Physics I Mid-semestral Examination, 2009, B.Math 1st Yr

Attempt all questions. Each question carries 10 marks. In all numerical problems, the acceleration due to gravity is taken as $g = 9.8 \ \ m/s^2$.

1. A man of mass M wearing frictionless roller skates stands at the origin of the real line and throws an iron shotput ball of mass m from shoulder height ($= h$), with speed u at an angle θ from the horizontal. Assuming that the mass of the skates is negligible, derive an expression for the distance from the man's feet at which the ball lands.

2. A motorcycle engine produces a torque of 12 Nm at its engine crankshaft. In first gear, the gear ratio is 16. (That is, 16 turns of the engine crankshaft produces one turn of the powered rear wheel). The radius of the rear wheel is 0.5 m., and the mass of the motorcycle and rider is 150 kg. Find (a) the maximum acceleration possible in first gear. (b) the maximum slope the motorcycle can climb in first gear.

3. (i): A paratrooper of mass m (including mass of the parachute) falls vertically downward under gravity, and experiences an upward force of air-resistance of magnitude kv, where v is his downward velocity, and k is some constant (depending on air density, size of parachute etc.). Find his velocity $v(t)$ as a function of time t.

   (ii): Prove that, regardless of the altitude the paratrooper has jumped from, $v(t)$ cannot exceed an absolute upper bound $v_\infty = \lim_{t\to\infty} v(t)$ (called the *terminal velocity*). Calculate v_∞ in terms of m, g and k.

4. A car racetrack is in the shape of a circle of radius 1 km. Assuming that the cars will be travelling at a maximum speed of 200 km/hr, find the angle at which the track must be banked (tilted from the horizontal) so that the cars don't fly off the track. (*Hint:* Resolve the normal reaction into vertical and horizontal components. You may leave your answer in the form of an inverse tangent).