Physics exam, nationwide, Baccalaureate july 2004, "real" track (science-oriented high schools)

You have to complete all items in 2 of the 4 subjects, i.e. A. Mechanics; B. Electricity and Magnetism; C. Elements of Thermodynamics and Molecular Physics; D. Optics. You have 10 points from the start -for taking the exam- (total 10+45+45=100 pnts). Work time is 3 hours. No calculators!

A. Mechanics

Consider the gravitational acceleration $g = 10m/s^2$.

I. For items 1-5 write on the exam sheet the letter corresponding to the answer considered to be correct (10 pnts).

1. Knowing that the symbols of the physical quantities and units are the ones used in Physics manuals, the unit for the quantity represented by the product $m \cdot \vec{v}$ is

$$a)\ N \cdot s \qquad b)\ N \cdot m \cdot s \qquad c)\ N \cdot m/s \qquad d)\ N/s \qquad (1)$$

2. An object with mass of 1 Kg tied to a dynamometer is lifted vertically with an acceleration of $1m/s^2$. The value of the force shown by the dynamometer is:

a) 1N b) 9N c) 10N. d) 11N.

3. Under the action of a certain force a spring is elongated by a certain amount. Under the actiuon of another force, the elongation of the spring is doubled. As a result, the potential energy of the spring:

a) doubled. b) increased four times. c) increased $\sqrt{2}$ times. d) increased 3 times.

4. An object suspended by a wire is moved to position (A) as in the figure and then set free. In the moment when the object passes through position (B), the lowest on its trajectory, the wire breaks. The object continues its motion on the trajectory:

a) (1) b) (2) c) (3) d) (4)

5. On a brick with its base against a rough vertical wall we exert a force oriented upwards and towards the wall, under an angle of 30^0 with the horizontal. The magnitude of the force is twice as large as the weight of the brick. In this situation the brick:

a) moves uniformly upwards b) remains at rest. c) moves uniformly downwards d) moves upwards accelerated.

II (5 pnts) A moving object doubles its velocity either moving on a horizontal for a distance d_1 with an acceleration a_1 or moving, also on a horizontal, a distance $d_2 < d_1$ with a higher acceleration, $a_2 > a_1$. In which of the two cases we have a higher work? Justify the answer.

Solve the following problems:

1. (15 pnts) An object with mass $m = 1kg$ is put at the end of a plank of mass $M = 2Kg$ as in the figure. The plank, with length $L = 2cm$, is moving without friction on the horizontal surface, and between the object and the plank the coefficient of kinetic friction is $\mu = 0.2$.

Initially the system is at rest and on the object starts acting a force $F = 6N$.

Determine:

a) the acceleration of the object with respect to the horizontal surface when the object is moving on the plank.

b) the time interval after which the object, considered pointlike, will fall off the plank.

c) the kinetic energy of the system of objects with respect to the horizontal surface a second after the begining of the motion.

2. (15 pnts) An object with mass $m = 1Kg$ is suspended on an intextendable wire with length $L = 1m$. It is lifted such that the wire remains under tension and forms an angle $\alpha = 60^0$, with its equilibrium position as in the figure, after which the object is let free. Object A will collide completely inelastically with object B situated at rest. Determine:

a) The velocity of the object A imediately before the collision with the second object B;

b) The tension in the wire at the moment considered at point a)

c) the maximum height to which the composite object formed by the completely inelastic collision of the two objects will rise, if the two objects have equal mass.

B. Electricity and Magnetism

The magnetic permeability of the vacuum is known to be $\mu_0 = 4\pi \times 10^{-7} N/A^2$.

I. For items 1-5 write on the exam sheet the letter corresponding to the answer considered to be correct (10 pnts).

1. Knowing that the symbols of the physical quantities are the ones used in Physics manuals, the unit for the quantity equal to $BIl \sin\alpha$ is:

a) V b) Wb c) T d) N.

