Name of the Student:_____
Max. Marks : 23 Marks **Time : 23 Minutes**

Mark Schemes

Q1.

(a) Attempt to determine area under graph ✔1
Use of correct scaling factors to find area in J ✔2
Calculates area to be between 22 J and 25 J ✔3
Finds work needed to drive at least one nail into wood using $W = F \times s$ ✔4
Concludes that expansion roughly matches energy to drive nail D ✔5

Eg counting squares
9 large sq × 2 × 10^5 × 10 × 10^{-6} = 18 J
67 small sq × 2/25 = 5.4 J
Total 23(.4) J
Accept 11 to 12½ large sq giving 22 to 25 J
W for D = 420 × 0.050 = 21.0 J
Nail E needs much more W, others need less W. OR F = (wd by gas) ÷ length and compares with forces in Table 2.
For ✔5 do not accept 'closest' answer unless answer for w.d by gas ≥ work needed to drive nail.
ECF for ✔5 for their calculated area

5

(b) Isothermal process/expansion requires (relatively) long time for expansion to take place

OR

Process/expansion must occur slowly ✔1

Reason: isothermal needs energy transfer (Q) for temperature/internal energy to remain constant ✔2

nail fired in less than ⅓ second so expansion very fast/not enough time for energy transfer ✔3
(so process cannot be isothermal)

For ✔2 do not credit energy must be supplied without reference to temperature or internal energy.
For ✔3 must relate time to the data in the question.

3

[8]

Q2.

(a) Sum of all constituent masses × their radius/distance from the axis squared

Allow Σmr^2 with m defined as small mass or constituent mass or particle at a radius r and Σ explained.

Condone: 'from the axis' missing

Condone: a quantity expressing a body's tendency to resist angular acceleration/change in angular speed

1

(b) E_P lost (by falling mass) = E_K pulley + E_K mass ✔

$0.5Mgh = ½(0.5M)v^2 + ½(0.5MR^2)\omega^2$
Cancel 0.5 and M and substitute $\omega = {}^{v}R$ for ω
gives $gh = ½v^2 + ½v^2 = v^2$ ✔
use of $v^2 = u^2 + 2as$ giving $v^2 = 2ah$ ✔
substitutes $v^2 = 2ah$ in $gh = v^2$ (so $a = 0.5g$) ✔

*1st mark for equating E_P lost by mass to E_K gained by **both** mass and pulley. Accept this step in words or symbols*

2nd mark for $gh = v^2$

3rd mark for v^2 in terms of h

4th mark for combining correctly (to get $a = 0.5g$)

OR
$0.5Mg - F = 0.5Ma$ ✔
Torque = $I\alpha$ $F \times R = (0.5MR^2)\alpha$ ✔
(giving $F = 0.5\ MR\alpha$)
and substitute $\alpha = a/R$
leading to $F = 0.5Ma$ ✔
Substitute for F in $0.5Mg - F = 0.5Ma$ (gives $a = 0.5g$) ✔

OR with F or other letter as tension in string:

1st mark for Newton's 2nd law applied to mass in words or symbols

2nd mark for accelerating torque equation

3rd mark F in terms of a

4th mark for substituting to get $a = 0.5g$

Note: $\alpha = a/R$ is not in the spec, but students may know it and use this route.

Give ECF if M is used for the falling mass in place of $0.5M$

4

(c)

Route 1	Route 2
M of I spoked pulley is greater ✔1 Reason given for greater M of I but must have reference to distribution or spread of mass about axis ✔2 Greater proportion of E_P loss given to pulley OR lower prop to E_K of falling mass ✔3 v of mass in same time will be lower so acceleration lower ✔4	M of I spoked pulley is greater ✔1 Reason given for greater M of I but must have reference to distribution or spread of mass about axis ✔2 Presents valid argument relating I to α ✔3 $\alpha = a/R$ (with α less) so acceleration of mass is less OR wheel turns through fewer rotations in same time so point

	on rim moves less distance so acceleration less ✔4

WTTE

For ✔3 and ✔4 marks in route 2

0.5M(g - a) = F

0.5M(g - a)R = I α

0.5Mg = a (0.5M + I/R²) a

If I increases, a decreases.

Max 3

[8]

Q3.

(a) No (net) external torque acts (on the system) ✔

Do not accept force for torque

1

(b) $I_A \omega_A + I_B \omega_B = (I_A + I_B) \omega$ ✔
(taking clockwise as positive)
$(7.2 \times 95) + (11.5 \times -45) = 18.7\omega$
ω = (+)8.9 rad s^{-1} ✔
clockwise ✔

Accept answers with anticlockwise taken as positive.

1st mark for equation or substitution, but condone any incorrect sign for angular velocity.

2nd mark: answer to at least 2 sf

3rd mark for direction, ECF provided direction agrees with sign in calculated answer and sign convention used.

3rd mark is not an independent mark and is contingent on some attempt at calculation using angular momentum

3

(c) Attempts to use Angular impulse = $Tt = \Delta(I \omega)$ ✔
Clutch C: 600 t = 7.2 × (95 − 8.9) = 620 (N m s)
t = 1.03 s
OR α = (95 − 8.9)/t
600 = $I \alpha$ = 7.2 (95 − 8.9)/t
t = 1.03 s
Clutch D: 320 t = 7.2 × (95 − 8.9)
t = 1.93 s ✔ (for either or both times calculated)

Compares correct times with 1s < t < 2s and concludes both clutches satisfy criterion. ✔

1st mark: attempts to use idea of angular impulse

Mark not given for just quoting formula.

2nd mark: correct time(s) calculated for either or both clutches

OR torques calculated for 1 s and/or 2 s [620 Nm and 310 Nm]

3rd mark: correct conclusion based on correct times for both clutches

OR based on comparing calculated torques for 1 and 2 s with data in Table 2

Answers may be worked out using shaft B:

$T \times t$ = 11.5 × (−45 − 8.9) = (−)620 N m s

Give full marks if 9 rad s^{-1} is used, giving angular impulse = 619 N m s

t for clutch C = 1.03 s

t for clutch D = 1.93 s

3

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