☒ 4 N ☒ 6 N ☒ 10 N ☐ 13 N

A23 When the temperature is increased by ΔT, the length of an aluminium rod increases by a factor m. Find an algebraic expression for the rod's extension (as a multiple of its initial length) when the temperature is increased by $2 \cdot \Delta T$.

2 P

$\Delta \ell = (m-1) \cdot \ell_0$ (1)

$\Rightarrow \Delta \ell' = 2 \cdot (m-1) \cdot \ell_0$ (1)

A24 Mark the correct statements with a cross:

3 P

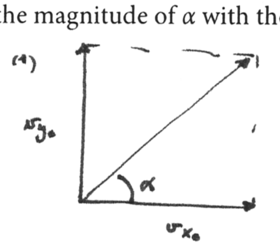
- ☐ Pressure waves in stone are always transverse.
- ☐ The total sound intensity level of two sources with levels 62 dB and 68 dB is greater than 100 dB.
- ☐ The interval between 100 Hz and 300 Hz corresponds to two octaves.
- ☒ The speed of sound in air increases when the temperature is increased.

A25 A stone is thrown away at an angle α to the horizontal. After 1.4 s it reaches the apex (highest point) of its trajectory, where its speed is 7 m/s. Determine the magnitude of α with the help of a construction.

4 P

$v_{y0} = 14$ m/s $(1.4\,s \cdot 10\,m/s^2)$ (1)

$v_{x0} = 7$ m/s (apex) (1)



construction (1)

$\alpha \cong 60°$ (1)

A26 The equivalent resistance of two resistors connected in parallel is 1.5 kΩ. The first resistor has a resistance of 2.0 kΩ. Calculate the second resistor's resistance.

3 P

$$\frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{R_p} \;^{(1)} \Rightarrow R_2 = \left(\frac{1}{R_p} - \frac{1}{R_1}\right)^{-1} \;^{(1)}$$

$$= \left(\frac{2}{3} - \frac{1}{2}\right)^{-1} k\Omega = \underline{6\ k\Omega} \;^{(1)}$$

A27 The weight driving an old pendulum clock moves downwards by 36 cm in 24 h. Its mass is 240 g. Calculate the mechanical power available to drive the clock.

3 P

$$P = \frac{m \cdot g \cdot h}{\Delta t} \;^{(1)} = \frac{\overset{0.01}{\cancel{0.24\,kg}} \cdot 10\,m/s^2 \cdot \overset{6.1\cdot 10^{-3}}{\cancel{0.36\,m}}}{\cancel{24} \cdot \cancel{3'600\,s}} \;^{(1)} = \underline{10^{-5}\,W} \;^{(1)}$$

A28 When a 40 cm long steel rod is struck with a hammer, a sound with fundamental frequency 7.5 kHz can be heard. Calculate the speed of sound in steel.

3 P

$$\lambda = 2 \cdot \ell \;^{(1)} \longrightarrow c = \lambda \cdot f \;^{(1)} = 2 \cdot \ell \cdot f$$

$$= 2 \cdot 0.4\,m \cdot 7.5 \cdot 10^3\,Hz$$

$$= \underline{6 \cdot 10^3\,m/s} \;^{(1)}$$

A29 A 12 cm long spring is used as a solenoid. For a given current the magnitude of the magnetic field in the spring is 2.5 mT. Calculate the magnitude of the field when the spring has been stretched to 15 cm.

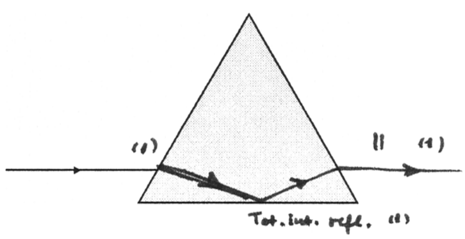
3 P

$$\frac{B'}{B} = \frac{\ell}{\ell'} \Rightarrow B' = B \cdot \frac{\ell}{\ell'} \;^{(1)} \qquad B \propto \frac{n}{\ell} \;^{(1)}$$

$$= 2.5\,mT \cdot \frac{12}{15} = \underline{2.0\ mT} \;^{(1)}$$

A30 Sketch the path of the light ray through the glass object and back into air. Respect total internal reflection wherever applicable.

3 P



A31 A fisherman throws some stones from his boat into the lake. How does this affect the lake's surface level? Give reasons for your answer.