2. Two sources have equal e.m.f.'s. The maximum power that the first source can give an external circuit is P_1, and the maximum power than the second source can give is P_2. The series grouping of the two sources will give the external circuit a maximum power of:

$$a) P_1 + P_2 \qquad b) \frac{4P_1P_2}{P_1 + P_2} \qquad c) \frac{P_1 + P_2}{2} \qquad d) \frac{2P_1P_2}{P_1 + P_2} \tag{2}$$

3. If the voltage at the ends of a resistor is $4.5V$, and its electric resistance is $5k\Omega$, the electric currentpassing through it is

$$a)\ 22.5mA \qquad b)\ 22.5A \qquad c)\ 0.9A \qquad d)\ 0.9mA \tag{3}$$

4. The unit for the magnetic field, expressed as a function of fundamental units of SI, is:

$$a)\ m \cdot kg \cdot s^{-2} \cdot A^{-1} \qquad b)\ m^2 \cdot s^{-1} \cdot A^{-1} \qquad c)\ kg \cdot s^{-2} \cdot A^{-1} \qquad d)\ m \cdot kg \cdot s^{-1} \cdot A^{-2} \tag{4}$$

5. The maximum value of the electric current that an ampermeter with internal resistance R_A can measure is I_0. For this ampermeter to be traversed by the same electric current I_0 when connected to a circuit in which the electric current is twice as large ($2I_0$), we have to connect in parallel with the ampermeter a resistor (named shunt) with resistance equal to:

$$a)\ R_A \qquad b)\ r_A/2 \qquad c)\ R_A/4 \qquad d)\ 2R_A \tag{5}$$

II (5 pnts) If an electric device is powered by a single source it is traversed by a current I, and if it is powered by a parallel grouping of such sources, it is traversed by a current I'. If the resistance R of the device is much greater than the internal resistance r of a source

($R \gg r$), then practically $I = I'$. What advantages justify in this case the parallel grouping of the sources with respect to using a single source?

III Solve the follwing problems:

1. (15 pnts) To regulate the voltage on an electric (power consuming) device (see figure: "sarcina") one uses the circuit in the figure, where the device and the variable resistor have the same electric resistance R, and the voltage at the endpoints of the circuit is U_0. Considering known R and U_0, determine:

a) The electric current through the part MC of the variable resistor when its position needle C is situated in the middle of the resistor.

b) The ratio of the power consumed by the device and the power consumed by the circuit when the position needle stays at the middle of the variable resistor.

c) The fraction $f = R_{MC}/R_{NC}$ at which the position needle C must divide the variable resistance such that the voltage on the device is $U_0/2$.

2. (15 pnts) A frame of metallic wire of square shape with side $l = 20cm$ is introduced in a uniform magnetic field of $B = 4mT$.

a) Determine the value of the magnetic flux through the frame if the lines of magnetic field form an angle of 30^0 *with the plane of the frame*;

b) The frame is situated perpendicularly to the lines of the magnetic field, after which the magnetic field is reduced to zero in a time interval of $0.5ms$. Calculate the induced voltage in the frame during this time.

c) The square frame is transformed in a circular frame formed of N=10 wire loops tightly bound together. The frame is situated in vacuum, perpendicular to the lines of the magnetic field given initially. Determine the electric current that must pass through the wire loops in an appropriate direction, such that in its center, the resulting magnetic field is zero. (Use $\pi^2 = 10$).

C. Elements of thermodynamics and molecular physics

I. For items 1-5 write on the exam sheet the letter corresponding to the answer considered to be correct (10 pnts).

1. Knowing that the symbols of the physical quantities and units are the ones used in Physics manuals, the unit for the quantity $p\mu/(RT)$ is:

$$a)\ J/(kg \cdot K) \qquad b)\ N/m^2 \qquad c)\ Kg/m^3 \qquad J/K \tag{6}$$

2. The law $p = p_0(1 + \beta t)$ describes a transformation of the type:

a) isothermal b) isochoric c) adiabatic isobaric

3. In an adiabatic expansion of an ideal gas the internal energy of a gas:

a) grows b) decreases c) stays the same d) first rises, then decreases

4. At the temperature T_0 the thermal velocity corresponding to hydrogen ($\mu_1 = 2 \cdot 10^{-3} Kg/mol$) is equal to the thermal velocity corresponding to oxygen ($\mu_2 = 32 \cdot 10^{-3} Kg/mol$) at a different temperature T. The ratio T/T_0 has the value:

a) 16 b) 8 c) 4 d) 2.

5. The unit for the molar heat capacity of an ideal gas as a function of fundamental units in SI is:

$$a)\ m^2 \cdot kg \cdot s^{-2} \cdot mol \cdot K^{-1} \quad b)\ m \cdot kg \cdot s^{-2} \cdot K^{-1} \quad c)\ m^{-1} \cdot kg \cdot s^{-2} \quad d)\ m^2 \cdot kg \cdot s^{-2} \cdot mol^{-1} \cdot K^{-1} \tag{7}$$

II (5 pnts) In the ballons in the figure we have, at equilibrium, the same gas in different quantities, at the initial temperatures T_1 and T_2, respectively ($T_1 > T_2$). The temperature in both baloons is increased by Δt. Determine if the level of the liquid remains unchanged. Justify!

