Past-paper walk-through

Momentum ▪ 4.3

eXercise

Questions in this set

- 9709/41 N25 Q2 ▪ 5 marks
- 9709/41 N25 Q6 ▪ 6 marks
- 9709/42 N25 Q4 ▪ 9 marks
- 9709/41 J25 Q5 ▪ 7 marks

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 2

9709/41 N25 ▪ Q2 ▪ 5 marks

Two particles, P and Q, of masses 3 kg and 5 kg respectively, are at rest on a smooth horizontal plane. P is projected at a speed of 4 m s^{-1} directly towards Q. After P and Q collide, P has speed 1 m s^{-1}.

(a) Find the two possible speeds of Q after the collision. **[3]**

(b) It is given that λ J of kinetic energy, where $\lambda > 0$, is lost during the collision. Find the value of λ. **[2]**

Solution 2

(a)

Mark scheme

- Momentum: $3(4) = 3v_P + 5v_Q$. With $v_P = +1$: $v_Q = 1.8$ m s^{-1}; with $v_P = -1$: $v_Q = 3$ m s^{-1}.

Solution 2

(b)

Mark scheme

- Only $v_P = +1$, $v_Q = 1.8$ loses KE:
  $\lambda = \frac{1}{2}(3)(4^2) - \left[\frac{1}{2}(3)(1^2) + \frac{1}{2}(5)(1.8^2)\right] = 24 - 9.6 = 14.4$ J.

Question 6

9709/41 N25 ▪ Q6 ▪ 6 marks

A particle A of mass 2.5 kg is released from rest from the top of a smooth plane inclined at $\sin^{-1} 0.2$ to the horizontal. A collides 2 seconds later with a particle B, of mass 3 kg, moving up a line of greatest slope of the plane. The speed of B immediately before the collision is 3.5 m s^{-1}. Immediately after the collision, B has a velocity of 0.5 m s^{-1} down the plane. Find the distance A moves up the plane after the collision. **[6]**

Solution 6

Mark scheme

- Down the smooth plane $a = g\sin\theta = 2$, so A reaches the collision at 4 m s^{-1}. Momentum (down $+$): $2.5(4) + 3(-3.5) = 2.5v_A + 3(0.5) \Rightarrow v_A = -0.8$ (up). Then $0 = 0.8^2 - 2(2)s \Rightarrow s = 0.16$ m.

Question 4

9709/42 N25 ▪ Q4 ▪ 9 marks

A particle P of mass 0.1 kg is projected vertically upwards with speed 30 m s^{-1} from horizontal ground. At the same instant a particle Q of mass 0.4 kg is projected vertically upwards with speed 10 m s^{-1} from a height of 15 m above the ground. P and Q move in the same vertical line.

(a) Find the height above the ground at which P and Q collide. **[4]**

(b) When P and Q collide, they coalesce. Find the speed of the combined particle at the instant that it reaches the ground. **[5]**

Solution 4

(a) Worked steps

Write a **displacement equation for each particle from the ground**, then set them equal.

- P from the ground: $s_P = 30t - 5t^2$
- Q from 15 m up: $s_Q = 15 + 10t - 5t^2$

They collide when $s_P = s_Q$:

- $30t - 5t^2 = 15 + 10t - 5t^2$
- The t^2 terms **cancel** — both particles are in the same gravitational field — leaving $20t = 15$, so $t = 0.75$ s.
- Height: $s_P = 30(0.75) - 5(0.75)^2 = 22.5 - 2.8125 = \mathbf{19.7}$ m

Solution 4

Measuring **both** displacements from the same origin is what makes this a one-line cancellation. Taking Q's displacement from its own starting point leaves the 15 m out and gives the wrong time.

Mark scheme

- $30t - 5t^2 = 15 + 10t - 5t^2 \Rightarrow t = 0.75$ s. Height $= 30(0.75) - 5(0.75)^2 = 19.7$ m.

Solution 4

(b) Worked steps

Three stages, and each needs its own principle.

1. Velocities just before impact — use $v = u - gt$ for each:

- $v_P = 30 - 10(0.75) = 22.5 \text{ m s}^{-1}$ (upward)
- $v_Q = 10 - 10(0.75) = 2.5 \text{ m s}^{-1}$ (upward)

2. Conservation of momentum at the coalescence — they stick together, so one combined mass:

- $0.1(22.5) + 0.4(2.5) = (0.1 + 0.4)v$
- $2.25 + 1.0 = 0.5v$, so $v = 6.5 \text{ m s}^{-1}$ upward.

Solution 4

3. The fall to the ground — $v^2 = u^2 + 2as$, taking downward as positive after the combined particle has risen and returned:

- $v^2 = 6.5^2 + 2(10)(19.6875) = 42.25 + 393.75 = 436$
- $v = \mathbf{20.9}\ \mathrm{m\,s^{-1}}$

Solution 4

Two things to be deliberate about. **Both velocities are upward** at the collision, so the momenta **add** — a sign error here is the commonest way to lose the second stage. And the $v^2 = u^2 + 2as$ step needs no separate treatment of the rise and fall: the particle returns to the collision height with the same speed, so starting the fall from there with $u = 6.5$ upward is equivalent and much shorter.

Mark scheme

- At collision $v_P = 22.5$, $v_Q = 2.5$ (both upward). Momentum: $0.1(22.5) + 0.4(2.5) = 0.5v \Rightarrow v = 6.5$ m s^{-1} up. Falling from 19.6875 m: $v^2 = 6.5^2 + 2(10)(19.6875) = 436 \Rightarrow v = 20.9$ m s^{-1}.

Question 5

9709/41 J25 ▪ Q5 ▪ 7 marks

When a particle P of mass m kg has speed u m s^{-1}, its momentum is 4 N s and its kinetic energy is 16 J.

(a) Find the value of m and the value of u. **[3]**

(b) P is now projected on a smooth horizontal surface with speed v m s^{-1} directly towards a particle Q of mass 1.25 kg which is stationary. After P and Q collide, the velocity of P is w m s^{-1} and the velocity of Q is $2w$ m s^{-1}. The loss of kinetic energy in the collision is 25 J. Find the value of v and the value of w. **[4]**

Solution 5

(a)

Mark scheme

- $mu = 4$ and $\frac{1}{2}mu^2 = 16 \Rightarrow u = 8,\ m = 0.5.$

Solution 5

(b)

Mark scheme

- Momentum: $0.5v = 0.5w + 1.25(2w) \Rightarrow v = 6w$. KE loss: $\frac{1}{2}(0.5)v^2 - \left(\frac{1}{2}(0.5)w^2 + \frac{1}{2}(1.25)(2w)^2\right) = 25 \Rightarrow 6.25w^2 = 25 \Rightarrow w = 2$, $v = 12$.