A-Level Physics

Torque and Angular Acceleration

Mark Scheme

Time available: 51 minutes
Marks available: 39 marks

1.

(a) Attempt at calculating area above or below *t* axis or both ✓
(Ang displacement =) 2.80 + 2.10 − 3.15 = 1.75 rad
($\frac{1.75}{12.0}$ =) 0.15 (rad s^{-1}) ✓

Method must be valid
MP2: correct answer only
(calculator value = 0.145833)
MAX1 if counting square method used and answer rounds to 0.15 (rad s^{-1})

2

(b) $P = T\omega$ giving 546 (W) ✓

Allow ecf for 590 (W) from
using ω_1 = 1.5 rad s^{-1}

1

(c) Selects steepest part of graph and

determines gradient $\alpha = \frac{1.40 - -0.90}{5.0}$ = 0.46 (rad s^{-2}) ✓$_1$

$T = I\alpha$ = 9660 N m ✓$_2$

Adds friction torque to give 10 100 (N m) ✓$_3$

Accept any correct calculation of steepest graph slope: eg from 2 s to 5 s

$a = \frac{1.4}{3.0}$ *= 0.467 giving T = 9800 N m*

or 5 s to 7 s

$a = \frac{0.9}{2.0}$ *= 0.45 giving T = 9450 N m*

Allow ECF from MP2 to MP3
Treat 10 000 (Nm) as a 2 sf answer if consistent with their working.

3

(d) (net) $T \times t$ = 9660 × 5.0 = 4.8 × 10^4 (N m s) ✓

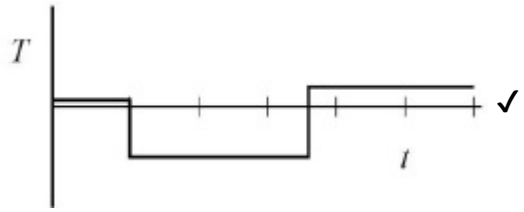
OR

$\Delta(I\omega)$ = 2.1 × 10^4 (1.40 –(–0.90)) = 4.8 × 10^4 (N m s) ✓

*For first method allow ECF for torque ✓$_2$ from **(c)**, but not for ✓$_3$ value*
(calculator value = 48300)

1

(e)



✓

Tick (✓) against 3rd box

1

[8]

2. (a) $T = mg \times l/2 = mgl/2$

1

(b) $\alpha = T/I$ ✓

Substitutes $T = mgl/2$ and $I = \frac{m}{3}l^2$ ✓

Leading to $\alpha = \frac{3g}{2l}$

Substitution and cancelling must be seen.

$$\alpha = \frac{mgl/2}{\frac{m}{3}l^2}$$

2

(c) $a = r \times \alpha$

$r = l$

$a = l \times \frac{3g}{2l} = \frac{3g}{2}$ ✓

This > g, so rule falls with linear accltn > g ✓

2

(d) $a = r \times \frac{3g}{2l}$

If $r = 2l/3$, $a = g$

So mass placed about 67 cm mark ✓

1

[6]

3.

(a) $\frac{3.5}{(2\pi \times 0.088)}$ = 6.3 rev

6.3 × 2π = 39.8 rad or 40 rad ✓

OR

$\frac{3.5}{0.088}$ = 39.8 or 40 rad ✓

If correct working shown with answer 40 rad give the mark
Accept alternative route using equations of motion

1

(b) $\omega = v / r = 2.2 / 0.088 = 25$ rad s^{-1} ✓

1

(c) (i) $E = \frac{1}{2}I\omega^2 + \frac{1}{2}mv^2 + mgh$
= $(0.5 \times 7.4 \times 25^2)$
+ $(0.5 \times 85 \times 2.2^2)$
+ $(85 \times 9.81 \times 3.5)$
= 2310 ✓
+ 206 ✓
+ 2920 ✓
(= 5440 J or 5400 J)

CE from 1b
$\frac{1}{2} I \omega^2 + \frac{1}{2}mv^2 = 2310 + 210 = 2520$ J
$\frac{1}{2} I \omega^2 + mgh = 2310 + 2920 = 5230$ J
$\frac{1}{2}mv^2 + mgh = 210 + 2920 = 3130$ J
Each of these is worth 2 marks

