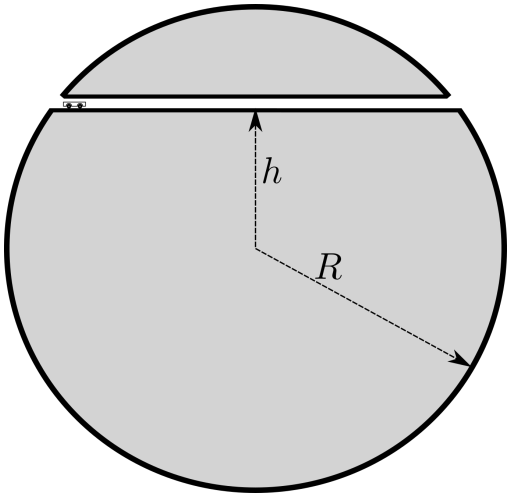
EXAM 1. Friday, July 7, 2017, 2:00-3:35pm

Problem 1. *A Cart in the Earth*

1. A straight narrow shaft is drilled in the Earth as shown in the figure. What time will it take for a cart to travel from one end to another with zero initial velocity? Neglect air resistance, friction, and Earth rotation. Take the Earth to be a uniform sphere. Express your answer through the acceleration of free fall g and Earth radius R and length h.

2. How does this time depend on h?



Problem 2. *Colliding charges*

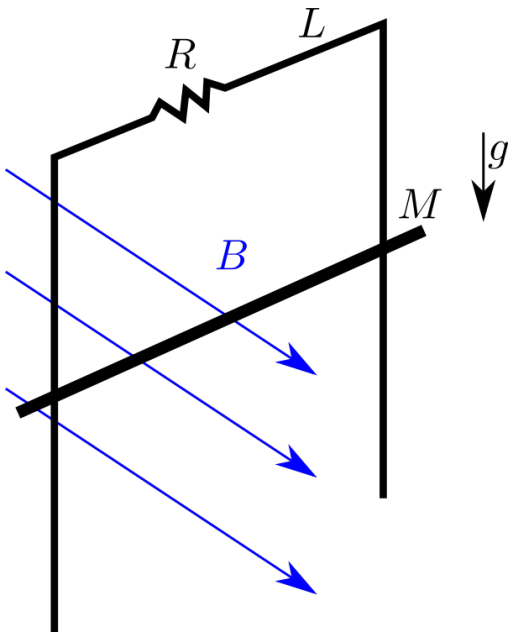
A small ball of charge Q and mass m has a velocity v at infinity. It collides head-on with a ball of the same charge and mass which is initially at rest. What is the minimal distance between the charges during the collision?

Problem 3. *Vertical Rails*

Long enough vertical rails distance L from each other made of an ideal conductor are connected by a resistor R. A bar of mass M, also made of an ideal conductor, can slide along the rails without friction and without loosing electrical contact with the rails. A uniform magnetic field B is horizontal and perpendicular to the plane of the rails. At some point the bar was released with zero initial velocity.

1. Find its velocity after long time.

2. Find the bar's velocity as a function of time (for all times).


L
R
g
M
B

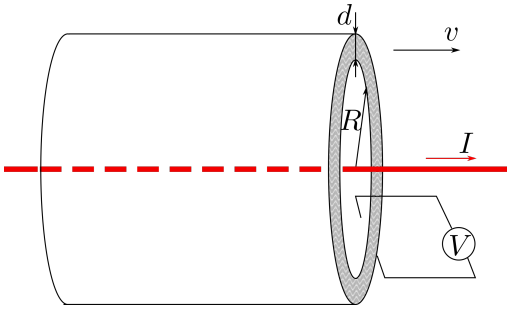
EXAM 2. Final. Tuesday, August 8, 2017, 3:30-5:30pm

Problem 1. *Bullet and Block*
A bullet of mass m and velocity v hits a block of mass M and gets stuck in it. The block is initially at rest on a frictionless table. The spring constant of the spring is k, see figure.

1. What will be the frequency of the oscillations after the bullet is stuck in the block?
2. What will be the amplitude of the oscillations?

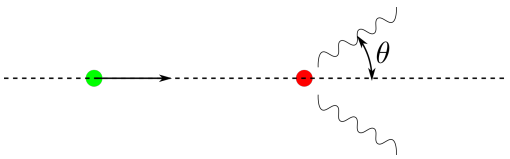
Problem 2. *Wire and Cylinder*
A thin metallic cylinder of radius R and thickness d, such that $d \ll R$ is moving with velocity v along a concentric wire which carries a current I (see figure)

1. What is the magnetic filed produces by the current at the distance R from the wire?
2. What is the potential difference between the inner and outer surfaces of the cylinder?



Problem 3. *Electron-positron annihilation*
An electron (rest mass m_e) of energy E makes a head-on collision with a positron (positron is electron's antiparticle, it has the same mass as electron, but opposite charge) In collision the two particles annihilate each other and are replaces by two photons (γ rays) of equal energy, each traveling at equal angles θ with electron's direction of motion. Find

1. The energy ϵ of each photon.
2. The momentum p of each photon.
3. The angle θ.



Problem 4. *Wave function and expectations*
For a particle in a quantum mechanical state given by a wave function $\psi(x) = Ce^{-|x|/\lambda}$ find.

1. The normalization constant C.
2. The probability to find the particle somewhere in the interval between $-\lambda$ and λ.
3. The average position $\bar{x}$.
4. The standard deviation from the average position $\Delta x = \sqrt{\overline{x^2} - \bar{x}^2}$.