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 correct answer (10 pnts).

1. The SI unit for kinetic energy, as a function of fundamental units, is

$$a)\ m^2 \cdot kg \cdot s^{-2} \qquad b)\ m^2 \cdot kg \cdot s^2 \qquad c)\ m \cdot kg \cdot s^{-2} \qquad d)\ m^2 \cdot kg \cdot s^{-1} \quad (1)$$

2. An object thrown vertically upwards, in a uniform gravitational field, with the initial velocity v_0, has velocity v at distance h above the launching point. The mathematical expression for the equation of Galileo Galilei in this case is:

$$a)\ v = v_0 + 2gh \qquad b)\ v = \sqrt{2gh} \qquad c)\ v^2 = v_0^2 + 2gh \qquad d)\ v^2 = v_0^2 - 2gh \qquad (2)$$

3. An object with weight G is put on the floor of an elevator that goes accelerated down ($a < g$). The normal (perpendicular) force (F_N) exerted by the object on the floor of the elevator is:

$$a)\ F_N > G \qquad b)\ F_N = G \qquad c)\ F_N < G \text{ and } F_N \neq 0 \qquad d)\ F_N = 0 \qquad (3)$$

Knowing that the notations are the ones used in Physics manuals, which of the following expressions has the dimensions of work?

$$a)\ F \cdot \Delta t \qquad b)\ \vec{F} \cdot \vec{v} \qquad c)\ \frac{p}{2m} \qquad d)\ \vec{F} \cdot \vec{d} \qquad (4)$$

5. On an object with mass m situated on a horizontal surface with friction (coefficient of kinetic friction μ) we exert a traction force F_t horizontally, twice larger than the frictional force. The acceleration of the object is

$$a)\ -\mu g \qquad b)\ \mu g \qquad c)\ \text{zero} \qquad d)\ 2\mu g \qquad (5)$$

II. (5 pnts) Two spheres A and B situated in contact, as in the figure, are left free to fall from a height h measured from the center of sphere A. Explain the conditions under which, after the collision of sphere B with the Earth, sphere A rises to a height larger than h. (Consider first the collision of sphere B with the Earth and then the collision between spheres).

III. Solve the following problems:

1. (15 pnts). The laws (1) $x = 10-2t(m)$ and (2) $x = 5+2t(m)$ describe the rectilinear (straight line) motion on the same axis of two objects with equal masses $m_1 = m_2 = m$. Determine:

a. The moment of their contact.

b. The law of motion of object (2) relative to object (1) before their collision.

c. The variation of the kinetic energy of each object produced as a result of their collision, perfectly ellastic and central.

2. (15 pnts). The coefficient of kinetic friction of an object A on an inclined plane of variable angle is $\mu = 0.58(\simeq \sqrt{3}/3)$.

a. Determine the angle of inclination of the plane for which the object, left free on the plane, goes down uniformly.

b. Fix the inclination of the plane at the angle $\alpha = 60^0$ and tie object A to another object B ($m_A = 4m_B$) through a wire passed over an ideal fixed pulley as in the figure, after which the system is let free. Draw a diagram and represent the forces that act on each object.

c. Determine the velocity of the system in the moment in which the object B rose to a height $h = 0.5m$ relative to the initial one, considering that the inclined plane and the wire have sufficient lengths for the two objects not to change the direction of their motions.

B. Electricity and Magnetism

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

1. Knowing that the symbols for the physical quantities and measuring units are the ones used in the Physics manuals, the unit for the quantity equal to $U \cdot I$ is

$$a)\ W \qquad b)\ J \qquad c)\ T \qquad d)\ Wb \tag{6}$$

2. The SI unit for magnetic flux, as a function of fundamental units, is:

$$a)\ m\cdot kg\cdot s^{-2}\cdot A^{-1} \qquad b)\ m^2\cdot kg\cdot s^2\cdot A^{-1} \qquad c)\ m^2\cdot kg\cdot s^{-2}\cdot A \qquad d)\ m^2\cdot kg\cdot s^{-2}\cdot A^{-1} \tag{7}$$

