NAME AND SURNAME ……………………………………… UNIVERSITY …………………………………………….

Selected issues:			

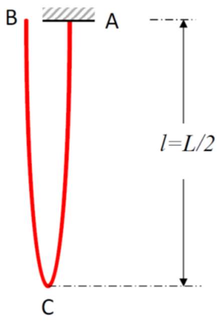
GENERAL PHYSICS COMPETITION FOR ENGINEERING STUDENTS "ION I. AGARBICEANU"

XI Edition 2023 13 May 2023

Theoretical test, Physical Section 1

Each contestant participates in the contest with 3 of the 6 subjects of their choice. On the first competition sheet, the candidate will specify under his signature the numbers of the subjects he has chosen.

1. A uniform chain (string) of length and mass is attached to the A end as in the figure. At the moment the end B is left free from the level of the end A. Find the rate of descent of point C at the moment when the kinetic energy of the moving part is maximum. Numerical application : $L = 2lM = 2mt = 0l = 100\ cm; g = 10\frac{m}{s^2}$.



- ex officio 1p

-Figure 1p

-End B falls with throttle g 1p

- point of curvature C moving with acceleration $\frac{g}{2}$ 1p

daughter $\varepsilon = \frac{M}{L} = \frac{2m}{2l} = \frac{m}{l}$ mass of unit length 0.5p

-Relations $2z + y = 2l$ Results $z = l - \frac{y}{2}$ 0.5p

- the mass of the moving portion

$m(z) = z \cdot \varepsilon = \left(l - \frac{y}{2}\right)\frac{m}{e}$ 0.5p

- Fall speed (Galileo)

$v_B^2(y) = 2gy$ 0.5p

- kinetic energy of the moving portion

$E_c(y) = \frac{1}{2} m(z) \cdot v^2(y) = \frac{mg}{e}\left(l_y - \frac{y^2}{2}\right)$ 1p

- value of y for which $Ecin$ is maximum

$\frac{dE_c}{dy} = \frac{mg}{e}(l - y) \equiv 0$ Results$l = y$ 1p

- speed of B at that time

$v_B^2(e) = 2gl$ 1p

- point speed C at that time (Galileo)

$v_C^2(e) = 2\frac{g}{2} \cdot \frac{l}{2} = \frac{gl}{2}$ $\qquad v_C = \sqrt{\frac{gl}{2}}$ 0.5p

-numeric

$v_c = \sqrt{\frac{10}{2} \cdot 1} = \sqrt{5}\, m/s$ 0.5p

2. A room in an apartment building is heated from the initial temperature $\theta_1 = 0^0 C$ to the final temperature $\theta_2 = 20^0 C$. The volume of the room is $V = 50\ m^3$. Taking into account the external pressure $p_0 = 10^5 N/m^2$, let us find out what is the amount of heat required. Air is thought to consist of biatomic molecules.

Solution scale *:*

- ex officio ***1.0 p***

- there is no change in chamber volume or pressure. As a result, the amount of gas in the chamber varies; ***1.5 p***

- in an infinitesimal process the system switches from parameters p_0, V, ν, T *at* $p_0, V, \nu - d\nu, T + dT$ ***0.5 p***

- In this infinitesimal process, the transformation can be considered isobaric ***1.0 p***

- the heat exchanged in this process is $dQ = \nu C_p dT = \frac{7}{2}\nu R dT$ ***1.5 p***

- from the thermal equation of state ($p_0 V = \nu RT$ *) results* $\nu = \frac{p_0 V}{RT}$ ***0.5 p***

- the changed heat becomes $dQ = \frac{7}{2} \cdot \frac{p_0 V}{RT} \cdot R dT = \frac{7}{2} p_0 V \cdot \frac{dT}{T}$ ***1.5 p***

- integration is obtained $Q = \int_0^Q dQ = \frac{7}{2} p_0 V \cdot \int_{T_1}^{T_2} \frac{dT}{T} = \frac{7}{2} p_0 V \cdot \ln\left(\frac{T_2}{T_1}\right)$ ***1.5 p***

- numerical calculation: $T_1 = 273\,K$, $T_2 = 293\,K$, $Q \cong 1{,}237\ MJ$ ***1.0 p***

3. A point body of mass *m* is at rest at the apex of a hemisphere of mass *M*, (see figure 1). With a small impulse, the body begins to slide, without friction, on the hemisphere. At an angle θ, measured relative to the vertical passing through the center of the hemisphere, the body detaches from the hemisphere. Consider that the hemisphere can move horizontally without friction and is initially at rest.

