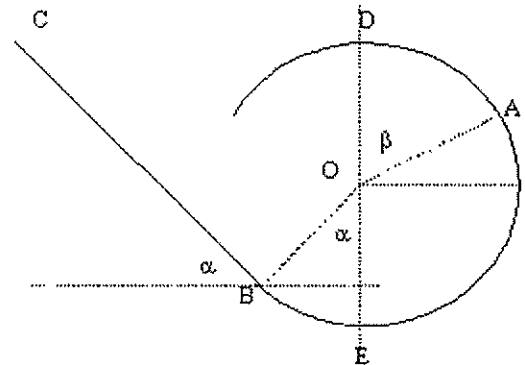


**Physics Midterm n°2***Calculators and extra-documents not allowed.**Answer directly on exam sheets***Exercise 1** (7 points)

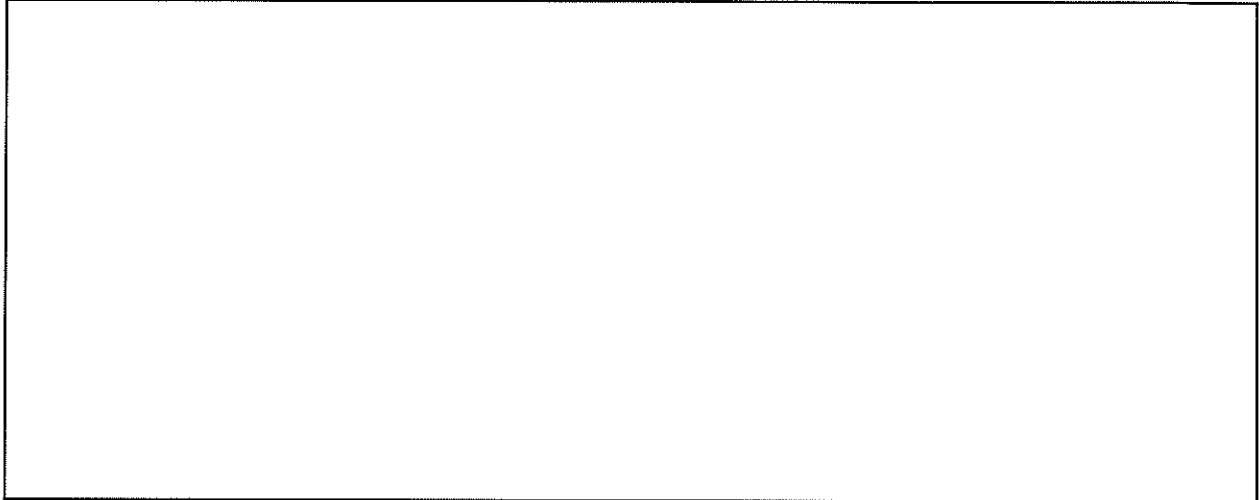
A solid of mass  $m=200\text{g}$  is moving in a slide which is made of a first straight part BC and a second circular part of center O and radius R. **Frictions are neglected.** The solid starts moving at point C **without initial speed**. Given  $\alpha=(BOE)$  and  $\beta=(AOD)$ .

- 1-a) Sketch forces acting on the solid at any point M between C and B.
- b) Use the kinetic energy theorem to express speed at point B. Origin of height axis is at point B. Path BC is at a slope of angle  $\alpha$ .  
Compute for  $BC = 2\text{m}$  ;  $g = 10\text{m.s}^{-2}$  ;  $\alpha = 30^\circ$

