A-Level Physics

Work and Power

Mark Scheme

Time available: 45 minutes
Marks available: 32 marks

Mark schemes

1. (a) Attempt to use work done = force × distance with either incline work or resistance work or both ✓$_1$

Work done by flywheel

$= [(1.46 \times 10^4 \times 9.81 \times \sin 5°) + 1.18 \times 10^3] \times 500$ ✓$_2$

$(= 6.83 \times 10^6 \text{ J})$

$1/2\ I\omega^2 = 6.83 \times 10^6$ giving $\omega = 468$ (rad s^{-1}) ✓$_3$

MP1: award mark for valid attempt to calculate

mgh or $F \times s$ or both

$mgh = 6.24 \times 10^6$ J

$F \times s = 5.9 \times 10^5$ J

MP2 for correct calculation of work done

MP3 for using their work done and $1/2\ I\omega^2$ to calculate ω

ECF for ✓$_3$

3

(b) ✓$_1$ for idea of use of flywheel as brake

✓$_2$ for idea of storing and reusing this energy

E_p change of tram can be converted to E_k of flywheel so less energy transferred to brakes/brakes last longer/tram will not reach a high speed ✓$_1$

OR

Energy otherwise dissipated/lost in brakes can be fed back to flywheel ✓$_1$

Fly wheel is charged/stores energy and energy can be used for later acceleration/driving ✓$_2$

OR

Fly wheel is charged/stores energy and at next stop less recharging energy will be needed. ✓$_2$

Give two marks if both points covered in their answer to part 1

Treat as neutral answers in terms of providing a smoother ride or less wear on parts due to connecting and reconnecting flywheel.

If no other marks are given, allow 1 MAX for a correct reference to regenerative braking.

2

(c) **The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer.**
Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist in marking this question.

Mark	Criteria
6	The factors which affect E_k and all three areas of shape, material and design for high ω will be covered in some detail. 6 marks can be awarded even if there is an error and/or if parts of one aspect are missing.
5	The factors which affect E_k and all three areas will be covered, at least two in detail.
4	Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be gaps, there should only be an occasional error.
3	One area discussed and one discussed partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.
2	Only one area discussed or makes a partial attempt at two areas.
1	None of the three areas covered without significant error.
0	No relevant analysis.

examples of the points made in the response

- E_k proportional to ω^2
- E_k proportional to I
- for same mass of tram I or ω increased but not mass of flywheel

<u>Shape</u>

- I depends on mass and distribution of mass around axis
- ($I = \sum mr^2$ so) arrange more m at outer edge of flywheel
- by using heavy rim and spokes/thin centre web
- increase radius

<u>Material</u>

- use higher density material at rim
- use material of higher tensile strength / breaking stress
- for higher speeds without bursting/to withstand rotational/centripetal stresses
- eg titanium, CFRP

Design for high ω - increase ω by:

- reduce friction at bearings
- use lubrication or roller bearings/air bearings/magnetic bearings
- smooth outer surfaces / encase in vacuum
- small increase in ω gives large increase in E_k (because ω^2)

Also allow

- sketches which convey correct info clearly
- use of 'depends on' for 'proportional to'
- need for perfect balance
- gyroscopic effects

6

[11]

2. (a) (i) 8.3 rev = $8.3 \times 2\pi$ rad ✓ (= 52 rad)

Use of $\omega_2^2 = \omega_1^2 + 2\alpha\theta$

$0 = 6.4^2 + 2 \times \alpha \times 52$ ✓

If eqtn(s) of motion used correctly with θ = 8.3 (giving α = 2.5), give 2 out of first 3 marks.

OR use of $\theta = ½(\omega_1 + \omega_2)t$ leading to t = 16.25 s and $\omega_2 = \omega_2 + \alpha t$

$\alpha = (-)\ 0.39$ ✓ rad s^{-2} ✓

Accept: s^{-2}

Unit mark is an independent mark

4

(ii) $T = I\alpha$

$= 8.2 \times 10^{-3} \times 0.39 = 3.2 \times 10^{-3}$ N m ✓

Give CE from a i

1

(b) (i) ($W = T\theta$ or $W = T\omega t$) where $\theta = 0.78 \times 270$ √ (= 210 rad)

$= 3.2 \times 10^{-3} \times 210 = 0.67$ J✓

Give CE from a ii

2

(b) (ii) $\text{ratio} = \frac{900 \times 270}{0.67}$ or $\frac{2.4(3)\times 10^5}{0.67}$ ✓

$= 3.6 \times 10^5$ ✓

CE from b i. Must be in the form: number × 10^5 with number calculated correctly.

900 × 270 or 2.4(3) × 10^5 or equivalent must be seen for 1st mark

1 mark for <u>only</u> writing 3.6 × 10^5

2

(Total 9 marks)

3. (a) (i) $T = Fr = 7.0 \times 0.075$

$= 0.53$ **(1)** N m **(1)**

2

(ii) $P = T\omega$

$= 0.53 \times 120 = 64$ W **(1)**

1

(b) use of equation(s) of motion:

$\theta = ½(120 + 0) \times 6.2 = 370$ rad **(1)**

$370/2\pi = 59$ rotations **(1)**

2

[5]

4. (a) $\omega_1 = \frac{2\pi}{18} = 3.5 \times 10^{-1}$ (rad s^{-1}) **(1)**

$\theta = \frac{(\omega_1 + \omega_2)t}{2}$ gives $t = \frac{2 \times 3 \times 2\pi}{3.5 \times 10^{-1}}$ **(1)**

$t = 108$ (or 110) s **(1)**

(3)

(b) $\alpha \left(= \frac{\omega_1 - \omega_2}{t}\right) = \frac{(-)3.5 \times 10^{-1}}{108} = (-)\ 3.2 \times 10^{-3}$ (rad s^{-2}) **(1)**

$T\ (= I\alpha) = 8 \times 10^3 \times 3.2 \times 10^{-3} = 26$ Nm **(1)**

(2)

(c) P (= $T\omega$) **(1)** = 26 × 3.5 × 10^{-1} = 9 W **(1)**

(2)

[7]