Elastic Collisions 4.6

A Level

C C C

In space, an elastic 'sling shot' collision is arranged between a $6.4 \times 10^{24}\,\mathrm{kg}$ planet moving at $9.0\,\mathrm{km\,s^{-1}}$ towards a $6000\,\mathrm{kg}$ spacecraft which is also moving at $4.5\,\mathrm{km\,s^{-1}}$ towards the planet.

Calculate the final speed of the spacecraft.

Elastic Collisions 4.7

A Level

P P P

A neutron (of mass m) travelling at $2.4 \times 10^5 \, \mathrm{m \, s^{-1}}$ collides elastically with a stationary carbon nucleus (mass $M = 12m$). Calculate,

Part A The final speed of the nucleus

Calculate the final speed of the carbon nucleus.

Part B The percentage of the KE given to the nucleus

Calculate the percentage of the neutron's kinetic energy which is given to the nucleus.

Elastic Collisions 4.5

A Level

C C C

In space, an elastic 'sling shot' collision is arranged between a stationary $6.4 \times 10^{24}\,\mathrm{kg}$ planet and a $6000\,\mathrm{kg}$ spacecraft moving at $4.5\,\mathrm{km\,s^{-1}}$. By looking at the pattern in your answers to question 4.4 (parts J, M, L, O) estimate

Part A The kinetic energy gained by the planet

Estimate the kinetic energy gained by the planet.

Part B The final speed of the spacecraft

Estimate the final speed of the spacecraft.

Elastic Collisions 4.4

A Level

Quantities:

p, P momentum ($\mathrm{kg\,m\,s^{-1}}$)
v, V velocity ($\mathrm{m\,s^{-1}}$)
k, K kinetic energy (J)
m, M mass (kg)

Equations:

$$p = mv \qquad k = \frac{1}{2}mv^2 \qquad P = MV \qquad K = \frac{1}{2}MV^2$$

$$p_0 + P_0 = p1 + P1 \qquad k_0 + K_0 = k_1 + K_1$$

Fill in the missing entries in the table below (for collisions as in the notes page). For these collisions $v_0 \neq v_1$.

m	M	v_0	V_0	v_1	V_1	$K+k$	$K_1 - K_0$
$/\mathrm{kg}$	$/\mathrm{kg}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{J}$	$/\mathrm{J}$
1.0	3.0	3.0	0.0	−1.5	(a)	(b)	(c)
0.050	0.050	1.5	0.0	0.0	(d)	(e)	(f)
2.0	3.0	3.0	(g)	(h)	(i)	15	0.0
0.010	0.99	50	0.0	(j)	1.0	(k)	(l)
0.010	9.99	50	0.0	(m)	0.10	(n)	(o)

Part A Final velocity V_1 (a)

m	M	v_0	V_0	v_1	V_1	$K+k$	$K_1 - K_0$
$/\mathrm{kg}$	$/\mathrm{kg}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{J}$	$/\mathrm{J}$
1.0	3.0	3.0	0.0	−1.5	(a)	(b)	(c)

Find the final velocity V_1 (a).

Part B Total kinetic energy $K + k$ (b)

m	M	v_0	V_0	v_1	V_1	$K + k$	$K_1 - K_0$
$/\mathrm{kg}$	$/\mathrm{kg}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{J}$	$/\mathrm{J}$
1.0	3.0	3.0	0.0	-1.5	(a)	(b)	(c)

Find the total kinetic energy $K + k$ (b).

Part C Kinetic energy change $K_1 - K_0$ (c)

m	M	v_0	V_0	v_1	V_1	$K + k$	$K_1 - K_0$
$/\mathrm{kg}$	$/\mathrm{kg}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{J}$	$/\mathrm{J}$
1.0	3.0	3.0	0.0	-1.5	(a)	(b)	(c)

Find the kinetic energy change of one mass $K_1 - K_0$ (c).

Part D Final velocity V_1 (d)

m	M	v_0	V_0	v_1	V_1	$K + k$	$K_1 - K_0$
$/\mathrm{kg}$	$/\mathrm{kg}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{J}$	$/\mathrm{J}$
0.050	0.050	1.5	0.0	0.0	(d)	(e)	(f)

Find the final velocity V_1 (d).

Part E Total kinetic energy $K + k$ (e)

m	M	v_0	V_0	v_1	V_1	$K + k$	$K_1 - K_0$
$/\mathrm{kg}$	$/\mathrm{kg}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{J}$	$/\mathrm{J}$
0.050	0.050	1.5	0.0	0.0	(d)	(e)	(f)

Find the total kinetic energy $K + k$ (e).

