Ideas in Context Questions (Examples)

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1. momentum = mass × velocity = $[50000 + (88 + 162) \times 80]$ kg × 10 m s^{-1}
   = 700000kg m s^{-1}

2. Change in momentum = final momentum – initial momentum
   = 70000 kg × (15–10) m s^{-1}
   = 350000 kg m s^{-1}

3. Momentum is conserved (i.e. momentum before = momentum after)

$$20 \text{ m s}^{-1} \times 50000 \text{ kg} = x \times 100000 \text{ m s}^{-1}$$

$$x = \frac{20 \text{ m s}^{-1} \times 50000 \text{ kg}}{100000 \text{ kg}}$$

$$= 10 \text{ m s}^{-1}$$

You need to show the calculation in the exam, even if the answer is quite obvious.

Extension This is not an elastic collision. Why?

4. force = mass × acceleration

$$\text{acceleration} = \frac{\text{change in speed}}{\text{time}}$$

$$= \frac{15 \text{ m s}^{-1}}{20 \text{ s}}$$

$$= 0.75 \text{ m s}^{-2}$$

So the force = 50000 kg × 0.75 m s^{-2}
= 37500 kg m s^{-2}
= 37500 N.

5.

6. 1 in 10 gradient, so vertical height is 10 m.
P.E. = mgh
= 50000 kg × 10 m s^{-2} × 10 m
= 5000000 kg m^2 s^{-2}
= 5000000 J = 5 MJ.

Why does kg m^2 s^{-2} = J ?
Well: energy = force × distance

force = mass × acceleration
So energy = mass × acceleration × distance
J = kg × m s^{-2} × m
= kg m^2 s^{-2}.

If you like you can call $g = 10$ N kg^{-1} (instead of 10 m s^{-2})
And then you get
P.E. = 5000000 kg N kg^{-1} m
= 5000000 N m
= 5000000 J
(Work = Force × distance, so J = N m)

7. Use conservation of energy
Potential energy at top of hill = Kinetic energy at bottom of freewheel
NB. We are presuming that there is not frictional loss.

$$mgh = \frac{1}{2}mv^2$$

Note that the mass cancels – Is this OK?
Yes—we know that objects dropped from the same height acquire the same speed when
they fall (or go down a slope), even if the masses are different (Galileo!)

$$gh = \frac{1}{2}v^2$$

$$v = \sqrt{2gh}$$

$= \sqrt{2 \times 10 \text{ m s}^{-2} \times 20 \text{ m}}$
$= \sqrt{400 \text{ m}^2\text{s}^{-2}}$
= 20 m s^{-1}. – Doesn't matter whether the tram is empty or full for this!

8. force = mass × acceleration
$= 50000 \text{ kg} \times \frac{(0 - 20) \text{ m s}^{-1}}{20 \text{ s}}$
$= -50 \text{ kg m s}^{-2} = -50000$ N The minus sign means that the force is in the opposite direction to the velocity.

9. If the brakes are perfect, we get all of the energy back
Energy regenerated = mgh or $\frac{1}{2}mv^2$ (whichever you prefer from question

7)
$= 10000000$ J
$= 10$ MJ.

10. power $= \dfrac{\text{energy}}{\text{time}}$
So time $= \dfrac{\text{energy}}{\text{power}}$
$= \dfrac{10 \text{ MJ}}{500 \text{ kW}}$
$= \dfrac{10 \times 10^6 \text{ J}}{500 \times 10^3 \text{ J s}^{-1}}$
$= 20$ s

11. $P = IV$
The voltage is 750 V from the sheet
$I = \dfrac{P}{V} = \dfrac{500 \text{ kW}}{750 \text{ V}} = \dfrac{500 \text{ kW}}{0.75 \text{ kV}}$
(k's cancel)
$=667 \dfrac{\text{J s}^{-1}}{\text{J C}^{-1}} = 667$ C s^{-1} –don't forget to check units like this
=667 A.

12. Electrical energy is transmitted through the national grid as AC since this allows the voltage to be stepped up and down easily via transformers. Stepping the voltage up allows the current in the transmission lines to be kept very low, meaning that losses in transmission are reduced

13. The substation converts the AC grid supply into DC since this will be safer for use with the trams.

14. In order to be electrocuted, a current must flow through your body. In the tram supply, the 'live' cable is above the tram, and the 'earth' will be in the rail. Therefore, simply stepping on a rail would not be enough to electrocute you (you would have to step on a rail and grab an overhead wire).

15. A substation could convert AC to DC (this is called rectification) by means of a diode. This only allows electricity to pass through one way.

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