PHYS 1131 Test 1, 2005

Question 1 (23 marks)

a) Investigators at the scene of an accident see that a car has left black rubber marks ("skid marks") that are L = 22 m long on a flat section of road. The car is stationary at one end of the marks, and it is assumed that the car began to skid at the other end. The coefficient of kinetic friction between the rubber and the wheels is μ_k = 0.80 and the skid marks show that all four wheels begin to skid simultaneously. Calculate the speed of the car at the beginning of the skid. Express your answer in kilometres per hour.

b) A bird flies at speed v_b = 5.0 m.s^{-1} in a straight line that will pass directly above you, at a height h = 5.0 m above your head. You are eating grapes and it occurs to you that the bird might want one and so you decide to throw it a grape. Of course, you don't want to hurt the bird, so you will throw the grape so that, at some time t, it has the same position, same height and same velocity as the bird. (Hint for 1221: what will be the height and velocity of the grape when the bird takes it?)

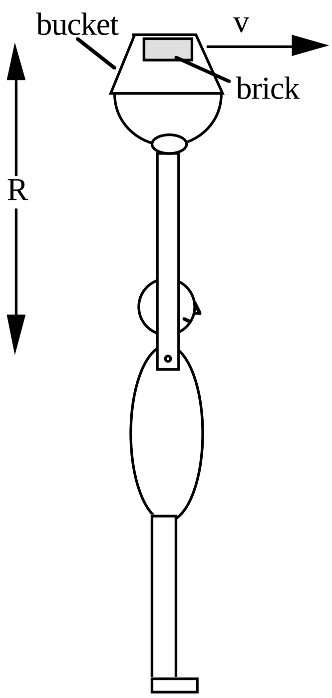
You throw the grape from a position very close to your head, with intial speed v_0 and at an angle θ to the horizontal. Air resistance is assumed to be negligible.

i) Should the bird be behind you, or ahead of you when you throw the grape, and by how much? Explain your answer briefly. (3-5 clear sentences should suffice.)

ii) Calculate the required values of v_t and θ.

iii) If air resistance on the grape were *not* negligible, how would that change your answer to (i)? A qualitative but explicit answer is required.

Question 2 (12 marks)



i) A physics lecturer swings a bucket in a vertical circle, about his shoulder, as shown. It executes circular motion with period T. The bucket contains a brick. Derive an expression for the maximum period T that the motion can have in order that that the brick stay in contact with the bucket. Assume that the motion has constant angular velocity.

ii) Put in appropriate values to give a numerical estimate of the period.

iii) Is the assumption of constant angular velocity reasonable? Comment briefly.

Question 3. (19 marks)

i) Assuming the orbit of the Earth about the sun to be a circle with radius $R = 1.50 \times 10^{11}$ m, calculate the magnitude of the Earth's centripital acceleration. Neglect the motion of the sun.

ii) State the direction of the centripital acceleration in (i).

iii) The constant of Gravitation is $G = 6.67 \times 10^{-11}$ Nm^2kg^{-2}. Use this value and your answer to (i) to determine the mass M of the sun.

iv) The moon has mass m_m 7.36×10^{22} kg. The Earth has mass $m = 5.98 \times 10^{24}$ kg. The sun has a mass $M = 1.99 \times 10^{30}$ kg.

The distance sun-earth = $R = 1.50 \times 10^{11}$ m. The distance earth-moon = $r = 3.82 \times 10^{8}$ m.

At new moon, the moon lies on a line between the Earth and the sun and is at a distance $r = 3.82\ 10^{8}$ m from the Earth. Calculate the total gravitational force on the moon due to the sun and the Earth. (Hint: a diagram may be helpful)

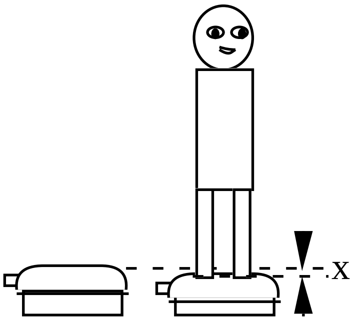
v) State the direction of the force in (iv)

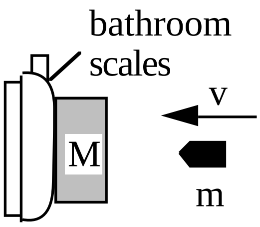
vi) State the magnitude of the acceleration of the moon at new moon, due to the forces exerted by the sun and the earth.

vii) State the direction of the acceleration in (vi).

viii) Compare your answers for (i & ii) and (vi & vii) and comment briefly (about two or three sentences).

