CP409 Problem Solving Block A – Week 4

It's party time in the problem solving course!

Have you ever wondered why blowing up a party balloon is so easy? Admittedly, it is tough at the start, when you have to get going – this is probably because the polymer strands in the rubber need to be aligned before elastic behaviour sets in. However, for the rest of the inflation, things are much more steady, at least until the limits of the rubber elasticity are reached.

Task A4

(a) We can feel that as we blow up the balloon, the pressure inside it stays more or less constant; this is due to the elastic properties of the rubber sheet. Therefore, when released, the air will exit the balloon at a constant velocity. To test this idea, a round balloon was inflated with the aperture pinched shut between thumb and finger. Then air was let out in bursts by releasing the aperture, and the following data recorded for how the diameter varied with time:

Time (s)	Circumference (cm)
0	72.5
1	65.5
2	57
3	44.5
4	30.5
4-5	Minimum

Estimate the volumetric flowrate of the air leaving the balloon, and thus the average speed of the exiting air (assume the aperture has diameter 1 cm). What is this speed on the Beaufort Scale, and is this reasonable?

(b) Use dimensional analysis to predict the force this exiting air exerts on the balloon. What is the Reynolds number for the flow?

(c) Develop a first order differential equation for the speed of a fully inflated balloon when it is released, assuming it travels in a straight line. Remember to include the varying mass of the balloon, including the air inside it. Assume the mass of the empty balloon is 0.004 kg.

(d) Since the balloon's mass is small, we can simplify the situation and set the acceleration to zero, so that thrust always balances the drag. Under this approximation, how fast will it move as a function of time?

(e) You can repeat your work using your own round or cylindrical balloons. Experiment at your leisure!

For the Friday zoom session:

(f) Plot the speed versus time from part (d) above for the round balloon using MATLAB, and calculate numerically how far it can travel before completely deflating.

(g) Return to the differential equation you derived in part (c) above. Solve this equation numerically using the Euler method, and compare the solution to that of part (d).