Diplomvorprüfung zur Vorlesung Experimentalphysik I

Prof. Dr. M. Stutzmann, 09.09. 2004

Time: 90 min
7 Tasks
Points in total: 45

Declaration:
Hereby I declare my agreement for publication of my results of this exam together with my student–ID (without name) on the E25 webpage to simplify the information procedure

Garching, September 9th 2004 Name (block letters):

Student ID: Signature

useful integrals (maybe one of them is needed):

$$\int sin^4 x dx = \frac{3}{8}x - \frac{1}{4}sin\,2x + \frac{1}{32}sin\,4x \qquad \int \frac{1}{sin^4 x}dx = \frac{1}{3}\frac{cos\,x}{sin^3 x} - \frac{2}{3}cot\,x$$

$$\int cos^4 x dx = \frac{3}{8}x + \frac{1}{4}sin\,2x + \frac{1}{32}sin\,4x \qquad \int \frac{1}{cos^4 x}dx = \frac{1}{3}\frac{sin\,x}{cos^3 x} + \frac{2}{3}tan\,x$$

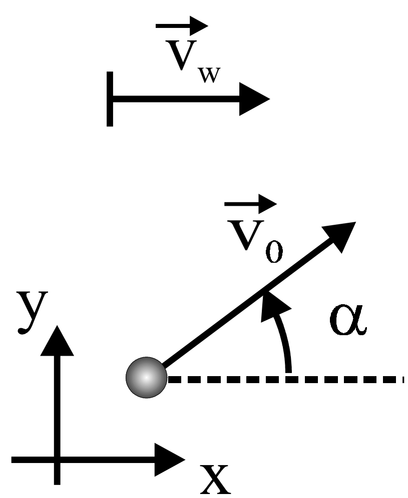
Problem 1: Slingshot (6 points)

A stone is thrown under an angle α towards the horizontal with the velocity $\vec{v}_0$. A constant wind is blowing (velocity of the wind $\vec{v}_w = 0.5 \cdot \vec{v}_0$) in *x*-direction (c.f. sketch). Assume Stokes friction (friction coefficient β) in the following considerations.

a) Calculate the angle α under which the stone has to be thrown, so there is no friction in *x*-direction!

b) Formulate the equation of motion in *y*-direction (consider Stokes friction!) and solve it! At the time $t = 0$ the stone is in the point of origin.

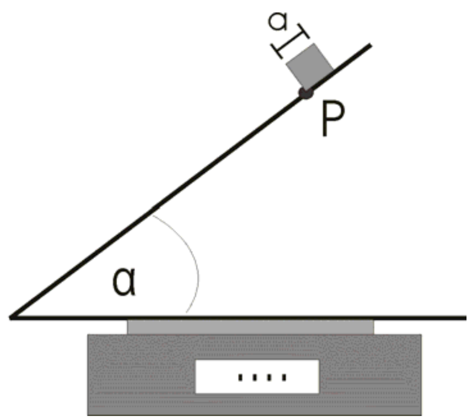
c) Describe the motion of the stone qualitatively when the coordinate system is moving with the wind!



Problem 2: Inclined Plane (4 points)

An inclined plane with a tilt angle of $\alpha = 60°$ is mounted onto a scale. First of all a piece of wood with mass m is fixed by a bracing to the position P on the inclined plane. The scale is adjusted in that way, that it only shows the mass of the piece of wood.

Now the bracing shall be released and the wood is sliding down the plane without friction. What does the scale show after the release of the bracing? Ignore the mass of the bracing.



Problem 3: Football (9 points)

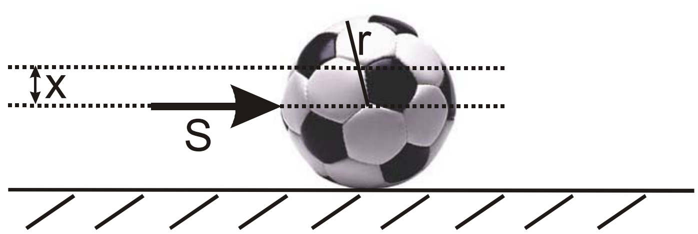
A motionless football (mass m, radius r) is kicked very quickly in the horizontal direction, whereby the impulse of force S is transferred. The kicking football shoe hits the football centrally. Assume the football to be an ideal hollow sphere.

a) Calculate the translational and rotational velocity of the football directly after the kick.

b) What is the time dependence of the translational and rotational velocity, if the sliding friction coefficient between football and ground equals μ_g?

c) At which time after the kick starts the pure rolling friction?

d) At which height x above the center has the football to be hit, so that it starts rolling directly from the beginning? Again, assume a horizontal kicking direction.



The moment of inertia Θ of a hollow sphere with mass m and radius r is given by:
$\Theta = 2/3\ m\ r^2$.