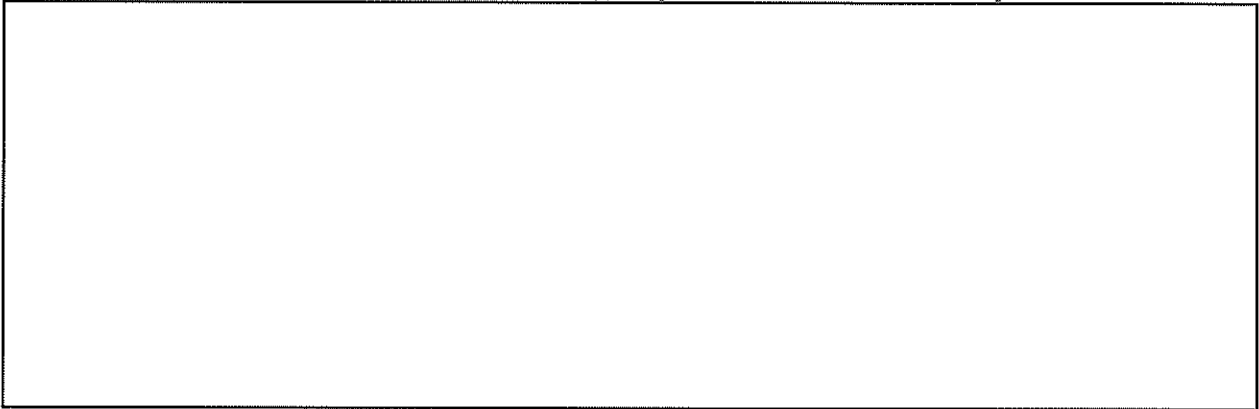


- 2- a) Use mechanical energy theorem to express speed at point A as function of BC,  $\alpha$ ,  $\beta$ , R and g.  
Compute numerically for  $R = 0,5\text{m}$  ;  $\beta = 60^\circ$  and  $g = 10\text{m.s}^{-2}$ .

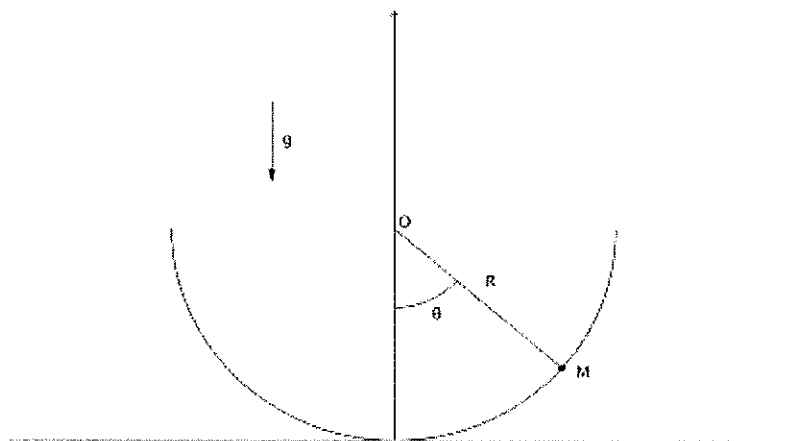
- b) Sketch forces acting on the solid at point A.  
 c) Use Newton's second law in Frenet's basis  $(\vec{u}_T, \vec{u}_N)$  to express the norm of reaction  $R_N$  at point A as function of  $m$ ,  $g$ ,  $BC$ ,  $R$ ,  $\alpha$  and  $\beta$ .



- 3- For which minimal value of mechanical energy at point C can the solid reach point D ?