Part F Kinetic energy change $K_1 - K_0$ (f)

m	M	v_0	V_0	v_1	V_1	$K + k$	$K_1 - K_0$
$/\mathrm{kg}$	$/\mathrm{kg}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{J}$	$/\mathrm{J}$
0.050	0.050	1.5	0.0	0.0	(d)	(e)	(f)

Find the kinetic energy change of one mass $K_1 - K_0$ (f).

Part G Starting velocity V_0 (g)

m	M	v_0	V_0	v_1	V_1	$K + k$	$K_1 - K_0$
$/\mathrm{kg}$	$/\mathrm{kg}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{J}$	$/\mathrm{J}$
2.0	3.0	3.0	(g)	(h)	(i)	15	0.0

Find the starting velocity V_0 (g).

Part H Final velocity v_1 (h)

m	M	v_0	V_0	v_1	V_1	$K+k$	K_1-K_0
$/\mathrm{kg}$	$/\mathrm{kg}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{J}$	$/\mathrm{J}$
2.0	3.0	3.0	(g)	(h)	(i)	15	0.0

Find the final velocity v_1 (h).

Part I Final velocity V_1 (i)

m	M	v_0	V_0	v_1	V_1	$K+k$	K_1-K_0
$/\mathrm{kg}$	$/\mathrm{kg}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{J}$	$/\mathrm{J}$
2.0	3.0	3.0	(g)	(h)	(i)	15	0.0

Find the final velocity V_1 (i).

Part J Final velocity v_1 (j)

m	M	v_0	V_0	v_1	V_1	$K+k$	K_1-K_0
$/\mathrm{kg}$	$/\mathrm{kg}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{J}$	$/\mathrm{J}$
0.010	0.99	50	0.0	(j)	1.0	(k)	(l)

Find the final velocity v_1 (j).

Part K Total kinetic energy $K+k$ (k)

m	M	v_0	V_0	v_1	V_1	$K+k$	K_1-K_0
$/\mathrm{kg}$	$/\mathrm{kg}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{J}$	$/\mathrm{J}$
0.010	0.99	50	0.0	(j)	1.0	(k)	(l)

Find the total kinetic energy $K+k$ (k).

Part L Kinetic energy change K_1-K_0 (l)

m	M	v_0	V_0	v_1	V_1	$K+k$	K_1-K_0
$/\mathrm{kg}$	$/\mathrm{kg}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{J}$	$/\mathrm{J}$
0.010	0.99	50	0.0	(j)	1.0	(k)	(l)

Find the kinetic energy change of one mass K_1-K_0 (l).

Part M Final velocity v_1 (m)

m	M	v_0	V_0	v_1	V_1	$K+k$	K_1-K_0
$/\mathrm{kg}$	$/\mathrm{kg}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{J}$	$/\mathrm{J}$
0.010	9.99	50	0.0	(m)	0.10	(n)	(o)

Find the final velocity v_1 (m).

Part N Total kinetic energy $K + k$ (n)

m	M	v_0	V_0	v_1	V_1	$K+k$	$K_1 - K_0$
$/\mathrm{kg}$	$/\mathrm{kg}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{J}$	$/\mathrm{J}$
0.010	9.99	50	0.0	(m)	0.10	(n)	(o)

Find the total kinetic energy $K + k$ (n).

Part O Kinetic energy change $K_1 - K_0$ (o)

m	M	v_0	V_0	v_1	V_1	$K+k$	$K_1 - K_0$
$/\mathrm{kg}$	$/\mathrm{kg}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{m\,s^{-1}}$	$/\mathrm{J}$	$/\mathrm{J}$
0.010	9.99	50	0.0	(m)	0.10	(n)	(o)

Find the kinetic energy change of one mass $K_1 - K_0$ (o).

Elastic Collisions 4.1

A Level

P P P

Quantities:

p, P momentum $(\mathrm{kg\,m\,s^{-1}})$
v, V velocity $(\mathrm{m\,s^{-1}})$
k, K kinetic energy (J)
m, M mass (kg)

Equations:

$$p = mv \qquad k = \frac{1}{2}mv^2 \qquad P = MV \qquad K = \frac{1}{2}MV^2$$

$$p_0 + P_0 = p1 + P1 \qquad k_0 + K_0 = k_1 + K_1$$

Use the equations above to derive expressions for:

Part A Final velocity V_1 of M

the final velocity V_1 of M if M was stationary at the beginning and the initial and final velocities of m (v_0 and v_1) are known.

The following symbols may be useful: `M, V_0, V_1, m, v_1`

Part B Final velocity V_1 of M

V_1 if the masses are equal $(M = m)$, M begins at rest $(V_0 = 0)$, m is stopped by the collision $(v_1 = 0)$ and v_0 is known.

