Application number: Name:

Entrance examination – Question sheet (Physics)
Space and Astronautical Science Program,
Graduate Institute for Advanced Studies, SOKENDAI

Question 1

A cylinder of mass m and radius a is placed on a slope of angle β so that the central axis is horizontal and released slowly. Consider the movement of the cylinder setting the downward direction of the slope as the x axis. Answer the following questions, where the gravitational acceleration is g.

(1)-i

When the cylinder slides down the slope without rolling, find the equation of motion in the x axis direction relative to the center of gravity of the cylinder, as well as speed and migration distance of the center of gravity after t seconds.

(1)-ii

When the cylinder slides down the slope without rolling, find the equation representing the rotational motion around the center of gravity of the cylinder, where the rotation angle of the cylinder is θ, moment of inertia around the center axis of the cylinder is I, frictional force between the slope and the side of the cylinder is F. * Not need to solve the equation.

(1)-iii

In which case does the center of gravity move slower, when the cylinder slides down or roll down? Answer the question with the reasons.

(This material is collected after the exam.)

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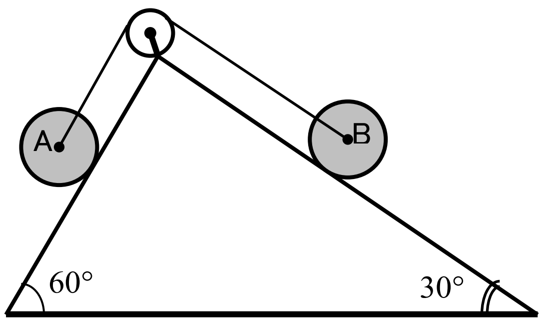
As shown in the following figure, same cylinders A and B are placed on slopes of 60° and 30°, respectively, and their center axes are connected with thread. The cylinders can freely rotate on the slopes without sliding down and the thread is supported by a light pulley without friction. Answer the following questions, where the moment of inertia of the cylinder is $\frac{1}{2}ma^2$ and the moment of inertia of the pulley at the top of the slope is ignorable.



(2)-i

In which direction will the cylinder start to move, left or right? Find how many times greater the acceleration is than the acceleration of gravity.

(2)-ii

Find how many times greater the tension applied to the thread is than the gravity on one cylinder.

(This material is collected after the exam.)

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Question 2

(1) -i

Consider the total electric charge flowing through a circular coil of radius r, number of turns N, and resistance R while a point magnetic charge* m on the center axis of the coil is approaching from the point P_1 at distance of r_1 from the center to the point P_2 at distance of r_2. Fill in the following blanks. You can use Gauss theorem, represented by the following equation, for the magnetic field created by the point magnetic charge m on the surrounding closed surface S. The equation for the flux linkage Φ is: $\Phi = N\phi$, where ϕ is the magnetic flux through the plane of the coil and N is the number of turns.

* Usually, magnets have N and S poles, however, here we consider a sufficiently long magnet and assume that there exists an approximately separated magnetic charge on one of the poles, which we call the point magnetic charge.

$\oint_S H_\nu \cdot dS = \frac{m}{\mu_0}$ (H_ν is a component in the normal ν direction on the dS plane, μ_0 is the magnetic permeability in vacuum)

Let P be a point on the axis and let $\theta_1, \theta, and\, \theta_2$ be angles at P_1, P, and P_2 subtended by the coil radius. The solid angle at the point P subtended by the coil radius is represented by $\Omega = 2\pi\,(1 - cos\theta)$. Therefore, when the magnetic charge m is at the point P, the magnetic flux ϕ through the coil is:

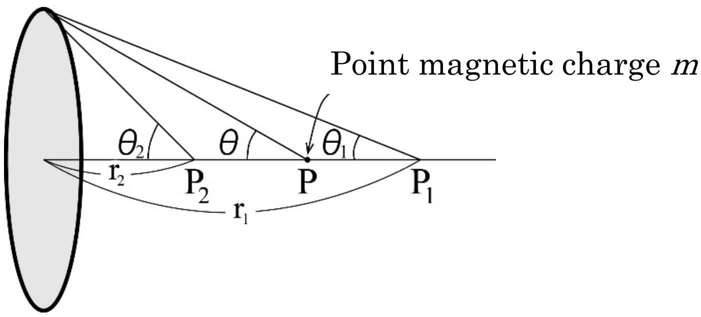

Figure 2-1 Positions of the coil and points

$\phi =$ $\boxed{\text{(a);}}$

and the flux linkage Φ passing through the coil of number of turns N is:

$\Phi =$ $\boxed{\text{(b)}}$

The approach of magnetic charge m causes changes of θ, resulting in electromotive force V represented by:

$V = -\frac{d\Phi}{dt} =$ $\boxed{\text{(c);}}$

current I represented by:

$I = \frac{V}{R} =$ $\boxed{\text{(d);}}$

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and electric charge Q represented by:

$Q =$ (e)

(1) -ii

When the magnetic flux passing through a coil of number of turns N and resistance R changes from ϕ_1 to ϕ_2, show that the current passing through the coil is $N|\phi_2 - \phi_1|/R$.