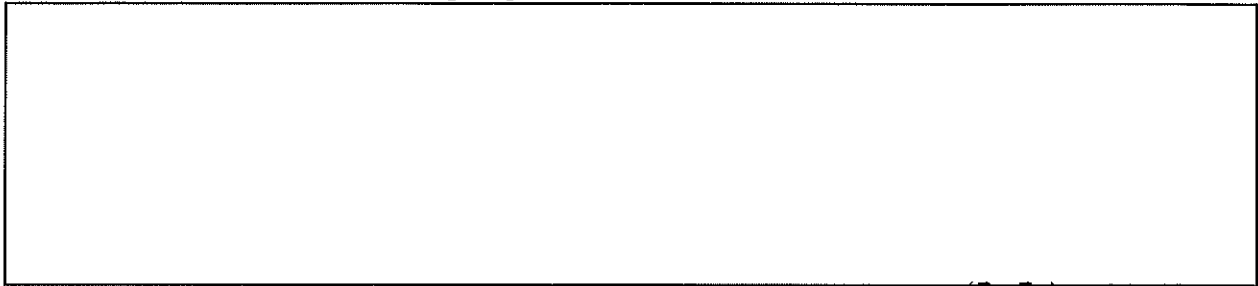


**Exercise 2** Study of a damped oscillation (6 points).

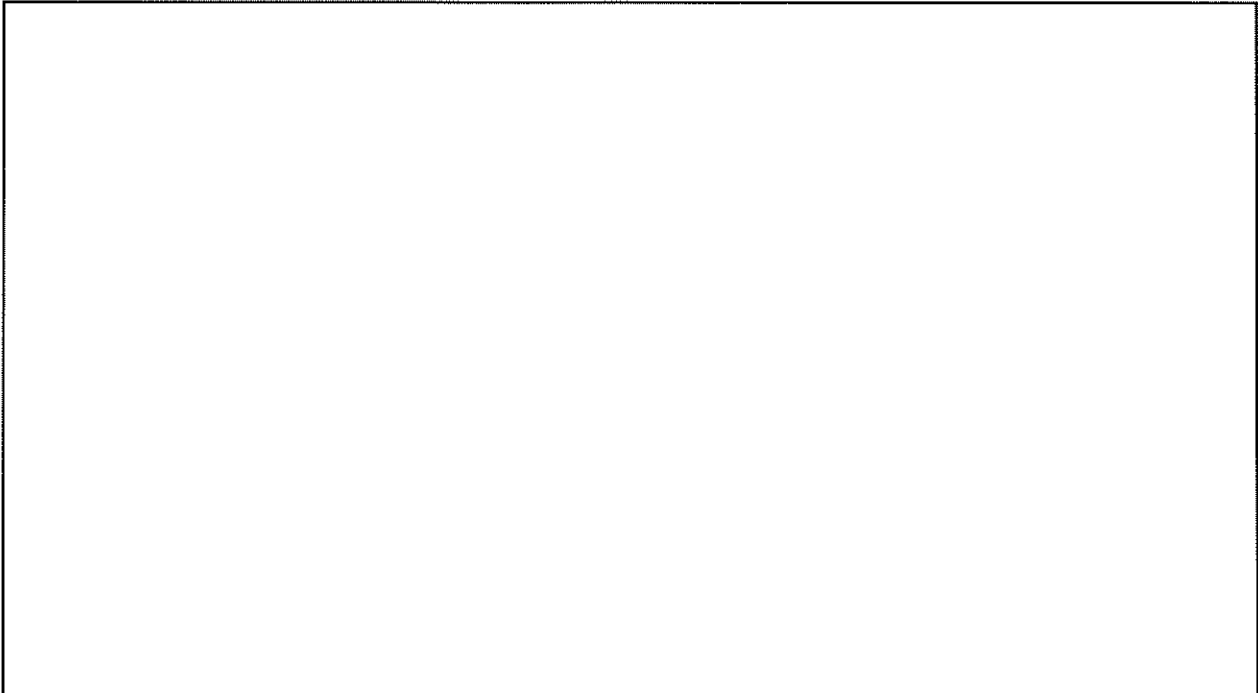


We are considering the motion of an object M of mass  $m$  along a semi-circle of radius  $R$  and center O. Frictions can be modelled by:  $\vec{f} = -\alpha \vec{v}$ . The mass  $m$  is released at some angle  $\theta_0$  without initial speed.

