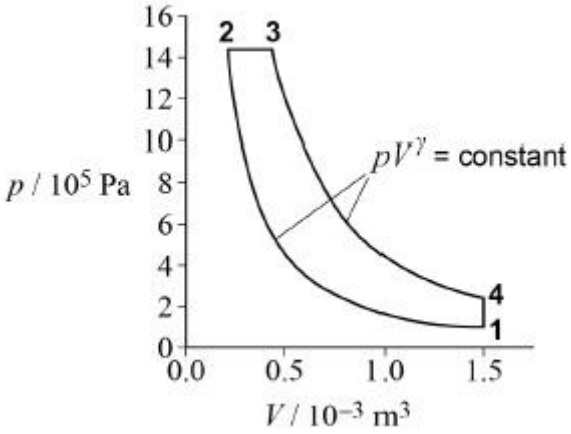
**Name of the Student**:_____
**Max. Marks : 21 Marks** **Time : 21 Minutes**

## Q1.

**Figure 1** shows the $p$–$V$ diagram for an idealised diesel engine cycle. In this cycle a fixed mass of air is taken through four processes **1** → **2** → **3** → **4** → **1**.

**Figure 1**




(a) Which statement about this cycle is true?
Tick (✔) the correct answer.

Work is done by the air in process **4** → **1**. ☐

Energy is supplied to the air by heating only in process **2** → **3**. ☐

The temperature of the air rises in process **3** → **4**. ☐

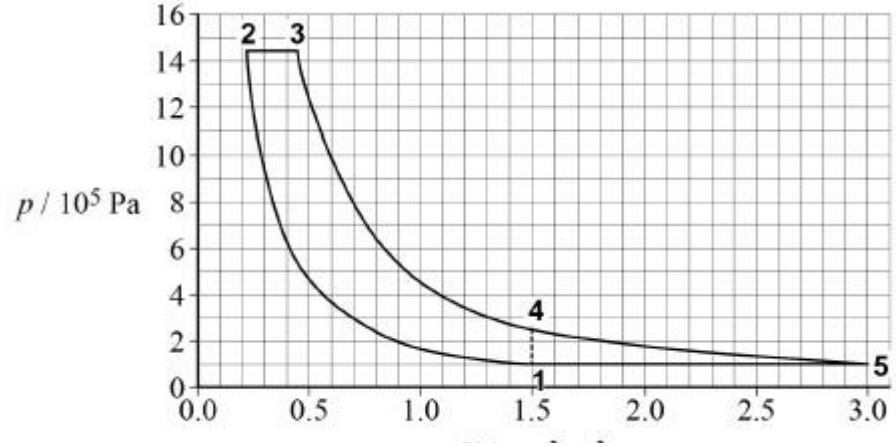
The area enclosed by the loop **1** → **2** → **3** → **4** → **1** is the power output of the cycle. ☐

**(1)**

(b) The cycle in **Figure 1** may be modified by allowing the air to continue to expand adiabatically from state **4** until it is at atmospheric pressure at state **5**.

**Figure 2** shows the modified cycle.

**Figure 2**




The expansion stroke **3** → **5** is now longer than the compression stroke **1** → **2**. Process **5** → **1** takes place at constant pressure.

It has been claimed that, compared to the cycle in **Figure 1**, the modified cycle of **Figure 2** gives

**A** an increase in work done per cycle of 130 J

**B** an increase in efficiency of more than 15%

Deduce whether these claims are true.

Claim **A**

Claim **B**

**(5)**

(c) The first law of thermodynamics can be written as

$$Q = \Delta U + W$$

State the meaning of the terms $Q$ and $\Delta U$ in this equation.

$Q$

$\Delta U$

**(2)**

(d) For the air in process **5** → **1** in **Figure 2**, $\Delta U$ = –374 J

Calculate the energy that must be removed by cooling for process **5** → **1**.

energy removed by cooling = _____ J

**(2)**

(e) 0.060 mol of air is taken through the cycle.

Determine the maximum temperature in the cycle.

maximum temperature = _____ K

**(3)**

**(Total 13 marks)**

## Q2.

(a) There is an analogy between quantities in rotational and translational dynamics.