Question 4 (13 marks)





Can a bathroom scale (a device usually used for measuring one's weight) be used to measure the speed of a bullet fired from a gun?

A student decides to find out. When she stands on the scale, it accurately reads her mass (60 kg). She observes that, when she stands on the scale, its lid is lowered by 5.0 mm. Assume that the scale behaves like an undamped spring, with spring constant k.

i) Calculate the value of the spring constant k.

(Hint: be careful with units.)

The student then mounts the scale vertically, and fixes a block (M = 10 kg) on its surface. Its mass is considerably greater than that of the scale. In this orientation, and with the block fixed, the scale reads zero. In a preliminary experiment, she discovers that the bulet does not penetrate through the block, and comes to rest inside it.

Her research tells her that a particular model gun fires bullets at a speed of $v = 400\ \mathrm{m.s^{-1}}$ (called its muzzle velocity) and that the bullets have a mass m = 6.0 g.

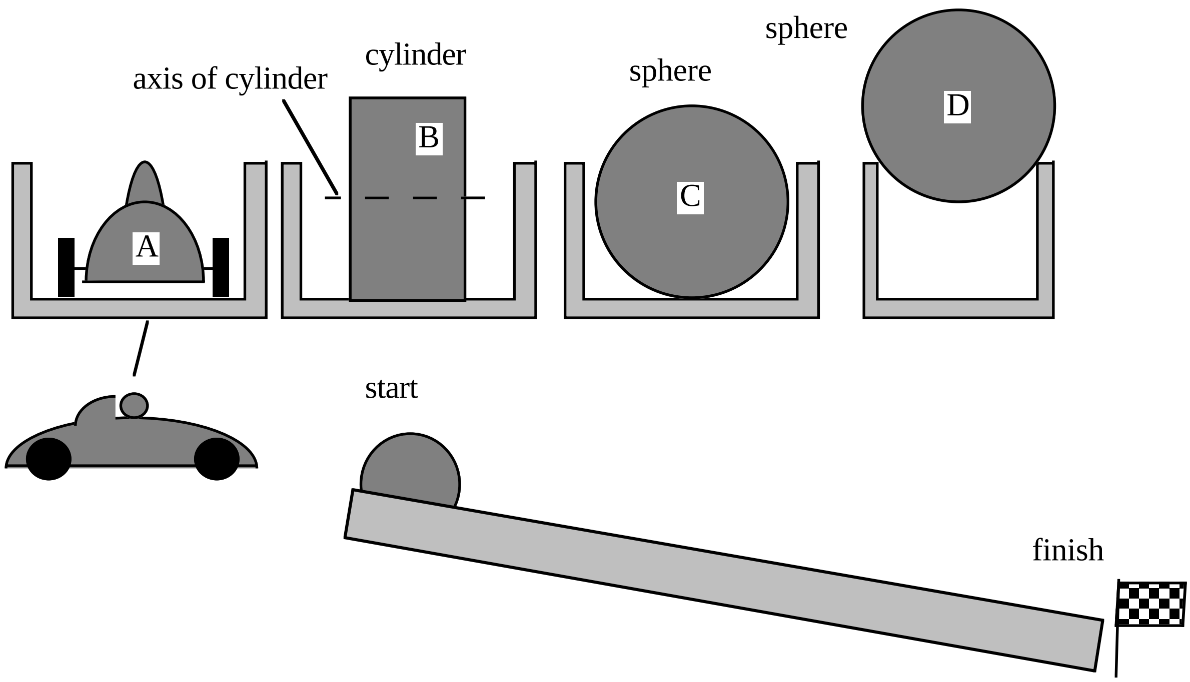
ii) Showing all working, and using the values given, calculate the maximum compression of the scale when a bullet is fired into it at normal incidence (as shown in lower diagram). State any assumptions you make and justify any conservation laws that you use.

iii) Calculate the reading on the scale at this point.

