Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2007-2008 (2 hours)

Electromechanical Energy Conversion 2

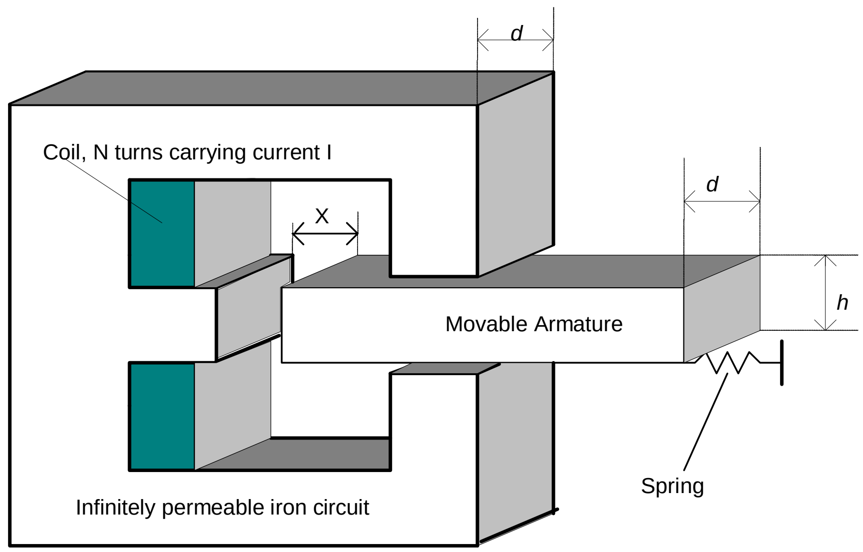
Answer **THREE** questions. **No marks will be awarded for solutions to a fourth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

1. a. An electromechanically actuated bolt, comprising of a simple rectangular section solenoid actuator, is shown in cross-section in the figure below. In this system it may be assumed that the only significant reluctance is the airgap of length X.

Derive an expression for the coil inductance, L, and show that, with all dimensions in metres, and for a constant coil current of I amps, the force on the linear movable armature is given by:

$$F = \frac{\mu_o \, d \, h \, N^2 \, I^2}{2 \, X^2} \qquad \textit{Newtons}$$

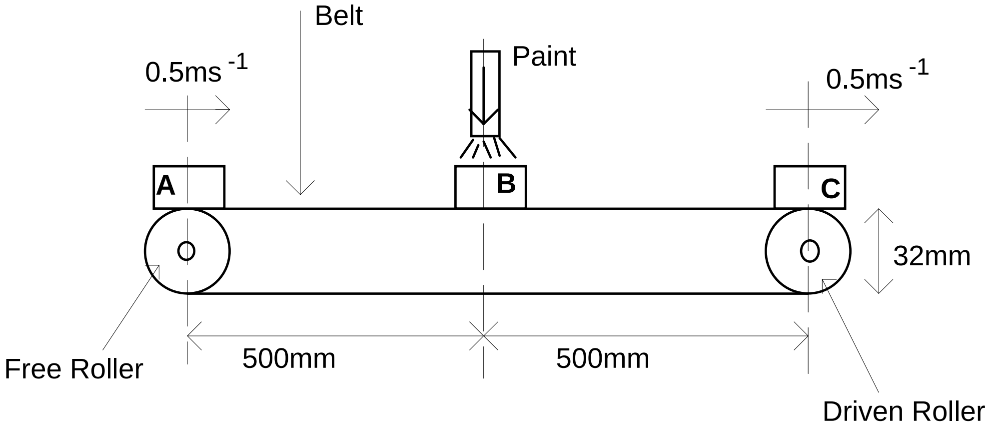
(8)



b. For a particular actuator, the number of turns, N = 500, and the dimensions of the movable armature are d =8mm, h = 5mm. Given that the distance X is 6mm in the locked position and 3mm in the unlocked position, and that the spring force is a constant 2N, calculate the current required to unlock the door, and the current at which it will re-lock. **(6)**

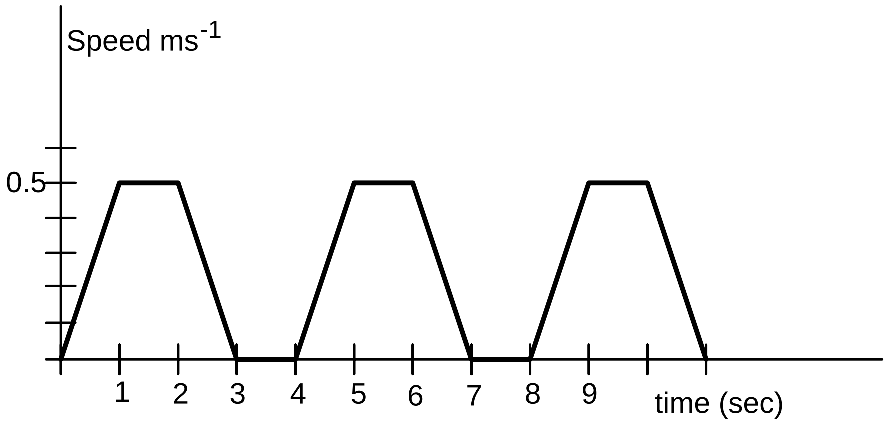
c. Explain what advantage may be gained by having the current to lock the bolt different from that required to unlock it. **(6)**

2. a.