III Solve the following problems:

1. (15 pnts) An ideal gas, situated in state (1) in which $p_1 = 8 \cdot 10^5 Pa$ and $V_1 = 1L$, makes a cyclical transformation consisting of: (1)-(2) isothermal compression until $p_2 = 4p_1$; (2)-(3) isobaric expansion until $V_3 = V_1$ and (3)-(1) isochoric cooling until coming back to the initial state.

a) Represent graphically the cycle in p-V and V-T diagrams.

b) Determine the ratio of the thermal velocities of the molecules of the gas corresponding to the extremal temperatures appearing in the cycle (v_{Tmax}/v_{Tmin}).

c) Calculate the work done by the gas on the entire cycle (1)-(2)-(3)-(1), considering that $\ln 2 = 0.693$.

2. (15 pnts) The thermal efficiency of a cycle formed by two isothermal and two adiabatic transformations (Carnot cycle) is $\eta = 30\%$, and in a cycle the work done is $L = 1.2kJ$. The temperature of the warm source is $627^0 C$. Determine:

a) The heat received in a cycle;

b) The temperature of the cold source;

c) The ratio of the extreme values (V_{max}/V_{min}) of the volume in the adiabatic expansion in the cycle knowing that the adiabatic exponent has the value $\gamma = 5/3$.

D. Optics

We know the speed of light in vacuum, $c = 3 \cdot 10^8 m/s$ and $n_{air} = 1$.

For items 1-5 write on the exam sheet the letter corresponding to the answer considered to be correct (10 pnts).

1. The image of a real object situated in front of a convex mirror is:

a) virtual b) larger than the object c) real d) inverted.

2. The formula for the transversal (lateral) linear magnification for a thin lens is:

$$a)\ \beta = \frac{x_2}{x_1} \qquad b)\ \beta = -\frac{x_2}{x_1} \qquad c)\ \beta = -\frac{x_1}{x_2} \qquad d)\ \beta = \frac{x_2}{x_1} \tag{8}$$

3. A planar-convex lens has one of the principal focal points at point F, as in the figure. The other principal focal point is:

a) on the surface of the lens, in F_1;

b) in F_2, at a distance equal to half the radius of the spherical face;

c) in F_3, the symmetric of the first principal focal point with respect to the optic center of the lens;

d) at infinity.

4. If a lens has a convergence of $C = 2.5$ diopters, its focal distance is

a) 2.5 m b) 25 cm c) 40 cm d) 75 cm

5. A light beam (bundle of rays) parallel to the principal optic axis of a system of two lenses situated at a distance d between each other, incident on one of the lenses, gets out of the system still parallel to the optic axis, but with the decreased diameter. Knowing the

focal distance of the first lens is larger than the distance between the lenses, $f_1 > d$, then the system is formed of:

a) two converging lenses with $f_1 > f_2$;

b) two converging lenses with $f_1 < f_2$;

c) two diverging lenses with $|f_1| > |f_2|$;

d) a converging lens and a diverging lens.

II (5 pnts) An observer can't see at all the bottom of the vase when he looks as in the figure. If he puts water in the vase he will be able to see a significant portion of the bottom of the vase. Explain these statements drawing an appropriate diagram.

III Solve the following problems:

1. (15 pnts). A thin plane-convex lens placed in air has the focal distance equal to the diameter of the sphere that the convex face of the lens is made of. The real image of an object situated at a distance of 1 m with respect to the lens is inverted and equal in height to the object. We replace the lens with an optical system made by stacking close together N thin lenses, identical with the first one. The real image of the same object placed at 1m distance from the system is situated at a distance of 20 cm from its optic center. Determine:

a) The index of refraction of the material from which the lens is made;

b) The focal distance of the lens;

c) The number of lenses that were stacked together to obtain the optic system.

2. (15 pnts) On the screen of a Young experiment situated in air we obtain an interference pattern with the distance between fringes of $i = 1.5mm$ corresponding to a radiation with $\lambda = 500nm$. The same experiment forms for another radiation the first maximum at a distance of 2.25 mm from the central maximum. Determine:

a) The frequency corresponding to the first radiation;

b) The wavelength of the second radiation;

c) The distance between the maximum of order 3 corresponding to the second radiation and the maximum of order 4 of the first radiation if these maxima are situated on the same side of the central maximum.