(1) -iii

There is a circuit with a coil and a resistor R in series, and when a small magnet is placed near the coil, the flux linkage through the coil is Φ_0. Consider the electric charge passing through the circuit while moving the magnet far enough away. Fill in the following blanks.

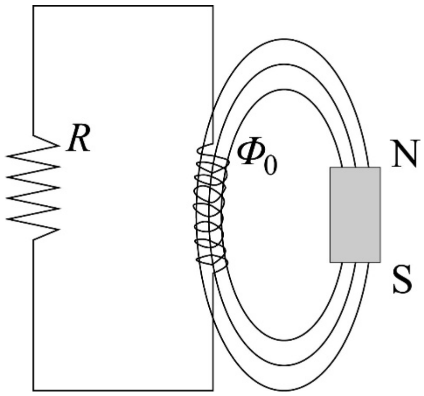

Figure 2-2 Magnetic flux created by the magnet, and the coil

Let the flux linkage while moving the small magnet be Φ. Then, the electromotive force V_1 is:

$V_1 =$ (a);

and the current I is:

$I =$ (b)

The electric charge Q while moving the small magnet far enough away to achieve $\Phi = 0$ can be calculated by integrating the current I:

$Q =$ (c)

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(2) -i

A parallel-plate capacitor is made from dielectric plate with area S, thickness d, and dielectric constant ε having two conducting plates with the same area on each side. Find the forces required to pull the electrode plate apart vertically when the voltage V and electric charge Q are constant, respectively. Assume that the dielectric constant of the space created by the pull-off is equal to the dielectric constant in vacuum. Note that the electrostatic energy U when the capacitor voltage V is constant is represented by $CV^2/2$.

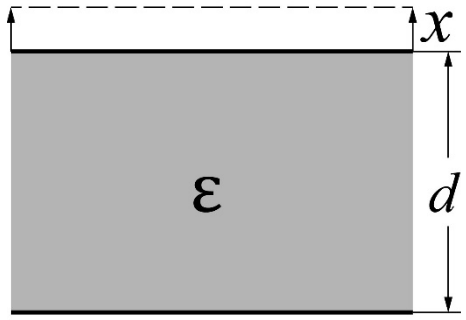

Figure 2-3 Parallel-plate capacitor

(2) -ii

A constant voltage V is applied to a parallel-plate capacitor with plate separation d. When a dielectric plate of the same area as the electrode plate, thickness t, and dielectric constant ε is placed parallel between the electrode plates, how many times greater is the force of attraction between the two electrode plates than that when the plate is not inserted?

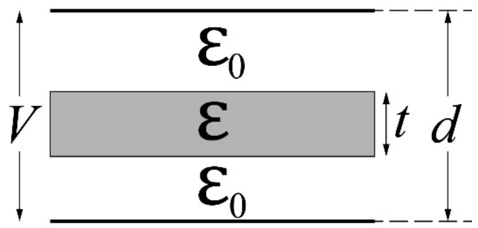

Figure 2-4 Parallel-plate capacitor and voltage V

(2) -iii

Electric charges $\pm Q$ are applied to a parallel-plate capacitor with cross-sectional area S and plate separation d. Find the force acting between the electrode plates when a dielectric pillar of cross-sectional area S' and dielectric constant ε is inserted just between the two electrodes.

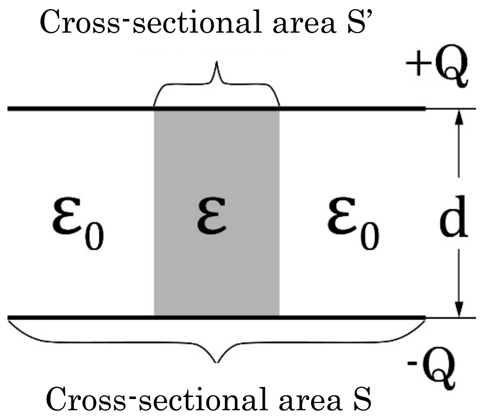

Figure 2-5 Parallel-plate capacitor and electric charge Q