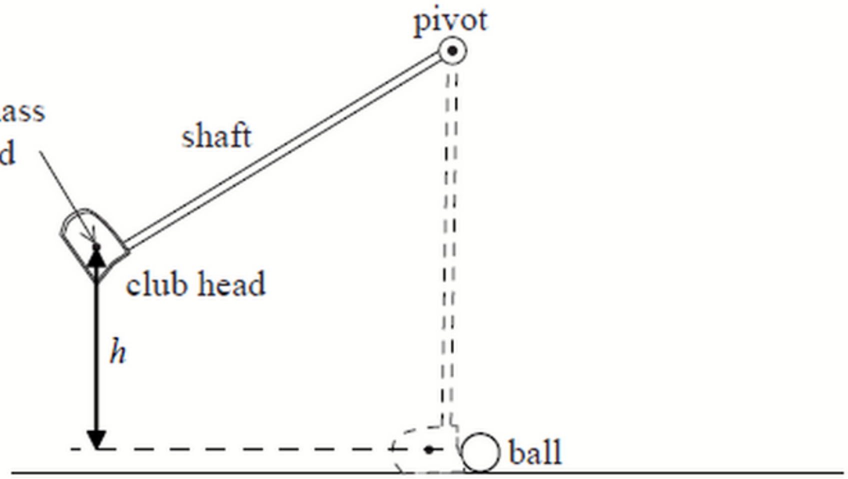
The diagram shows an arrangement used to test golf club heads.



The shaft of a club is pivoted and the centre of mass of the club head is raised by a height h before being released. On reaching the vertical position the club head strikes the ball.

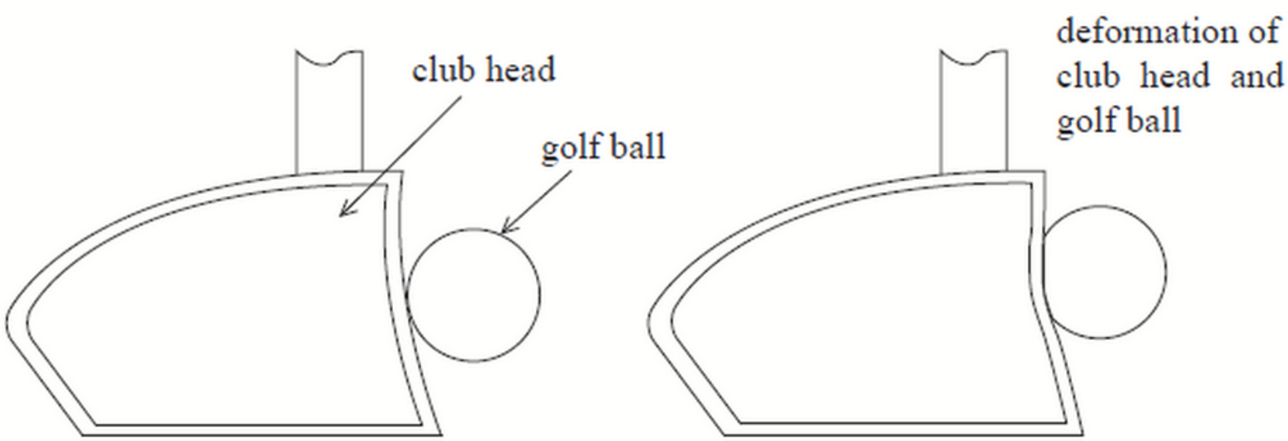
(a) (i) Describe the energy changes that take place in the club head from the instant the club is released until the club head and the ball separate. [2]

Gravitational → kinetic → elastic → sound / heat → kinetic

(ii) Calculate the maximum speed of the club head achievable when $h = 0.85$ m. [2]

$\cancel{m}gy_1 = \frac{1}{2}\cancel{m}v^2$ $v = \sqrt{2(10)(0.85)}$ $= 4.1\ \text{ms}^{-1}$

(b) The diagram shows the deformation of a golf ball and club head as they collide during a test.



Explain how increasing the deformation of the club head may be expected to increase the speed at which the ball leaves the club. [2]

greater deformation / greater time / greater Δp

(c) In a different experimental arrangement, the club head is in contact with the ball for a time of 220 μs. The club head has mass 0.17 kg and the ball has mass 0.045 kg. At the moment of contact the ball is at rest and the club head is moving with a speed of $38\,\mathrm{m\,s^{-1}}$. The ball moves off with an initial speed of $63\,\mathrm{m\,s^{-1}}$.

(i) Calculate the average force acting on the ball while the club head is in contact with the ball. [2]

$F = \Delta p / t = \dfrac{(63)(0.045) - 0}{220 \times 10^{-6}}$

$\simeq 13\,000$ N

(ii) State the average force acting on the club head while it is in contact with the ball. [1]

$\simeq -13\,000$ N

(iii) Calculate the speed of the club head at the instant that it loses contact with the ball. [2]

$\Delta p_{ball} = -\Delta p_{club}$

$-2.84 = p_f - (63)(0.17)$

$p_f = 7.9\ \mathrm{kg\,m\,s^{-1}}$

$\therefore v_f = 7.9 / 0.17 = 46\ \mathrm{m\,s^{-1}}$

Jane and Joe are two ice skaters initially at rest on a horizontal skating rink. They are facing each other and Jane is holding a ball. Jane throws the ball to Joe who catches it. The speed at which the ball leaves Jane, measured relative to the ground, is $8.0\,\mathrm{m\,s^{-1}}$. The following data are available.

Mass of Jane = 52 kg
Mass of Joe = 74 kg
Mass of ball = 1.3 kg

Use the data to calculate the

(i) speed v of Jane relative to the ground immediately after she throws the ball. [2]

$0 = P_{ball} + P_{Jane}$ $\quad 0 = (1.3)(8) + (52)v$

$v = 0.2\,\mathrm{ms^{-1}}$

(ii) speed V of Joe relative to the ground immediately after he catches the ball. [2]

$(8)(1.3) = (1.3 + 74)v$

$v = 0.14\,\mathrm{ms^{-1}}$

(e) Jane and Joe are initially separated by 4.0 m. The average frictional force between their skates and the ice is 0.12 N. Show that the separation of Jane and Joe after the ball is thrown and they are at rest again is about 20 m. [5]

$W_{Jane} = F \cdot \vec{s}$

$\frac{1}{2}(52)(0.2)^2 = (0.12) \cdot \vec{s}$

$s = 8.67\,\mathrm{m}$

$W_{joe} = F\vec{s}$

$\frac{1}{2}(74)(0.14)^2 = (0.12)\,\vec{s}$

$S_{joe} = 6\,m.$

$\therefore \; Net = 6 + 8.67 + 4$

$\simeq \underline{19\,m}$