3. The resistance of a linear, homogenous conductor, with a constant area of its transversal (perpendicular) section, maintained at constant temperature, depends on its length l according to the graphical representation: (a,b,c,d)

4. The heat released in a time t by a resistor of resistance R which has an electric current of intensity I passing through it when connected to a real battery (source) of (E, r) is:

$$a)\ \frac{(E-Ir)^2}{r}t \qquad b)\ \frac{(E-IR)^2}{R}t \qquad c)\ \frac{(E-Ir)^2}{R}t \qquad d)\ (E-IR)It \tag{8}$$

5. Two parallel conductors with very large length and having elcetric currents passing through them interact with forces that are:

a. perpendicular on the plane formed by the two conductors

b. attractive if the two currents have opposite directions

c. repulsive if the two currents have the same direction

d. attractive if the two currents have the same direction

II (5 pnts) A circular loop suspended by a wire is situated in the vicinity of a solenoid, coaxial with it, as in the figure. In the circuit powering the solenoid is connected a variable resistor. One observes a that for a certain movement of the variable resistor's position needle C, the loop is attracted by the solenoid. Eplain the phenomenon and find the direction in which C was moved (towards the endpoint A or B of the resistor?)

II Solve the following problems

a. (15 pnts) A real battery ($E = 6V,\ r = 1\Omega$) powers a parallel grouping of a resistor with a solenoid without core, both having the same resistance $R = 10\Omega$. The solenoid is made out of an isolated metalic conductor, in a single layer, wire next to wire. A circular frame with diameter $D = 2cm$ has $N = 10$ wire loops on it, well bound together, and produces in its center a magnetic field with magnetic induction B equal to with the magnetic induction in the center of the solenoid when having the same electric current running through it. Determine:

a. The electric current going through the battery.

b. The heat released by the resistor in five minutes time.

c. The diameter d of the solenoid's wire.

2. (15 pnts). A straight metalic wire of length $l = 1m$ is moving according to the drawing on two conducting rails, without friction, perpendicular to the lines of a uniform magnetic field with induction $B = 0.1T$. The ampermeter is ideal, the electric resistance of the wire is $R = 10\Omega$, and that of the rails is negligible. Determine:

a. The variation of the magnetic flux through the surface of the circuit when the wire is moving on a distance of 1m in the direction shown.

b. The velocity of the wire in the moment that the ampermeter is showing a value of $10mA$.

c. The force that must be exerted on the wire to maintain it in motion at the constant speed of 12 m/s.

C. Elements of Thermodynamics and molecular physics

It is known: the univeral constant of ideal gases $R = 8.31J/mol \cdot K$ and $C_P - C_V = R$.

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

1. Knowing that the symbols for the physical quantities are the ones used in Physics manuals, the expression of the thermal equation of state is:

$$a)\ p = NkT \qquad b)\ p = \frac{1}{3}Nm\bar{v}^2 \qquad c)\ p = \frac{NkT}{V} \qquad d)\ = \frac{1}{3}\frac{N}{V}\bar{\epsilon} \tag{9}$$

2. Knowing that the symbols for the physical quantities and units are the ones in the Physics manuals, the unit for the quantity equal to $\nu R\Delta T$ is:

$$a)\ J \qquad b)\ K \qquad c)\ Pa \qquad W \tag{10}$$

3. In an isobaric compression of a constant mass of ideal gas its internal energy:

a. increases. b. first increases, then decreases. c. remains constant. d. decreases.

4. Which one of the states 1-4 of the cyclical transformation in the figure corresponds to the maximal volume reached by an ideal gas whose mass remains constant during the transformation?