3

(ii) Work done against friction = $T\theta$
= 5.2 × 40 = 210J ✓
Total work done = $\boldsymbol{W}$ = 5400 + 210
= 5600J ✓ 2 sig fig ✓

CE if used their answer to i rather than 5400J
Accept 5700 J (using 5440 J)
Sig fig mark is an independent mark

3

(d) Time of travel = distance / average speed = 3.5 / 1.1 = 3.2s ✓

$P_{ave} = \frac{5600}{3.2}$ = 1750 W

$P_{max} = P_{ave} \times 2$ = 3500 W ✓

OR accelerating torque = $T = W / \theta$
= 5600 / 40 = 140 N m ✓
$P = T \omega_{max}$ = 140× 25 = 3500 W ✓
CE from ii
1780 W if 5650 J used

2

[10]

4. (a) moment of inertia of the rockets

= (2 × 0.54 × (0.80)^2) + (2 × 0.54 × (0.50)^2) = 0.96 (kg m^2) **(1)**

total moment of inertia = 0.96 + 0.14 (kg m^2) **(1)** (= 1.10 kg m^2)

2

(b) (i) torque = (2 × 3.5 × 0.80) + (2 × 3.5 × 0.50) = 9.1 N m **(1)**

(ii) $\alpha \left(= \frac{T}{I}\right) = \frac{9.1}{1.1}$ = 8.3 rad s^{-2} **(1)** (8.27 rad s^{-2})

(allow C.E. for value of torque from (i))

(iii) one turn = 6.28 rad **(1)**
$\theta = \omega_1 t + \frac{1}{2} \alpha t^2$ gives 6.28 = 0.5 × 8.3 × t^2 and t = 1.2(3) s **(1)**
(allow C.E. for value of α from (ii))

4

(c) frictional couple (due to air resistance) increases as angular speed increases **(1)**
when frictional couple = driving torque [or when no resultant torque], then no acceleration **(1)**

2

[8]

5. (a) Work done ✓

1

(b) **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 marking this question.**

Mark	Criteria
6	There is a response to all 3 bullet points in the question. There is a good understanding of the function of a flywheel, and why the torque varies markedly in a diesel engine. Student can relate the answer to the two graphs. Includes 6 or more answer points from the list alongside
5	There is a response to all 3 bullet points in the question covering 6 answer points. Answers will not be as confident or detailed as for 6 marks, or answers may not be expressed using scientific terminology.
4	The student gives five or more answer points covering at least two of the bullet points.
3	At least four pertinent statements. They may show little understanding of the electric motor but should be able to give some reasons why a diesel engine needs a flywheel.
2	Two or three pertinent statements taken from the list of likely answer points.
1	One pertinent statement.
0	No sensible statements made.

Other sensible and applicable points can be accepted in lieu of any of those alongside.

Likely answer points:

1st bullet

1. *Electric motor's constant torque means smooth motion/doesn't need smoothing/doesn't need a flywheel*
2. *motor's output torque matches the described load*

2nd bullet

3. *relates force/pressure on piston to torque*
4. *force on piston varies over one cycle (as pressure in cylinder varies)*
5. *Torque = Fr and effective r varies as crank rotates*
6. *-ve torque: when work is being done on (the gas in) the engine (during induction, comp, exhaust strokes)*
7. *Zero torque when con rod and crank are in line/at top and bottom dead centres*
8. *This happens at crank angles which are multiples of π*

3rd bullet

9. *Diesel engine's (varying torque) will give uneven/jerky motion/cause stalling*
10. *Flywheel acts as energy store*
11. *Flywheel absorbs energy on power/expansion stroke*
12. *and gives up energy on other parts of cycle*
13. *Flywheel speeds up on expansion stroke*
14. *and slows down during other strokes.*
15. *The greater the M of I of flywheel, the smoother the motion*
16. *If no flywheel engine will stall/become very uneven/jerky*
17. *The greater the M of I of flywheel, the longer engine will take to speed up, slow down/stop*
18. *Because machine has low M of I it will not be able to store energy itself or smooth the motion.*

6

[7]