Past-paper walk-through

Energy, work and power ▪ 4.5

eXercise

Questions in this set

- 9709/41 N25 Q1 ▪ 4 marks
- 9709/41 N25 Q4 ▪ 6 marks
- 9709/42 N25 Q3 ▪ 8 marks
- 9709/41 J25 Q4 ▪ 6 marks
- 9709/41 J25 Q6 ▪ 9 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 1

9709/41 N25 ▪ Q1 ▪ 4 marks

A car of mass 900 kg is moving along a straight horizontal road against a constant resistance to motion of 350 N. At an instant when the car is moving at 15 m s^{-1} its acceleration is 0.25 m s^{-2}.

(a) Find the driving force of the car's engine at this instant. **[2]**

(b) Find the power of the car's engine at this instant. **[2]**

Solution 1

(a)

Mark scheme

- $F - 350 = 900(0.25) = 225 \Rightarrow F = 575$ N.

Solution 1

(b)

Mark scheme

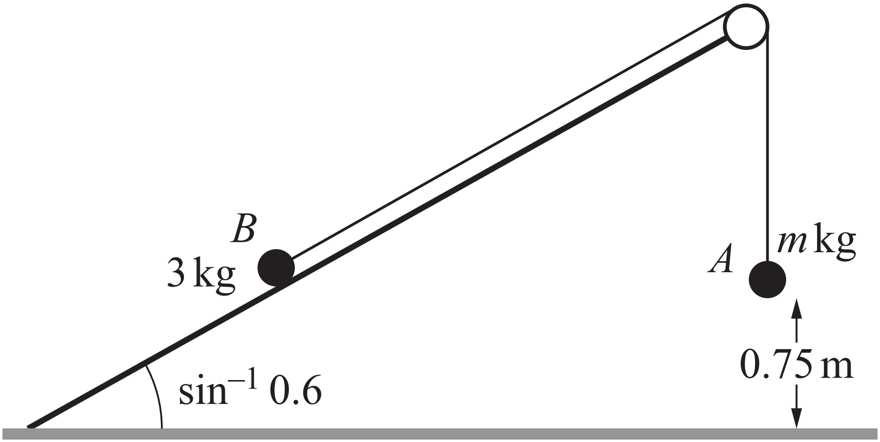
- Power $= Fv = 575 \times 15 = 8625$ W.

Question 4

9709/41 N25 ▪ Q4 ▪ 6 marks

Two particles, *A* and *B*, of masses *m* kg and 3 kg respectively, are connected by a light inextensible string. Particle *B* is on a fixed plane at an angle of $\sin^{-1} 0.6$ to the horizontal ground; the string passes over a smooth pulley at the top of the plane and *A* hangs vertically, 0.75 m above the ground. The system is released from rest; *B* moves up the plane (not reaching the pulley) against a constant resistance of $\frac{10}{3}$ N, and the speed of *A* immediately before it hits the ground is 2 m s^{-1}. Use an energy method to find the value of *m*. **[6]**

Question 4



Solution 4

Mark scheme

- A falls 0.75 m, B rises $0.75\sin\theta = 0.45$ m. Energy: $mg(0.75) = 3g(0.45) + \frac{10}{3}(0.75) + \frac{1}{2}(m+3)(2^2) \Rightarrow 7.5m = 22 + 2m \Rightarrow m = 4.$

Question 3

9709/42 N25 ▪ Q3 ▪ 8 marks

A car of mass 1400 kg travelling on a straight horizontal road accelerates uniformly from a speed of 15 m s^{-1} to 20 m s^{-1} over a distance of 175 m.

(a) Find the time taken to travel the 175 m. **[2]**

(b)(i) Use an energy method throughout to find the average power of the car's engine as the speed increases from 15 m s^{-1} to 20 m s^{-1}. **[4]**

(b)(ii) Find the steady speed that the car could maintain on the horizontal road if the engine is working at the power found in (b)(i). **[2]**

Solution 3

(a) Worked steps

With **uniform** acceleration the average speed is the mean of the initial and final speeds — no need to find a at all.

- $\bar{v} = \dfrac{15 + 20}{2} = 17.5\ \mathrm{m\,s^{-1}}$
- $t = \dfrac{175}{17.5} = \mathbf{10}\ \mathrm{s}$

Solution 3

That shortcut works **only** for constant acceleration, which is why the question says "uniformly". The alternative is $v^2 = u^2 + 2as$ to find a, then $v = u + at$ — three lines instead of two, and the same answer.

Mark scheme

- Average speed $= \frac{15+20}{2} = 17.5$, so time $= 175/17.5 = 10$ s.

Solution 3

(b)(i) Worked steps

The question says **use an energy method throughout**, so no forces and no $F = ma$ — account for the energy instead.

$$\text{work by engine} = \text{gain in kinetic energy} + \text{work against resistance}$$

- Gain in KE: $\frac{1}{2}(1400)\left(20^2 - 15^2\right) = 700(400 - 225) = 122\,500$ J
- Work against resistance: $800 \times 175 = 140\,000$ J
- Engine work: $122\,500 + 140\,000 = 262\,500$ J
- Average power: $\dfrac{262\,500}{10} = \mathbf{26\,250}$ W

Solution 3

Two things carry the marks. **Both terms** — the resistance does not vanish because the car is speeding up, and it is the larger of the two here. And **use the time from part (a)**: power is work per unit time, so the 10 s is what turns joules into watts. $\frac{1}{2}m\left(v^2 - u^2\right)$ is one subtraction of squares, not two separate energies subtracted after rounding.