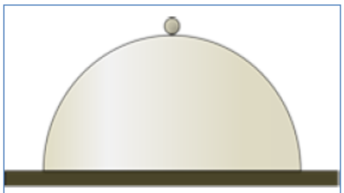


Figura 1

a) Write the equation that allows the calculation of angle q.

b) Calculate the angle θ if $M = m$.

P.O. 1 p.

Daughter v_x and v_y the components (horizontal and vertical) respectively of the speed of the body, and V_x Hemisphere speed.

From conservation of momentum (on the horizontal axis): $mv_x = MV_x$.

1 p.

Consider the moment at which the particle is at angle θ. From SR related to the hemisphere it is immediately noticeable that

$\frac{v_y}{v_x + V_x} = \mathrm{tg}\theta \Rightarrow v_y = \left(1 + \frac{m}{M}\right) v_x \mathrm{tg}\theta$ (condition that the particle remains in contact with the hemisphere).

2 p.

From energy conservation, $\frac{1}{2}m\left(v_x^2 + v_y^2\right) + \frac{1}{2}MV_x^2 = mgR\left(1 - \cos\theta\right)$. 1 p.

Eliminating v_y It is obtained: $v_x^2 = \frac{2gR(1-\cos\theta)}{(1+k)\left(1+(1+k)\mathrm{tg}^2\theta\right)}$ where $k = \frac{m}{M}$.

1 p.

The component v_x can only increase (the horizontal component of the normal reaction accelerates the particle).

This will be maximum when the detachment of the bodies occurs.

As a result, the angle θ ατ ωηιχη ιτ ρεαχηεσ ιτσ v_x maximum value must be found.

$$\frac{\mathrm{d}}{\mathrm{d}\theta} v_x^2 = \left(1 + (1+k)\mathrm{tg}^2\theta\right)\sin\theta - (1-\cos\theta)(1+k)\frac{2\mathrm{tg}\theta}{\cos^2\theta} = 0,$$ 1 p.

in other words

$$k\cos^3\theta - 3(1+k)\cos\theta + 2(1+k) = 0.$$ 1 p.

b. For the particular case $k = 1$ the equation can be written:

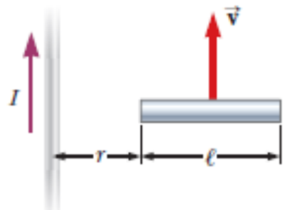
$$\left(\cos\theta - 2\right)\left(\cos^2\theta + 2\cos\theta - 2\right) = 0$$ 1 p.

The only solution that makes sense is $\cos\theta = \sqrt{3} - 1 \cong 0,732 \Rightarrow \theta \cong 42,9^\circ$

0.5 p.

c. If the hemisphere is fixed ($k = 0$) $\Rightarrow \cos\theta = 2/3$. 0.5 p.

4. A conductive bar of length l moves with constant velocity v parallel to a filiform conductor through which passes an electric current of intensity I as shown in the figure. The bar remains perpendicular to the conductor, with the nearest end at a distance . r The bar-conductor system is in vacuum (). Find the value of the electrical voltage generated between the ends of the bar. Numerical application: .$\mu_0 = 4\pi \times 10^{-7}\, H/m l = 15.5\ cm; r = 0.5\ cm; v = 20\frac{m}{s}; I = 5\ A; ln2 = 0.693$



- ex officio 1p

-drawing 2 p

- $B(x) = \mu_0 \frac{I}{2\pi x}$ 1p

- elementary flow through the shaded surface

$$d\phi = B(x) \cdot y = B(x) \cdot vt = \frac{\mu_0 vIt}{2\pi} \cdot \frac{dx}{x}$$ 1p