Problem 4: Morse Potential (6 points)

The Morse potential is an empirical potential which describes the interatomic potential in molecules. It is given by the following expression:

$$U(r) = D \cdot \left(1 - e^{-\alpha(r - r_i)}\right)^2$$

In this equation r_i denotes the distance of equlibrium, D and α are a constant.

a) Develop $U(r)$ around $r = r_i$ up to the quadratic term. Compare the result with the potential of a harmonic oscillator.

b) Determine the limits of $U(r)$ for $r \to \infty$ and for $r \to 0$ and sketch the profile of the potential. What is the reason for the different limits? What is the meaning of the limit $r \to 0$?

c) A particle with a maximum kinetic energy E is oscillating in the potential $U(r)$. What happens for the case $E \to D$ and what does that mean for the molecule described by $U(r)$?

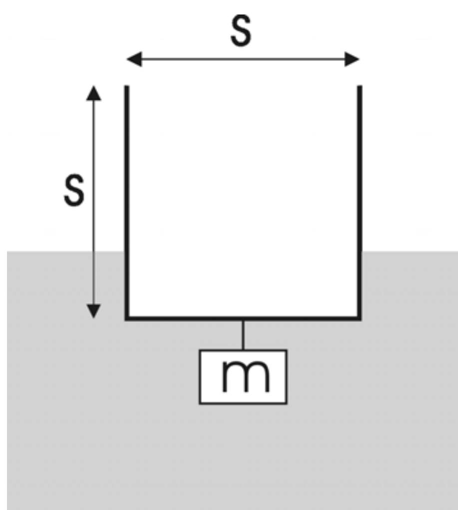
Problem 5: Sinking Ship (8 points)

An idealised ship consists of a cube with very thin walls, which is open at the top. Each side is *1 m* long. To obtain a stable position of the swimming ship a mass $m = 10\ kg$ is fixed to its bottom. The mass of the ship and the buoyant force of the stabilizing mass can be neglected. The water shall be treated as an ideal liquid ($\rho_{water}=1000\ kg/m^3$).

a) How deep does the ship immerse into the water?

b) Now a hole with a diameter of $d = 2$ cm is opened in the bottom wall, allowing water to fill up the ship. How large is the pressure difference at the bottom of the ship that forces the water through the hole? How does this pressure change with time, while the ship fills up?

c) How long does it take until the ship is completely immersed and starts to sink?

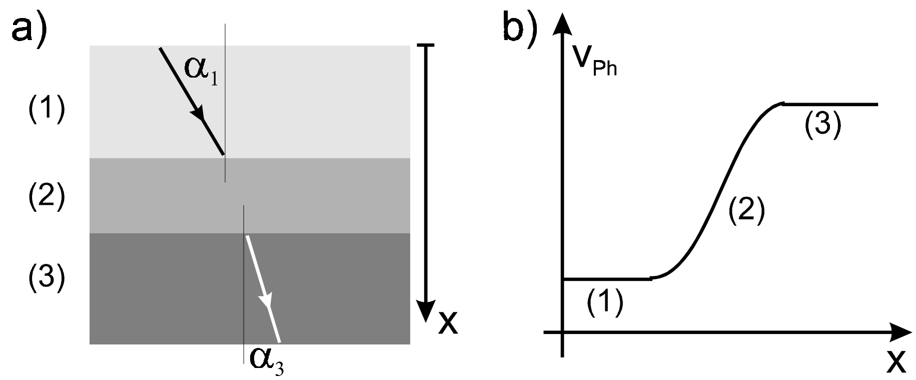


Problem 6: Signal Transmission (4 points)

A signal (e.g. light, acoustic wave) is propagating from medium (1) via medium (2) to medium (3). The propagation direction in medium (1) has the angle α_1 with respect to the surface normal. The phase velocities of the signal in the different media are related to each other like $v_{Ph}(1) < v_{Ph}(2) < v_{Ph}(3)$.

a) How does medium (2) influence the angle of emergence α_3? Give reasons for your answer.

b) What is the value of α_3, if the phase velocity in medium (2) is not constant?



Problem 7: Inverted Yo-yo (8 points)

A yo-yo [c.f. sketch a)] consists of three circular plates with equal densities ρ, equal radii R, but different thicknesses h_1 and h_2, which are chosen in such a way, that the masses of the three parts of the yo-yo are equal. One of the plates is in between the two others, which have rectangular indentations with a side length R.

a) Calculate the moment of inertia of **one** plate with such an indentation depending on M and R.

b) Determine the overall moment of inertia of the yo-yo.

Along its symmetry axis the yo-yo is fixed to (massless) wires (torsion spring) with the directed angle quantity D. The directed angle quantity is the proportionality constant of the moment of rotation and the angle of deflection. The other endings of the wires are mounted to a rack. A massless thread is wrapped around the yo-yo's circumference and to the loose ending an additional mass M is attached.

c) The yo-yo is now deflected around its symmetry axis (the wire is getting twisted) and it starts to oscillate. Formulate the equation of motion for this oscillation.

d) What is the oscillation fequency ω of the attached mass M?