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

5. The concentration of the molecules of a gas is n, and the mass of a molecule is m_0. The gas is situated in a container with volume V. The density ρ of the gas is:

$$a)\ \rho = \frac{m_0}{nV} \qquad b)\ \rho = \frac{nV}{m_0} \qquad c)\ \rho = nm_0 \qquad d)\ \rho = \frac{m_0}{V} \tag{11}$$

II (5 pnts) In a tube situated in the horizontal position, with the endpoints closed, of length L, we have a mercury (Hg) column of length h that limits two compartments A and B in which we have air at the same temperature (as in the figure). If the tube is brought to the vertical position, the mercury column is stabilized at the middle of the tube. Explain the phenomenon and determine which of the extremities A or B has been brought to the lower part of the tube.

III solve the following problems:

1. (15 pnts). A container with volume $V = 1.5l$ contains $\nu = 1$ mols of nytrogen ($\mu = 28g/mol, C_V = 5R/2$) at the temperature $t_1 = 27^0C$. The container is heated until the pressure of the gas doubles. The dilatation of the container is negligible. Determine:

a. The pressure of the gas in its initial state.

b. The heat received by the gas in this process.

c. The molar heat capacity at constant volume of the gas mix obtained in the container by dissociating a fraction $f = 1/3$ of the initial number of nytrogen molecules.

2. (15 pnts) A quantity of ideal gas goes through a cyclical transformation 1-2-3-1 in the figure, in which process 1-2 is isothermic. The ration $V_1/V_2 = 8$ is known.

a) Draw the diagram of this cyclical transformation in V-T coordinates.

b) Determine the parameters of the states 2 and 3 as a function of p_1, V_1, T_1.

c) Calculate the ratio of thermal velocities (v_{max}/v_{min}) corresponding to the extremal values of the temperature reached in the cycle.

D. Optics

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

1.Knowing that the symbols of physical quantities are the ones used in the Physics manuals, the expression for the convergence of a thin lens situated in air is:

$$a)\ \frac{1}{(n-1)}\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad b)\ (n-1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right) \quad c)\ (n-1)\frac{R_2 - R_1}{R_1 R_2} \quad d)\ (n-1)\frac{1}{R_1 - R_2} \tag{12}$$

2. For the spherical diopter in the figure, the refraction indices are related as:

a. $n_2 = n_1$.

b. $n_2 < n_1$.

c. $n_2 = -n_1$.

d. $n_2 > n_1$.

3. How does the focal length of lens vary, if it is introduced in a liquid whose index of refraction is equal to the one of the lens?

a. not modified b. becomes infinite c. becomes zero. d. changes sign.

4. The constant of the diffraction grating has the SI units of

a. m   b. m^{-1}.   c. radian   d. adimensional

5. If λ is the wavelength of two monochromatic coherent light waves and k is an integer number, the condition that they form an interference maximum is that the difference of the legths of the two paths is equal to

$$a)\ k\frac{\lambda}{4} \qquad b)\ k\frac{\lambda}{2} \qquad c)\ 2k\lambda \qquad d)\ k\lambda \tag{13}$$

II (5 pnts) If we are near a fire the object situated on the other side of it appear to be unstable (the images "jump around"). Explain why.

III. Solve the following problems:

1. (15 pnts). A linear luminous object is situated perpendicular to the principal optical axis of a thin lens at the distance of 10 cm from the lens. The formed image is virtual and twice as large as the object. If we put a second lens right next to the first and coaxial with it, the image of the object situated at the same distance becomes now real and twice as large as the object.

a. Construct (draw a diagram for) the image of the object in the first lens.

b. Determine the curvature radius of the faces of the first lens knowing that it is biconvex, symmetrical, placed in air and its index of refraction is n=1.5.

c. Calculate the focal length of the second lens.

2. (15 pnts). On a diffraction grating with 100 lines per mm, situated in air, we shine perpendicularly radiation with wavelength of $\lambda = 500nm$. The diffraction pattern is obtained on a screen situated at a distance of 0.5 m from the plane of the grating, parallel with it. Consider the speed of light in air is $3 \cdot 10^8 m/s$. Determine:

a. The frequency of the radiation.

b. The distance between the central maximum and the first order maximum.

c. The maximum order of the spectrum that could form on the screen.