SINGAPORE JUNIOR PHYSICS OLYMPIAD
SPECIAL ROUND SAMPLE QUESTIONS

1. [18 points] A ball is dropped vertically, falls through a height *h* and strikes a ramp that is inclined 45^o to the horizontal. The ball undergoes perfectly elastic collision.

(a) How far down the ramp does the ball land after the first bounce?

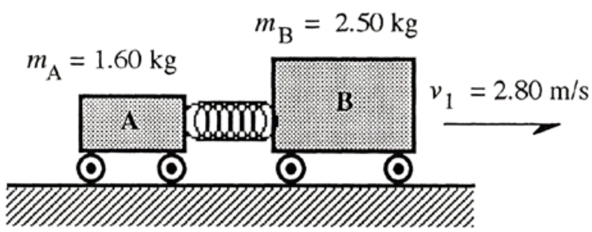
(b) Calculate the time *t* between the first bounce and the second bounce.

(c) Calculate the speed of impact, v_o and the angle θ that the ball makes with the vertical at the second impact.

(d) For the second and third bounces, find the distance the ball travels down the ramp (in term of *h*), the time in the air (in terms of *t*), and the speed at impact (in term of v_o) and the tangent of the angle with the vertical at impact.

(e) Generalize your answers to the *nth* bounce for the quantities in part (e).

2. [10 points] A spring is compressed between two carts and is temporarily clamped so that carts and spring move as a single unit. Initially, the carts move towards the right on a level surface with a velocity of 2.80 m/s. The masses of the carts are 1.60kg and 2.50kg, respectively as shown. The mass of the spring is much smaller than that of either cart and can be neglected. At a certain instant the clamp is suddenly released, and the carts separate, with cart B moving to the right at 3.20m/s.



(a) Calculate the velocity of cart A immediately after decompression of the spring.

(b) As a result of this interaction, do you expect the final total kinetic energy of the system to be equal to, greater than or less than the total initial kinetic energy? Explain your reasoning carefully and check your answer by making the relevant calculations.

(c) Is this event to be described as involving an elastic collision? Explain your reasoning.

3. [8 points] Assume that we have isolated a 1.00-g sample of carbon from a frozen animal and that the atmospheric ratio of the two carbon isotopes (^{14}C:^{12}C) was the same when the animal died as it is now. (half-life of ^{14}C is 5730 yrs; ratio of ^{14}C to ^{12}C in the atmosphere is 1.3×10^{-12} to 1.)

(a) What was the decay rate in decays per minute of the ^{14}C shortly after the animal die?

(b) If the current decay rate is 1 per minute, how many years ago did the animal die?

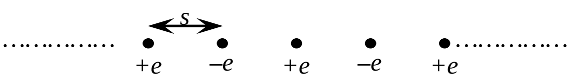
Unfortunately, the ratio of the two isotopes of carbon has not been constant throughout time.

(c) How does the age of the sample change if the ratio is varied linearly in the past? Assume that the ratio decreases by 0.1% of the current value for each century that we go back in time.

4. [8 points]

(a) In Rutherford's famous scattering experiments that led to the planetary model of the atom, alpha particles (masses of $6.64 \times 10^{-27}\,\mathrm{kg}$) were fired toward a gold nucleus with charge $+79e$. An alpha particle, initially very far from the gold nucleus, is fired at $2.00 \times 10^{7}\,\mathrm{m\,s^{-1}}$ directly toward the nucleus. How close does the alpha particle get to the gold nucleus before turning around? For simplicity, assume the gold nucleus has infinite mass.

(b) Consider a one-dimensional infinite string of ions, of charges of magnitude *e* and alternating sign.



Let the distance between the ions be *s*. Calculate the electric potential energy per ion. [*Hint:* $\ln(1+x) = x - \frac{x^2}{2} + \frac{x^3}{3} - \frac{x^4}{4} + \cdots$]

5. [8 points]

A boiler contains 1.00 kg of liquid water at 100^{o}C which needs to be converted to steam at 100° C by boiling at standard atmospheric pressure (1.00 atm or 1.01 × 10^{5} Pa).

The volume of the water changes from an initial value of 1.00×10^{-3} m^3 as a liquid to a volume of 1.671 m^3 as steam. Taking the latent heat of vaporization of water is 2260 kJ kg^{-1},

(a) how much work is done by the system during this process?

(b) how much heat must be added to the system during the process?

(c) determine the change in the internal energy of the system during the boiling process.