Solution

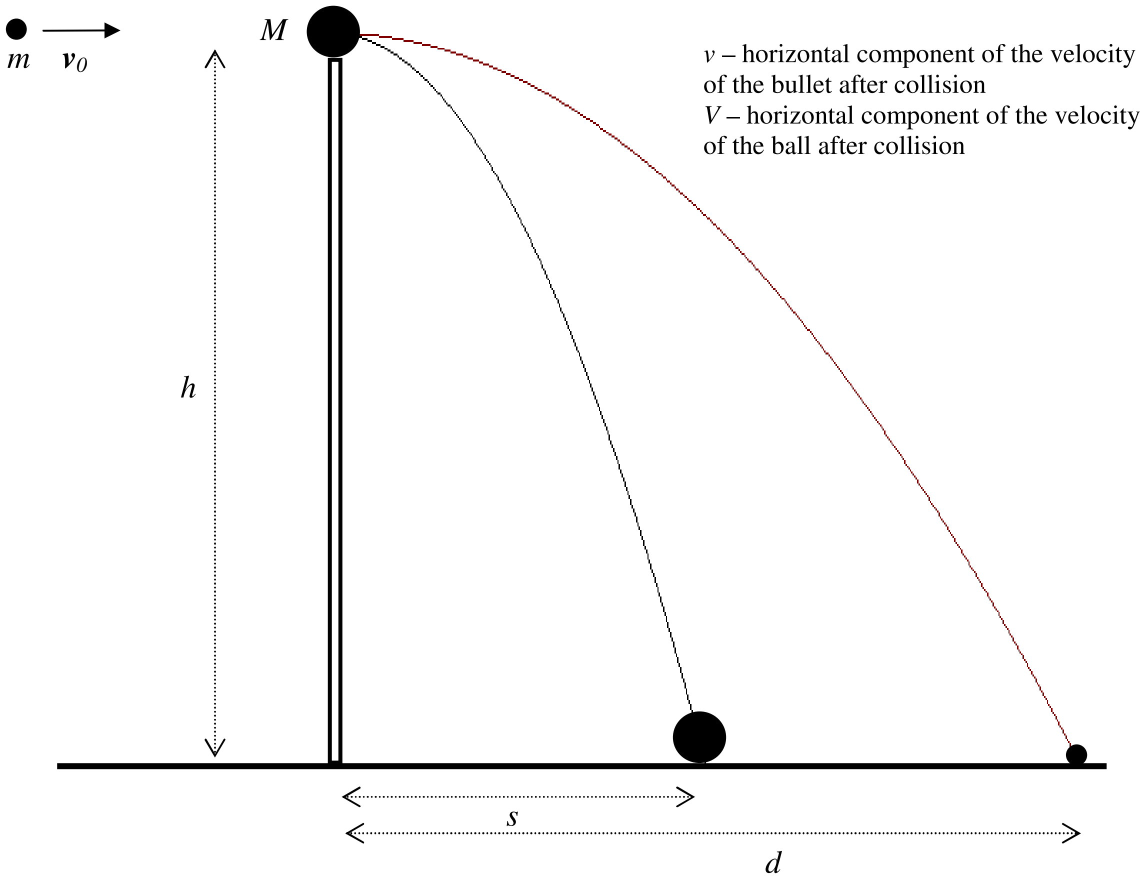

Fig. 2

We will use notation shown in Fig. 2.

As no horizontal force acts on the system ball + bullet, the horizontal component of momentum of this system before collision and after collision must be the same:

$$mv_0 = mv + MV.$$

So,

$$v = v_0 - \frac{M}{m}V .$$

From conditions described in the text of the problem it follows that

$$v > V.$$

After collision both the ball and the bullet continue a free motion in the gravitational field with initial horizontal velocities v and V, respectively. Motion of the ball and motion of the bullet are continued for the same time:

$$t = \sqrt{\frac{2h}{g}}.$$

It is time of free fall from height h.

The distances passed by the ball and bullet during time t are:

$$s = Vt \quad \text{and} \quad d = vt\,,$$

respectively. Thus

$$V = s\sqrt{\frac{g}{2h}}.$$

Therefore

$$v = v_0 - \frac{M}{m} s\sqrt{\frac{g}{2h}}\,.$$

Finally:

$$d = v_0\sqrt{\frac{2h}{g}} - \frac{M}{m} s\,.$$

Numerically:

$$d = 100 \text{ m}.$$

The total kinetic energy of the system was equal to the initial kinetic energy of the bullet:

$$E_0 = \frac{mv_0^2}{2}\,.$$

Immediately after the collision the total kinetic energy of the system is equal to the sum of the kinetic energy of the bullet and the ball:

$$E_m = \frac{mv^2}{2}, \qquad E_M = \frac{MV^2}{2}\,.$$

Their difference, converted into heat, was

$$\Delta E = E_0 - (E_m + E_M)\,.$$

It is the following part of the initial kinetic energy of the bullet:

$$p = \frac{\Delta E}{E_0} = 1 - \frac{E_m + E_M}{E_0}.$$

By using expressions for energies and velocities (quoted earlier) we get

$$p = \frac{M}{m}\frac{s^2}{v_0^2}\frac{g}{2h}\left(2\frac{v_0}{s}\sqrt{\frac{2h}{g}} - \frac{M+m}{m}\right).$$

Numerically:

$$p = 92{,}8\%.$$