The machine shown in cross-section above is used as part of a component manufacturing process, to automatically paint components. The machine consists of a continuous belt which is driven by a dc servo motor directly coupled to a 32mm diameter roller. The components arrive from an earlier process at point **A**, travelling at a speed of $0.5ms^{-1}$ and at regular 4 second intervals. The belt then decelerates the component to standstill, at position **B** under the painting machine, where it must remain for 1 second as the paint is deposited. The component is then accelerated and exits the machine at $0.5ms^{-1}$ to the next process at point **C**. The distances travelled from **A** to **B**, and from **B** to **C** is 500mm.

A speed-time profile for the belt is given below, show why this is suitable for the described operation. **(4)**



The servo motor used has the following parameters:

Voltage constant :	100 Volts / 1000 rpm
Resistance :	0.25 Ω
Maximum Speed :	2000 rpm
Continuous stall torque :	20 Nm
Moment of inertia :	$0.02kgm^2$

b. Given the total load has an effective moment of inertia (referred to the motor) of $0.3kgm^2$, and it may be assumed to be lossless, calculate the peak voltage and current requirements of the servo amplifier which supplies the motor. **(4)**

c. Sketch the motor supply voltage and current waveforms over an operational cycle, & confirm that the motor specified is adequate **(4)**

d. Sketch a circuit diagram of a suitable electronic drive for the servo motor, stating the number of quadrants in which the drive is required to operate. **(4)**

e. Briefly explain the difference between the 'Continuous stall torque' rating and the 'Maximum torque' rating of a servo motor. **(4)**

3. a. Sketch the approximate equivalent circuit for a three-phase induction motor, explaining what each component represents. Show how the locked rotor test may be used to calculate some of the motor parameters in the equivalent circuit. **(8)**

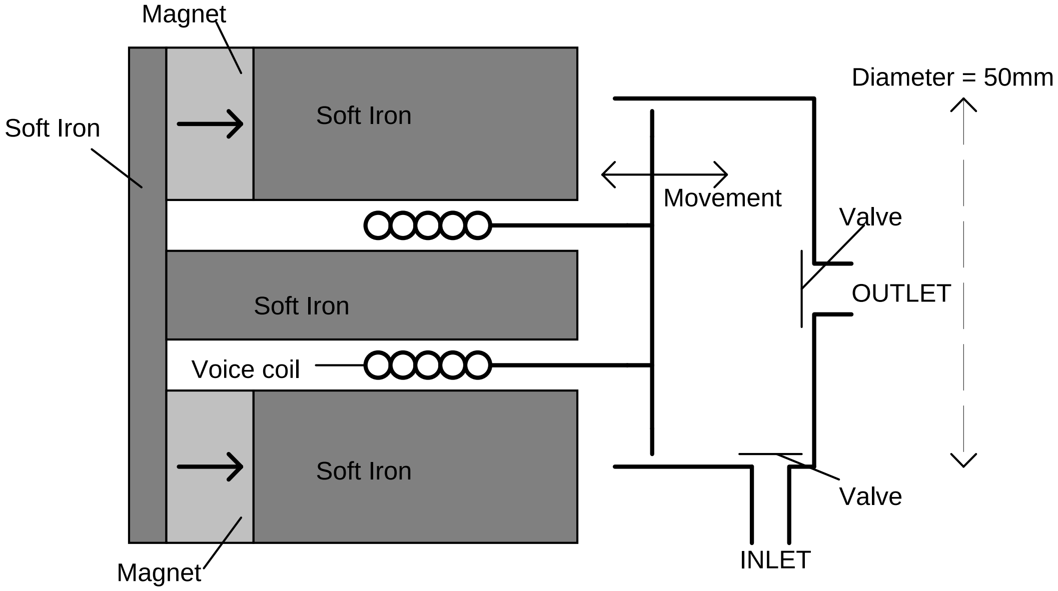
b. The following readings were taken during a locked rotor test performed on a 6-pole, 415V, 3-phase, 50Hz, star-connected induction motor.

Line voltage = 80V, Line current = 20A, Input power = 2.0kW

The stator resistance was measured at 0.4Ω per phase.

Find the maximum mechanical load torque which it is safe for the motor to drive, such that the motor will not stall under the worst-case supply conditions, given that the 50Hz supply to the motor is prone to voltage drops of up to 25%. **(12)**

4. a. The figure below shows the radial cross-section of a diaphragm air pump. A circular voice coil of **N** turns and diameter **D** is attached to the pump diaphragm and suspended on an axially compliant spring in a uniform radial magnetic field of magnitude **B** Tesla. Derive an expression for the electromagnetic force on the voice coil when it carries a current **I** amps. **(4)**



A particular pump actuator has the following parameters:

Radial field flux density (B):	1.0T
Voice coil diameter (D):	32 mm
Number of turns on voice coil (N):	100
Voice coil resistance:	140 Ohms
Voice coil self inductance:	172mH
Mass of combined coil and diaphragm:	6 grammes

b. Given that the mechanics of the pump are dominated by the combined mass of the coil and diapragm, derive a simple equivalent electrical circuit for the pump, and show that it has a resonant natural frequency of 50Hz. **(6)**

c. Calculate the current drawn from the supply, when the voice coil is supplied with a 12Vrms voltage at 50Hz **(4)**

d. Calculate the peak to peak displacement of the diaphragm, and the airflow in litres/minute obtained under the same conditions used in part (c). **(6)**

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