The following symbols may be useful: `M, V_0, V_1, m, v_1`

Part C $k + K$ in terms of $p + P$

(*very involved*) $k + K$ in terms of $p + P$, M, m and the relative velocity $r = v - V$, where the quantities are all before **or** all after the collision. (See Hint 2 below)

The following symbols may be useful: `K, M, P, k, m, p, r`

Relative Motion 5.4

A Level

The tortoise and Achilles decide to participate in a jousting competition, whereupon the two charge at each other as fast as they can. They are initially stood $50.0\,\mathrm{m}$ apart from each other. The tortoise charges towards Achilles at $5.00\,\mathrm{m\,s^{-1}}$, and Achilles charges towards the tortoise at $15.0\,\mathrm{m\,s^{-1}}$. Calculate

Part A The time taken before they collide

Calculate the time taken before they collide.

Part B How far Achilles has travelled when they collide

Calculate how far Achilles has travelled when they collide.

Essential Pre-Uni Physics F2.5

GCSE A Level

A rocket (containing a space probe) is travelling at $7000\,\mathrm{m\,s^{-1}}$ in outer space. The $2000\,\mathrm{kg}$ probe is ejected from the front of the rocket (forwards) using a big spring. If the speed of the probe afterwards is $7200\,\mathrm{m\,s^{-1}}$, and the rest of the rocket has a mass of $6000\,\mathrm{kg}$, what is the speed of the rest of the rocket? Give your answer to 4 significant figures.

Physics. You work it out.

Relative Motion 5.3

A Level

Following on from Example 1, when the tortoise travelling at $18.0\,\mathrm{m\,s^{-1}}$ is $1.00\,\mathrm{km}$ away from Achilles, Achilles gets into a motor vehicle that can travel at $96.5\,\mathrm{km\,h^{-1}}$. Calculate how far ahead of the tortoise Achilles is after $2\,\mathrm{minutes}$.

Physics. You work it out.

Home Physics Mechanics Kinematics Relative Motion 5.1

Relative Motion 5.1

A Level
P P P

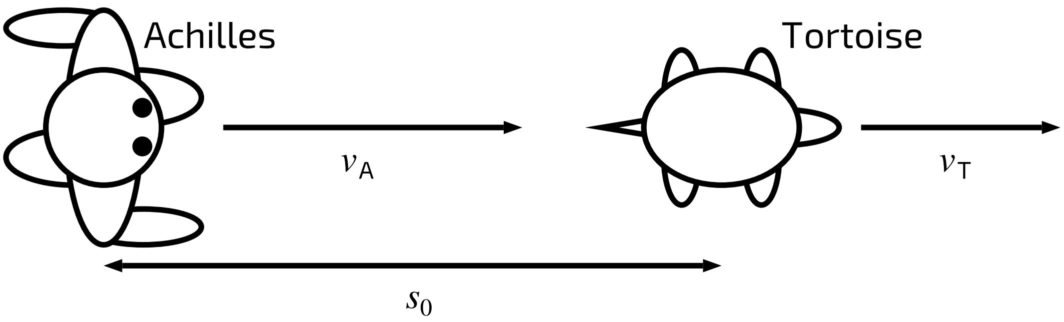

Figure 1: Achilles chasing the tortoise.

Quantities:

v_{A} velocity of Achilles $(\mathrm{m\,s^{-1}})$
v_{T} velocity of tortoise $(\mathrm{m\,s^{-1}})$
T time for Achilles to catch up (s)

s_0 initial displacement (m)
s displacement (m)
t time since start (s)

Equations:

$$v = \frac{s}{t}$$

Use the equations above to derive expressions for:

Part A The velocity of Achilles relative to the tortoise

the velocity of Achilles relative to the tortoise v_{REL}.

The following symbols may be useful: `T, s, s_0, t, v_A, v_REL, v_T`

Part B The time for Achilles to catch up

the time for Achilles to catch up with the tortoise T, in terms of v_{A} and v_{T}.

The following symbols may be useful: `T, s, s_0, t, v_A, v_REL, v_T`

Part C The displacement of the tortoise relative to Achilles

the displacement of the tortoise relative to Achilles as a function of time s.

The following symbols may be useful: `T, s, s_0, t, v_A, v_REL, v_T`

Elastic Collisions 4.8

A Level

A neutron (of mass m) travelling at $2.4 \times 10^5\,\mathrm{m\,s^{-1}}$ collides elastically with a stationary iron nucleus (mass $M = 65m$). Calculate,

Part A The final speed of the nucleus

Calculate the final speed of the iron nucleus.

Part B The percentage of the energy given to the nucleus

Calculate the percentage of the neutron's kinetic energy which is given to the nucleus.