Mark scheme

- Work-energy: engine work $= \Delta KE +$ work against resistance $= \frac{1}{2}(1400)(20^2 - 15^2) + 800(175) = 122500 + 140000 = 262500$ J. Average power $= 262500/10 = 26250$ W.

Solution 3

(b)(ii) Worked steps

At a **steady** speed there is no acceleration, so the driving force exactly balances the resistance.

- $F = 800$ N
- $P = Fv$, so $26\,250 = 800v$
- $v = \mathbf{32.8}$ m s^{-1}

Solution 3

The reasoning worth writing down is the first line: constant speed means zero net force, which is what lets you replace the unknown driving force with the known resistance. Without it the equation has two unknowns.
Sense-check: 32.8 m s^{-1} is about 118 km/h, a plausible top speed for a car at that power.

Mark scheme

- At a steady speed, driving force $=$ resistance $= 800$ N, so $26250 = 800v \Rightarrow v = 32.8$ m s^{-1}.

Question 4

9709/41 J25 ▪ Q4 ▪ 6 marks

A lorry of mass 18 000 kg is travelling along a straight road.

(a)(i) The steady speed which the lorry can maintain with the engine working at power *P* W is 30 m s^{-1}. Find the value of *P*. **[1]**

(a)(ii) At an instant when the speed of the lorry is 16 m s^{-1}, its engine is working at a power of 40 kW. Find the acceleration of the lorry at this instant. **[2]**

(b) When the lorry has reached a speed of 20 m s^{-1}, it begins to ascend a section of road inclined at an angle α to the horizontal. The engine now works at a power of 120 kW. There is no change in the lorry's speed as it ascends the hill. The constant resistance to motion remains 1600 N. Find the value of α. **[3]**

Solution 4

(a)(i)

Mark scheme

- $\dfrac{P}{30} - 1600 = 0 \Rightarrow P = 48000$ W.

(a)(ii)

Mark scheme

- $\dfrac{40000}{16} - 1600 = 18000a \Rightarrow 900 = 18000a \Rightarrow a = 0.05$ m s^{-2}.

Solution 4

(b)

Mark scheme

- $\dfrac{120000}{20} - 1600 - 18000g \sin\alpha = 0 \Rightarrow \sin\alpha = \dfrac{4400}{180000} \Rightarrow \alpha = 1.40.$

Question 6

9709/41 J25 ▪ Q6 ▪ 9 marks

Two particles, P and Q, of masses 0.3 kg and 0.6 kg respectively, are attached to the ends of a light inextensible string. The string passes over a smooth pulley fixed at a point B where the inclined planes AB and BC meet. P lies on the smooth plane AB which is inclined at an angle θ to the horizontal where $\sin\theta = 0.4$. Q lies on the plane BC which is inclined at 30 to the horizontal. The string is taut and the particles can move on lines of greatest slope of the two planes (see diagram). The particles are released from rest.

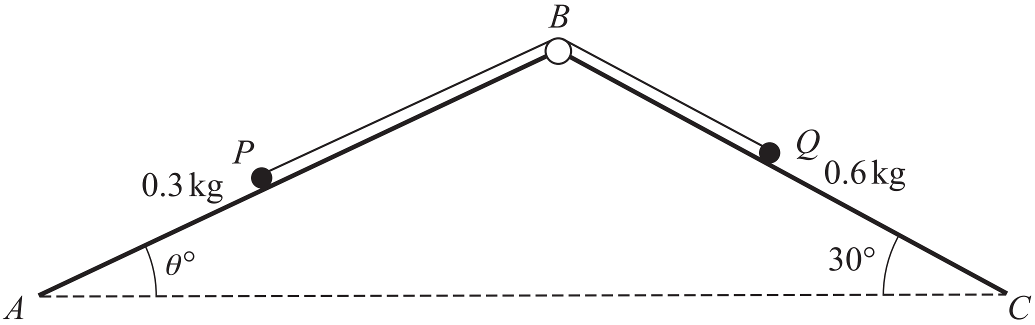
(a) It is given that the plane BC is smooth. Find the tension in the string and the acceleration of Q. **[5]**

(b) It is given instead that the plane BC is rough. The work done against the frictional force when Q moves 2 m down the plane is 1.8 J. You should assume that P does not

Question 6

reach the pulley and that Q does not reach C. Use an energy method to find the speed of Q when it has moved 2 m down the plane. **[4]**

Question 6



Solution 6

(a)

Mark scheme

- $0.6g \sin 30 - T = 0.6a$ and $T - 0.3g(0.4) = 0.3a$; adding gives $1.8 = 0.9a \Rightarrow a = 2$ m s^{-2}, and $T = 1.8$ N.

Solution 6

(b)

Mark scheme

- Energy: $\frac{1}{2}(0.9)v^2 = 0.6g(2\sin 30) - 0.3g(2)(0.4) - 1.8 = 6 - 2.4 - 1.8 = 1.8 \Rightarrow v^2 = 4 \Rightarrow v = 2 \text{ m s}^{-1}$.