- total flow

$$\phi = \int_r^{r+l} d\phi = \frac{\mu_0 vIt}{2\pi} \int_r^{r+l} \frac{dx}{x} = \frac{\mu_0 vIt}{2\pi} ln\left(1 + \frac{l}{r}\right)$$ 3p

- induced voltage

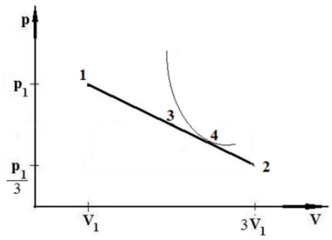
$$|e| = \frac{d\phi}{dt} = \frac{\mu_0 vI}{2\pi} ln\left(1 + \frac{l}{r}\right)$$ 1p

-numeric

$$|e| = \frac{4\pi 10^{-7} 20\cdot 5}{2\pi} = ln\left(1 + \frac{15{,}5}{0{,}5}\right) = 69{,}3\ \mu V$$ 1p

5. A quantity of ideal monatomic gas ($C_V = \frac{3}{2}R$) goes through a thermodynamic process from the initial state ($p1$, $V1$) to the final state ($p1$/3, 3V1). The graph of this process, in coordinates (p, V), is a line segment, over $p_1 = 100\text{kPa}$ and . $V_1 = 6\,\text{L}$ Calculate: a) the heat received by the gas during heating; (b) the heat exchanged by the gas throughout the thermodynamic process; (c) the heat received by the gas.

P.O. 1 p.



The equation of line passing through points 1 and 2 is $p = aV + b$. 0.5 p.

By imposing the condition that the right passes through states 1 and 2, one obtains

$a=-\frac{p_1}{3V_1}$ And $b=\frac{4p_1}{3}$. 0.5 p.

a) Since states 1 and 2 are found on the same isotherm, the temperature of the gas rises to the point of tangency with the last isotherm, which is point 3. It is in the middle of the right 1-2, so it has

$V_3=2V_1$ And $p_3=\frac{2p_1}{3}$. 1 p.

The heat received by gas when heating is

$Q_i=Q_{13}=\Delta U_{13}-L_{13}=\frac{4}{3}p_1V_1=800\,\mathrm{J}$. 1 p.

b) The heat exchanged by the gas with the external environment throughout the transformation is

$Q_{12}=\Delta U_{12}-L_{12}=-L_{12}=\frac{4}{3}p_1V_1=800\,\mathrm{J}$. 1 p.

c) The gas will receive heat up to the point of tangency with adiabata (4). 0.5 p.

The equations that the coordinates of that point must satisfy are $pV^{\gamma}=\text{const.}$ and $p=aV+b$, i.e.

$(aV+b)V^{\gamma}=\text{const.}$ 0.5 p.

By derivation, it is obtained

$V_4=-\frac{b\gamma}{a(\gamma+1)}=\frac{5}{2}V_1$, 1 p.

again

$p_4=\frac{b}{\gamma+1}=\frac{p_1}{2}$. 1 p.

The total heat received by the gas is

$Q_p=Q_{14}=\frac{3}{2}p_1V_1=900\,\mathrm{J}$. 2 p.

6. The permittivity of an inhomogeneous R-ray sphere in vacuum varies according to the law

$$\varepsilon\,(r) = \varepsilon_0\left(\frac{r}{R}+2\right)$$

Calculate the electric field created by a charge Q distributed throughout the volume of the sphere.

Ex officio 1p

$\iint \vec{D}\vec{n}dS = Q$ 2p

For where is the radius of the sphere it follows:$r < RR$

$D4\pi r^2 = Q_{int}$ 2p

Taking into account the variation in permittivity of the medium and 5.5 is obtained:

$$\varepsilon_0\left(\frac{r}{R}+2\right)E4\pi r^2 = Q_{int} = \frac{r^3}{R^3}Q \qquad 2p$$

Results:

$$E = \frac{Qr}{4\pi\varepsilon_0 R^2(r+2R)} \qquad 2p$$

For the application of Gauss's law on a concentric spherical surface with the sphere leads to:$r > R_0$

$$\varepsilon_0 E4\pi r^2 = Q$$

Results:

$$E = \frac{Q}{4\pi\varepsilon_0 r^2} \qquad 1p$$