Exam 1

1. All questions carry 10 point each.
2. Specifications
   - Please return your answer sheets (preferably hard copies) before midnight of Sunday (Dec 22).
   - Write the logic of the solution such that a smart highschool student can appreciate the flow of the logic.
   - Demonstrate your scholarship – state the physical & mathematical principles that you used clearly and correctly; then clarify how the principles are applicable to your solution.
   - The scoring will be as follows:
     (a) Correct answer = 35% of the maximum possible score
     (b) Logic of the solution clearly formulated = 35%
     (c) Clarity of expression (appropriate use of figures, tables and other means of summarizing information, use of consistent symbols&terminology etc.) = 20%
     (d) Neatness = 10% (legibility of writing; make sure that digital copies are easy to read if you submit in digital format)
     (e) Negative scores – if the answers are too similar among a group of people, all who answered similarly will be given negative scores.

1. A particle moves in a circular path of radius r with a speed v. At the same time, the speed v is increasing at a constant rate a_t (tangential acceleration). Derive:

   a) The expression for the net acceleration a_{net} of the particle at any instant in terms of v, a_t, and r.
   b) The angle ϕ between the net acceleration and the radial direction as a function of v, a_t, and r.

2. Saji is taking his new Ferrari for a drive around the campus. For a picture of his new racing machine, please refer here (`https://ferrariagri.com/en-150/product/mizar-70-ar/`).

   Unfortunately, his rear wheel is stuck in the mud. Oh! It is spinning madly in place. The radius of the wheel being R, the points on the rim move with speed v. Bits of the mud depart from the Ferrari's wheel at various random locations. In particular, some bits become unstuck from the rim in the upper left quadrant, as shown in Fig. 3.11. What should θ be so that the mud reaches the maximum possible height (above the ground) as it flies through the air? What is this maximum height? You may assume $v^2 > gR$.

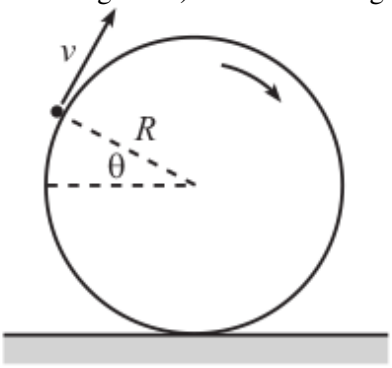

Figure 3.11

3. A ball is dropped from rest at height 4h. After it has fallen a distance d, a second ball is dropped from rest at height h. What should d be (in terms of h) so that the balls hit the ground at the same time?

4. Pi's boat cannot travel at a speed greater than $3m/s$ on still water. He wants to cross two rivers and carry off his favourite tiger to the other bank whilst covering the shortest possible distance. In what direction

should he row with respect to the bank if the speed of the water in the first river is 2m/s? And what direction should he row if the speed of the water in the second river is 4m/s? To finish the calculation before Sunday, let us assume that the speed of the water is the same everywhere in a given river. And how much is the distance travelled by the boat in each of these situations relative to the width of the river?

5. Winnie the Pooh has eaten too much honey and feels very lazy and blessed, and bloated too. On the way home, a large tree trunk has cut off his path to sweet sweet home. Mr. Pooh has no way but to jump over the tree because his claws are badly damaged. Can you help him? Fortunately, for you the tree trunk is a perfect circle in its cross-section with a diameter 20 cm. More fortunately, this tree trunk with its perfectly circular cross section lies in a perfectly horizontal plane across the road. What is the minimum take-off speed that W-T-Pooh needs to jump over this obstacle? And what is his take-off angle and his take-off distance? Let us be kind to ourselves and assume that air-resistance can be left out of the calculation.