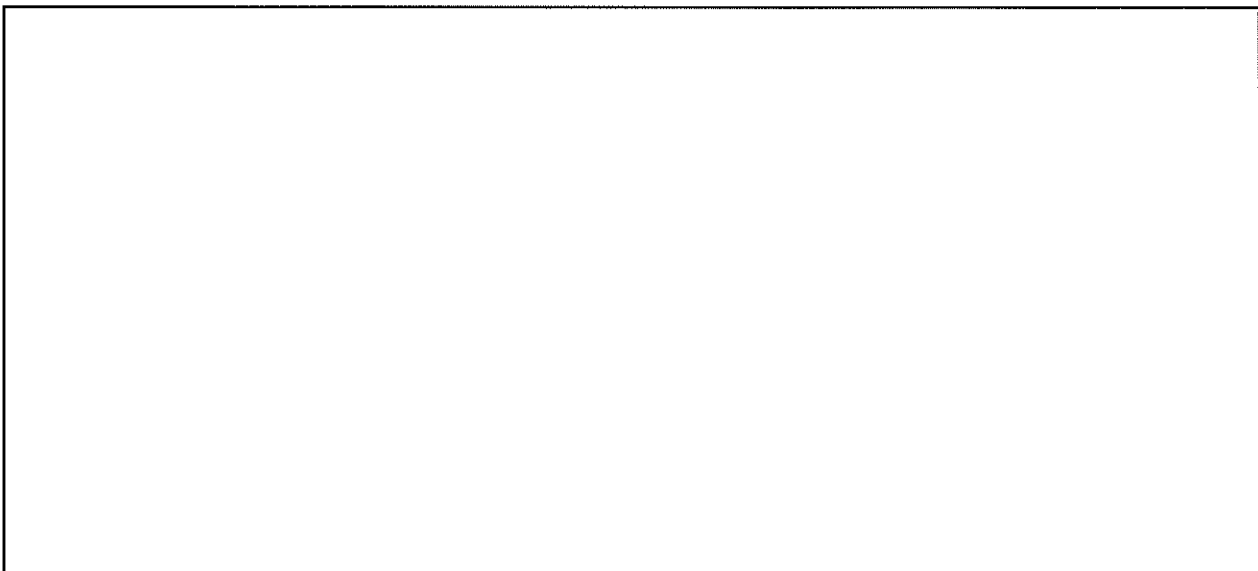
1- Describe the exterior forces acting on point M and sketch them above.



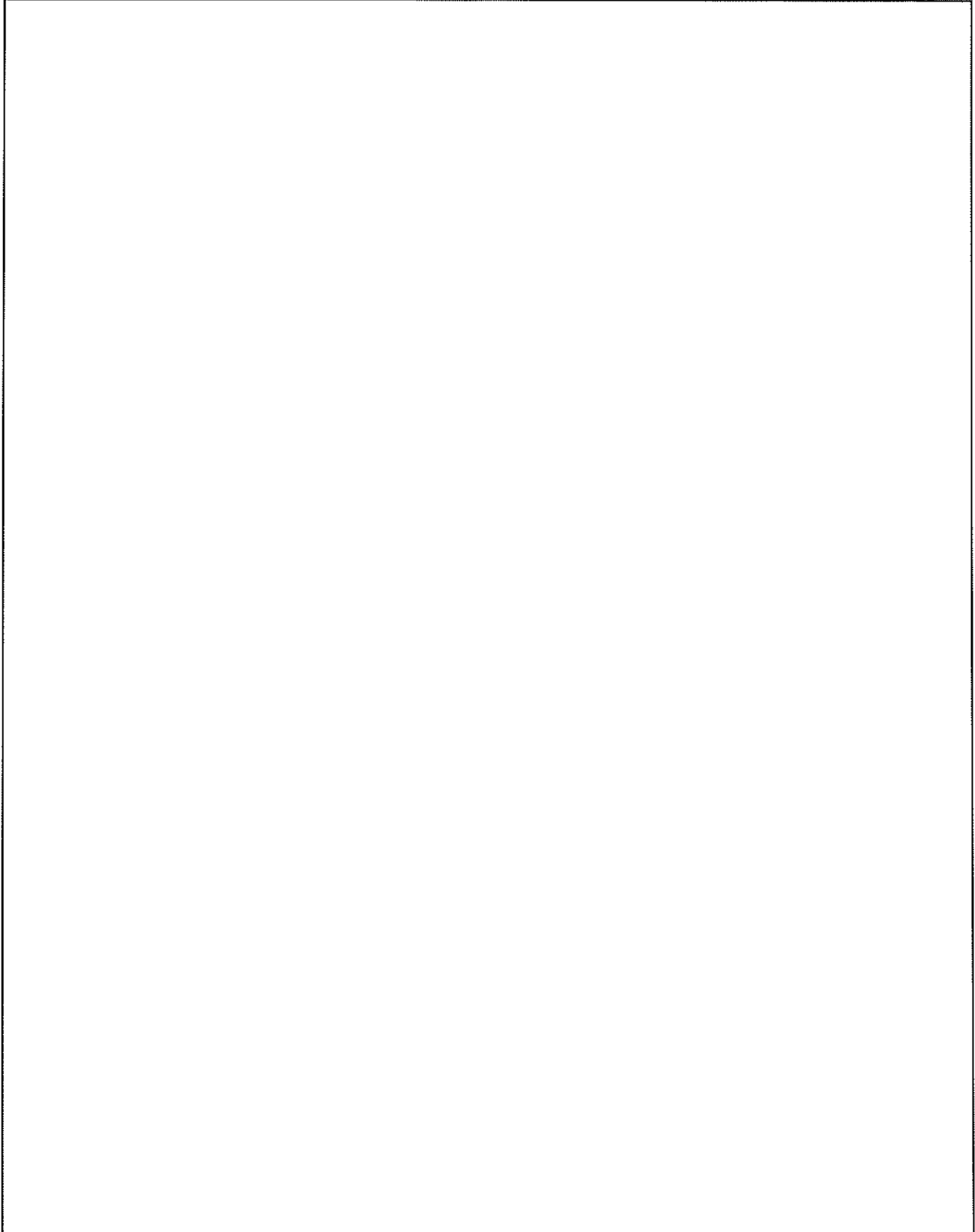
2-a) Write Newton's second law. Then project this equation in Frenet's basis  $(\vec{u}_T, \vec{u}_N)$ .