3 P

in boat : water replaced ≙ mass of stones (1) > volume of stones

in water : water replaced ≙ Volume of stones (1)

⟹ decreases (1)

B 1 Tungsten Filament

a) $R = \rho \cdot \frac{\ell}{A} = 904 \cdot 10^{-9} \, \Omega \cdot m \cdot \frac{1\,m}{(43.7/2 \cdot 10^{-6}\,m)^2 \cdot \pi}$ (1) (1)

$= \underline{603\,\Omega}$ (1)

$P = \frac{(\Delta V)^2}{R} \Rightarrow R = \frac{(\Delta V)^2}{P} = \frac{(230\,V)^2}{100\,W} = \underline{530\,\Omega}$ (1) (1)

reasonable agreement since resistivity smaller than assumed value (1)

b) $\frac{P'}{P} = \frac{R}{R'} \Rightarrow P' = P \cdot \frac{R}{R'} = P \cdot \frac{\rho}{\rho'}$ (1)

$= 100\,W \cdot \frac{904}{55} = \underline{1.6\,kW}$ (1) (1)

$Q = \bar{P} \cdot \Delta t = c \cdot m \cdot \Delta\vartheta$ (1)

$\Rightarrow \Delta t = \frac{c \cdot m \cdot \Delta\vartheta}{\bar{P}} = \frac{\tilde{\rho}_T \cdot \ell \cdot \left(\frac{d}{2}\right)^2 \cdot \pi \cdot c \cdot \Delta\vartheta}{\bar{P}}$ (1) (1)

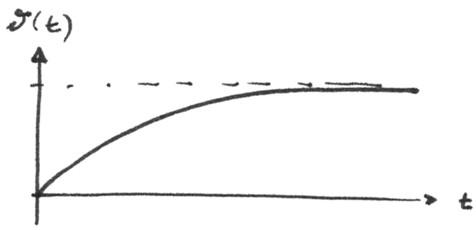
$= \frac{19.1 \cdot 10^3\,kg/m^3 \cdot 1m \cdot \left(\frac{43.7 \cdot 10^{-6}\,m}{2}\right)^2 \cdot \pi \cdot 134\,J/kg \cdot K \cdot 2'700\,K}{1'600\,W}$ (1) (1) ← or any other reasonable value

$= \underline{6.4\,ms}$ (1)

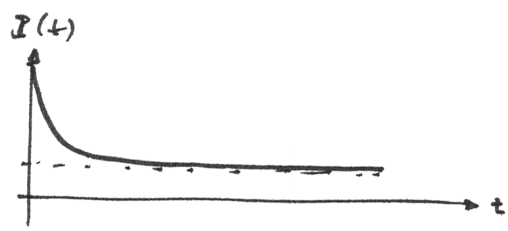
c) heat radiation (1)

electric energy → heating of filament (A)
→ radiation (B) (1)

radiation $\propto T^4$ (1) → (A) decreases while (B) increases
→ stationary temperature (1)



(1)



d) fit function : $y(x) = 46.139 + 0.2629 \cdot x + 2 \cdot 10^{-5} \cdot x^2$

$$\Rightarrow \quad \rho_0 = 46.1 \ n\Omega \cdot m$$

$$\alpha = \frac{0.2629}{46.139} \ K^{-1} = 5.7 \cdot 10^{-3} \ K^{-1} \qquad (4)$$

$$\beta = \frac{2 \cdot 10^{-5}}{46.139} \ K^{-2} = 4.3 \cdot 10^{-7} \ K^{-2}$$

linear term acceptable, but not quadratic term (1)

→ good agreement for low temperatures (1)

Source : choice with reasonable argument (2)

B2 Proton Cyclotron

a) $E_{kin} = \frac{1}{2} m \cdot v^2 \Longrightarrow v = \sqrt{\frac{2 \cdot E_{kin}}{m}}$ (1)

$= \sqrt{\frac{2 \cdot 16.5 \text{ MeV}}{939 \text{ MeV}/c^2}}$ (1)

$= \cancel{0.185} \quad \underline{0.187 \cdot c}$ (1)

b) $I = \frac{\Delta q}{\Delta t} = \frac{n \cdot e}{\Delta t}$ (1) $\Longrightarrow n = \frac{I \cdot \Delta t}{e}$ (1)

