Autumn Term, Week 15 Tutorial
Jiachen Jiang

Read the following sections of University Physics and lectures.

Newtonian and Relativistic Collisions in 1D (Elastic and Inelastic)

22: A heavy 'superball' of mass M and a very much lighter 'superball' of mass m are dropped together vertically with the light ball directly above the heavy ball, but not quite in contact. (A superball is a rubber ball which is almost perfectly elastic.) Assuming that $M \gg m$ show that the lighter ball will fly up to almost nine times the height from which it was dropped as follows.

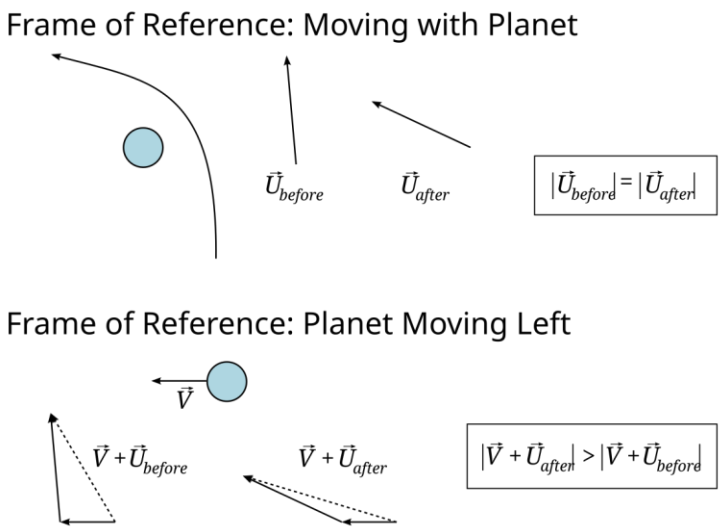
(a) Draw two diagrams showing the two balls, not quite touching each other, in the laboratory frame just before and just after the heavy ball hits the ground. Note that the lighter ball is still moving towards the ground in the second diagram.

(b) Draw two more diagrams, both in the frame of reference moving with the heavy ball (i.e. its 'instantaneous rest frame') after it has hit the ground, just before and just after it collides with the light ball.

(c) Transform back to the laboratory frame and use the law of conservation of energy to find the answer.

This question demonstrates how gravity assist works. Watch the following video for The Gravity Assist.

"A gravity assist, gravity assist maneuver, swing-by, or generally a gravitational slingshot in orbital mechanics, is a type of spaceflight flyby which makes use of the relative movement (e.g. orbit around the Sun) and gravity of a planet or other astronomical object to alter the path and speed of a spacecraft, typically to save propellant and reduce expense."



Q2: The propagation of extremely high energy photons through the Universe is limited by a reaction with the cosmic microwave background radiation in which electron-positron pairs are formed:

$$\gamma_1 + \gamma_2 \rightarrow e^+ + e^- .$$

Assuming for the sake of simplicity that all background photons have a single energy of 10^{-3} eV, calculate the minimum energy ("threshold energy") which a propagating photon must have in order for the above reaction to take place