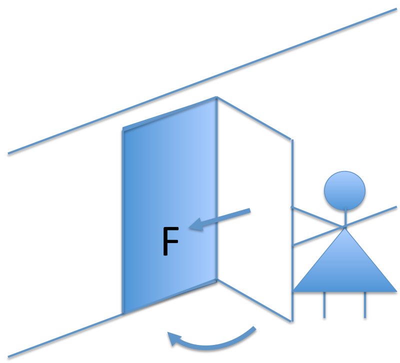
Høsten 2015

FYS100 Fysikk
Obligatorisk Indlevering IV

To be handed in at the latest **Friday 6. November, at 23.59**. You must hand it in by scanning your handwritten solution into a single .pdf file, and uploading it to It's learning in "Indlevering 4". If you have written the solution as a electronic document (and not by hand), convert this to .pdf and upload.

Good luck!

Problem 1 (Family tension)



A door of width $l = 1.00$ m and mass $M = 15.0$ kg is attached to a door frame by two hinges. For this problem, you may ignore gravity, as we are interested in rotational motion around the vertical axis. There is no friction of any kind.

An angry mother-in-law slams the door shut, by pushing at the middle of the door ($l/2$ from the hinges) with a force of $F = 100N$, lasting a time $\Delta t = 0.200$ s. The door is initially not rotating. The door can be taken to be a uniform rod, for the purpose of this exercise.

a) What is the angular acceleration of the door while it is being pushed?

b) What is the resulting angular velocity, angular momentum and rotational kinetic energy from this push?

c) Assuming that she lets go of the door (leaving it to slam shut) at the moment in the motion when the door is perpendicular to the wall, how long does it take for the door to close?

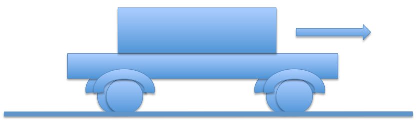
d) What would be the result of a), b), c) and d) if she had pushed not in the middle of the door but at the edge (l from the hinges)?

In addition to the force of the mother-in-law, the hinges also provide force, both radial (centripetal) and tangential force while the mother-in-law pushes (they also compensate for gravity to keep the door upright, but ignore that for now).

e) Combining angular acceleration and linear acceleration considerations, find the tangential force F_h supplied by the hinges as a function of d, the distance between the hinges and the point of application of the mother-in-law force (d was $l/2$ in part a) and b), and l in part c); now use a general d). Don't put in explicit numbers, just find the equation.

f) For which d do the hinges not need to provide any tangential force?

Problem 2 (Drag race; Exam 2014)



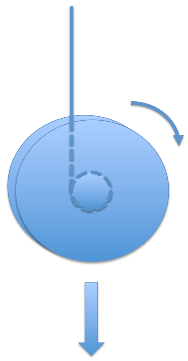
A 4-wheel drive car of mass $M = 2100$ kg accelerates from rest to 100 km/h in 3.40 seconds, and we will assume that the acceleration is constant. In the following, ignore resistance from the air and the rolling friction of the wheels against the surface. The wheels are rolling without sliding, and they have a diameter of $D = 50.0$ cm. Each wheel has a mass of $m = 18.0$ kg, and has a moment of inertia around their centre of mass corresponding to a disc, $I = 1/2\,mR^2$. The mass of the wheels is included in the total 2100 kg. The wheels are taken to be identical and carry the same amount of weight. The gravitational constant is $g = 9.80$ m/s^2.

a) What is the required torque that the engine has to provide for each wheel, to have this acceleration? Provide both the algebraic expression, and the numerical result.

b) What is the required coefficient of static friction between road and wheel, to avoid spinning? Provide both the algebraic expression, and the numerical result.

c) What is the total kinetic energy of the car as it reaches 100 km/h?

Problem 3 (Yo! Yo-Yo!)



A yo-yo roughly speaking consists of two round, uniform discs, sandwiched around a third smaller disc. A string is wound around the middle disc, and so the yo-yo may roll up and down as the string winds and unwinds. Consider such a yo-yo, with the two bigger discs having radius $R = 4.00$ cm and mass $M = 30.0$ g each; and the smaller disc in the middle having radius $r = 0.700$ cm and mass $m = 5.00$ g. The string is taken to be massless, and infinitely thin.

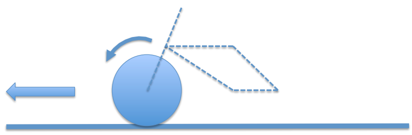
a) What is the total moment of inertia of the yo-yo, around an axis going through the centre of the discs? Indicate both the algebraic expression and a number.

b) The end of the string is now fastened to something at a fixed position (like a finger), and the yo-yo is let drop towards the floor. Identify the forces acting on the yo-yo, and for each, indicate whether they provide torque, work, impulse and/or acceleration to the yo-yo.

c) What is the acceleration of the yo-yo downwards; what is its angular acceleration? How large is the string force?

d) How big a fraction of the total kinetic energy goes into the rotating motion?

Problem 4 (Bicycle wheel)



A guy is riding a bicycle, and we consider the front wheel, which has mass M, radius R and for the purpose of the moment of inertia can be thought of as a uniform disc.

a) When the bike is going with linear speed v, what is the magnitude and direction of the angular momentum of the wheel, around its centre of mass?

b) At some instant, what is the angular momentum of the wheel around the point at which it touches the ground?

c) The bike guy now comes slightly off balance, so that the front wheel is not completely upright, but leans over with an angle θ from vertical. What is the magnitude and direction of the torque from gravity, around the point where the wheel touches the ground?

d) Which the way does the wheel try to turn as a result of this torque?