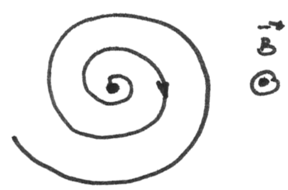
$= \frac{75 \cdot 10^{-6} A \cdot 1s}{1.6 \cdot 10^{-19} C}$ (1) $= \underline{4.7 \cdot 10^{14}}$ (1)

$P = \frac{n \cdot E_{kin}}{\Delta t}$ (1) $= \frac{4.7 \cdot 10^{14} \cdot 16.5 \cdot 10^6 \cdot 1.6 \cdot 10^{-19} J}{1s}$ (1) $= \underline{1.2 \text{ kW}}$ (1)

$\delta t = \frac{\Delta t}{n}$ (1) $= \frac{1s}{4.7 \cdot 10^{14}} = \underline{2{,}1 \cdot 10^{-15} s}$ (1)

$\delta s = v \cdot \delta t = 0.187 \cdot 3 \cdot 10^8 m/s \cdot 2.1 \cdot 10^{-15} s$ (1) $= \underline{0.12 \mu m}$ (1)

c)



spiral trajectory (1)

direction (1)

$\vec{B}$ (1)

E_{kin} is increased in an electric field (1) in gap between two D-shaped electrodes (1)

d) $F_L = e \cdot v \cdot B = m \cdot v^2/r$ (1)

$\longrightarrow r = \frac{m \cdot v}{e \cdot B}$ (1) $= \frac{1.67 \cdot 10^{-27} kg \cdot 0.187 \cdot 3 \cdot 10^8 m/s}{1.69 \cdot 10^{-19} C \cdot 0.63 T}$ (1)

$= \underline{0.88 \text{ m}}$ (1)

e) $P = A \cdot E = 370 \cdot 10^{6}\,\text{Bq} \cdot 0.8737 \cdot 10^{6} \cdot 1.6 \cdot 10^{-19}\,\text{J}$ (1)

$= \underline{52\ \mu\text{W}}$ (1)

f) $\dfrac{A'}{A} = 2^{-t/T_{1/2}}$ (1) $= 2^{-1.8291/0.75} = 0.18$ (1)

$\Longrightarrow \underline{-82\%}$ (1)

g) $A = \lambda \cdot N$ (1)

$\Longrightarrow N = \dfrac{A}{\lambda} = \dfrac{A \cdot T_{1/2}}{\ln 2}$ (1)

$= \dfrac{370 \cdot 10^{6}\,\text{Bq} \cdot 1.8291 \cdot 3600\,\text{s}}{\ln 2}$ (1)

$= \underline{3.5 \cdot 10^{12}}$ (1)

B3 Fullerene Diffraction

a) wavelets (1)

constructive / destructive interference (1)

explanations / sketch (1)

difference (1)

b) $\tan \alpha_1 = \frac{a_1}{\ell} \cong \sin \alpha_1 = 1 \cdot \frac{\lambda}{d}$ (1)

$\longrightarrow \lambda \cong d \cdot \frac{a_1}{\ell}$ (1) $= 100\ \text{nm} \cdot \frac{50 \cdot 10^{-6}\ \text{m}}{1.25\ \text{m}}$ (1) $= \underline{4\ \text{pm}}$ (1)

$f = \frac{c}{\lambda}$ (1) $= \frac{3 \cdot 10^{8}\ \text{m/s}}{4 \cdot 10^{-12}\ \text{m}}$ (1) $= \underline{7.5 \cdot 10^{19}\ \text{Hz}}$ (1)

Röntgen (1)

c) $\lambda_B = \frac{h}{m \cdot v} = \frac{6.626 \cdot 10^{-34}\ \text{Js} \cdot 6.02 \cdot 10^{23}}{60 \cdot 12 \cdot 10^{-3}\ \text{kg} \cdot 117\ \text{m/s}}$ (2)

$= \underline{4.7\ \text{pm}}$ (1)

$\Delta\lambda_B = r_v \cdot \lambda_B = \frac{\Delta v}{v} \cdot \lambda_B$ (1) $= \frac{20}{117} \cdot 4.7\ \text{pm}$

$= \underline{0.8\ \text{pm}}$ (1)

$\longrightarrow$ compatible (1)

d) $\lambda_B' = 60 \cdot \lambda_B$ (1) $\longrightarrow \sin \alpha' = 60 \cdot \sin \alpha$ (1)

$\longrightarrow$ maxima further apart (1)