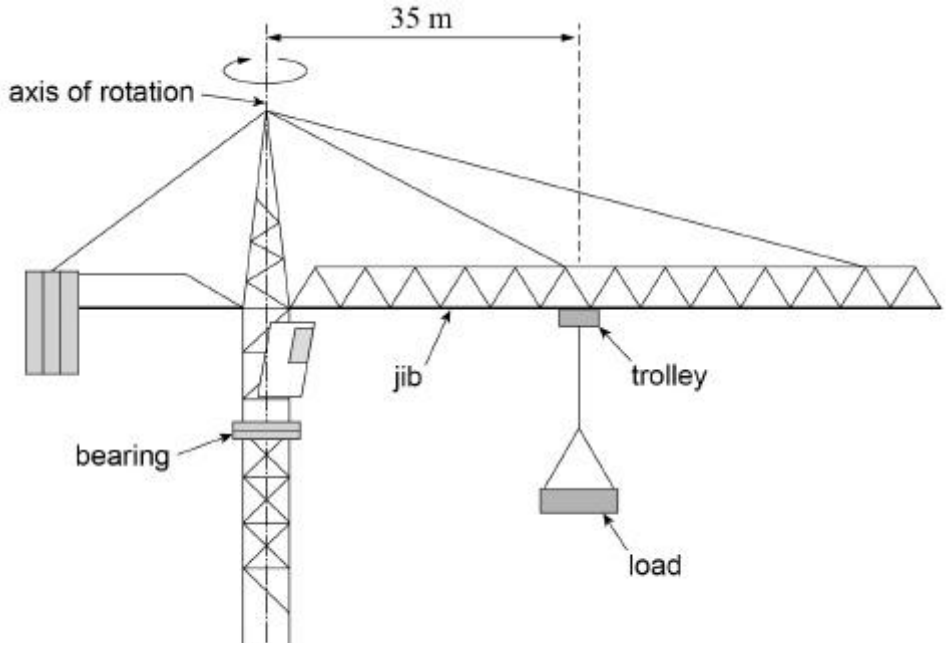
Complete the table, stating in words the quantities in rotational dynamics that are analogous to force and mass in translational dynamics.

| Translational dynamics | Rotational dynamics |
|---|---|
| force | |
| mass | |

**(2)**

**Figure 1** shows a side view of the jib of a tower crane. The load is supported by a trolley which can move along the jib. The jib consists of all the parts of the crane above the bearing, but excluding the trolley and load.

**Figure 1**




The moment of inertia of the jib about the axis of rotation = $2.6 \times 10^7$ kg m$^2$

Mass of trolley and load = $2.2 \times 10^3$ kg

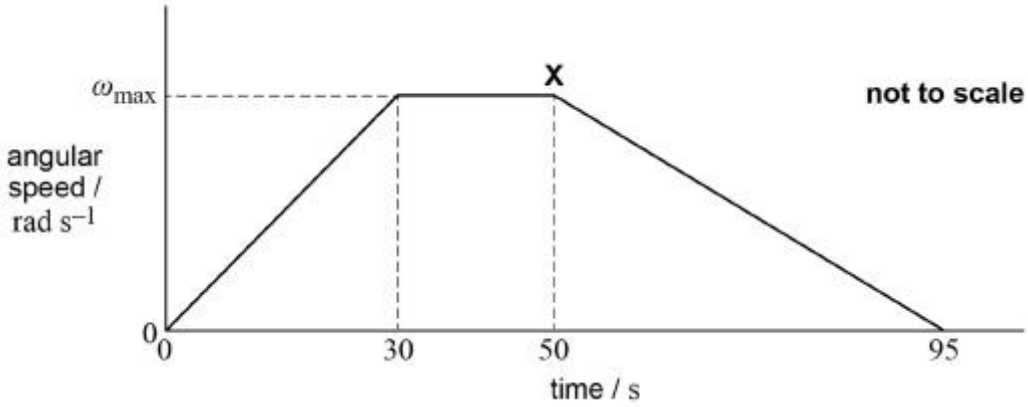
(b) The load is at a distance of 35 m from the axis of rotation.

Show that the total moment of inertia of the jib, and the trolley and load, about the axis of rotation is about $3 \times 10^7$ kg m$^2$.

**(1)**

(c) **Figure 2** shows the variation of angular speed of the jib as it turns through an angle of 4.7 rad (270°) in a total time of 95 s. The trolley and load remain at a distance of 35 m from the axis.

**Figure 2**




Calculate the maximum angular speed $\omega_{max}$ of the jib.

maximum angular speed = _____ rad $s^{-1}$

**(2)**

(d) At time **X** in **Figure 2** the motor that is driving the jib is disengaged. A constant braking torque is then applied to bring the jib to a standstill from its maximum angular speed.

The crane driver repeats the movement of the jib with the same load at 35 m from the axis of rotation. Up to time **X** the motion is the same as before. From time **X** the trolley is driven at a steady speed away from the axis as the jib continues to rotate until the jib comes to a standstill.

Assume the braking torque remains the same as before.

Discuss how the motion of the trolley affects the time taken for the jib to come to a standstill.

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**(3)**

**(Total 8 marks)**