b) Deduce from it the reaction  $R_N$  and the differential equation which is expressing the angle  $\theta(t)$  as a function of its derivatives  $\dot{\theta}$  and  $\ddot{\theta}$ .



- c) Consider the case where the mass  $m$  is released at small angle  $\theta_0$  such that one can use the approximation  $\sin(\theta) \approx \theta$ . Rewrite the differential equation and discuss the different regimes as function of friction coefficient  $\alpha$ .
- d) Illustrate those regimes with curves  $\theta(t)$ .



**Exercise 3**      Questions 1, 2 and 3 are independent.    (7 points)

1- A calorimeter contains a mass  $m_1 = 200\text{g}$  of water. The initial temperature of this system is  $\theta_1 = 20^\circ\text{C}$ . One adds a mass  $m_2 = 300\text{g}$  of water which is at temperature  $\theta_2 = 80^\circ\text{C}$ .

a) Which temperature  $\theta_e$  would the total system reach at equilibrium if heat capacity of calorimeter  $C_{\text{cal}}$  were neglected? Given data : Heat capacity of water  $c_w = 4.10^3 \text{JK}^{-1}\text{kg}^{-1}$ .

b) One actually measures a temperature  $\theta_e = 50^\circ\text{C}$  at thermal equilibrium. Compute the calorimeter heat capacity  $C_{\text{cal}}$ .

2- A calorimeter, whose capacity is neglected, contains a mass  $m_1 = 200\text{g}$  of water at temperature  $\theta_1 = 70^\circ\text{C}$ . One put inside an ice cube of mass  $m_2 = 80\text{g}$  which was in a freezer at temperature  $\theta_2 = -23^\circ\text{C}$ . Compute the equilibrium temperature  $\theta_e$  assuming that the whole ice cube has melted.

Data: Fusion latent heat of ice:  $L_f = 300.10^3\text{Jkg}^{-1}$ .

Heat capacity of water per mass unit:  $c_w = 4.10^3\text{JK}^{-1}\text{kg}^{-1}$ .

Heat capacity of ice per mass unit:  $c_i = 2.10^3\text{JK}^{-1}\text{kg}^{-1}$ .

3- We would like to get a warm bathwater at  $37^\circ\text{C}$  of total volume  $V = 250\text{L}$  and which is obtained by mixing a volume  $V_1$  of hot water at initial temperature  $\theta_1 = 70^\circ\text{C}$  and a volume  $V_2$  of cold water at initial temperature  $\theta_2 = 15^\circ\text{C}$ .

Find volumes  $V_1$  and  $V_2$  by neglecting all thermal loss while mixing.

Data: Heat capacity per mass unit of water:  $c_e = 4.10^3\text{JK}^{-1}\text{kg}^{-1}$ .

Volumic mass of water:  $\rho_e = 1\text{kg/L}$ .