(Under no circumstances should you try to answer this problem experimentally.)

Question 5 (12 marks)

The Australian Grand Prix has been cancelled. You decide to offer an alternative event.



The contestants are two identical brass spheres, a brass cylinder (whose axis is horizontal so it can roll), and a toy racing car. All have the same mass. The wheels of the car are light and they turn with negligible friction on the axle. The objects roll down four tracks, which are shown in cross section in the top sketch. The tracks are straight, but inclined downwards (all at the same angle). One of the tracks is narrower than the sphere (D) on it, as shown. The friction between the track and the objects is sufficiently high that the sphere, cylinder and wheels all roll. Air resistance and other losses are negligible.

They race in pairs, and are released from rest at the same time.

You may use without proof $I_{sphere} = \frac{2}{5} mR^2$ and $I_{cylinder} = \frac{1}{2} mR^2$

i) In the first race, only A and B compete. Which will win? Explain your answer. (You may use equations if you like, but this is not required. A few clear sentences could be enough.)

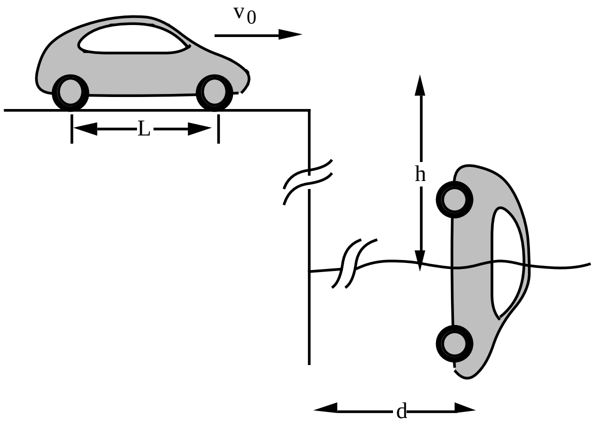
Hint: it may be helpful to state some general principles that will be relevant to all of (i), (ii) and (iii).

ii) In the second race, B and C compete. Which will win? Explain your answer. (Here you probably will need an equation or two, plus some explanation.)

iii) In the third race, C and D compete. Which will win? Explain your answer. (You may use equations if you like, but this is not required. A few clear sentences could be enough.)

Question 6 (21 marks)

A movie special effects team has consulted you with the following problem. A car (containing only crash test dummies and a radio control unit) is to be driven off a cliff. An underwater camera crew at the base of the cliff will film the action and the team wants the car to enter the water vertically, front first, as shown in the diagram. The car has mass m = 1100 kg, a distance between the wheels L = 2.5 m and a radius of gyration 0.80 m. The centre of mass of the car lies half-way between the front and rear wheels. The cliff height h = 30 m. The crew wants to know the speed v_0 should the car leave the horizontal clifftop. Let's help them. You may make the assumption h >> the dimensions of the car, where necessary.



i) If the car is not rotating as it drives along the clifftop, what will make it rotate? Your answer should include a clear diagram showing the relevant forces acting.

ii) For a fast-moving car, if v_0 is increased, does it make the angular velocity ω of the rotations of the `car during the fall greater or less? Explain your answer in about two clear sentences.

iii) Is there more than one value of v_0 that will achieve the vertical entry? If so why? Explain your answer in one or two clear sentences.

iv) How long will the car take to fall into the ocean from the moment when the wheels leave the cliff? (You may assume that the distance fallen before the rear wheels leave the cliff is negligible.)

v) Showing your working, calculate one of the values of v_0 that satisfies the vertical entry requirement. (You may assume that the angle rotated by the car before the rear wheels leave the cliff is negligible.)

vi) Using your answer to (v), comment briefly but quantitatively on the assumptions in (iv) and (v).

There is no need to verify your answer experimentally, and indeed the School of Physics strongly advises against it.