SYSTMS ENGINEERING

Written examination

Friday 12 November 2010

Reading time: 11.45 am to 12.00 noon (15 minutes)
Writing time: 12.00 noon to 1.30 pm (1 hour 30 minutes)

QUESTION AND ANSWER BOOK

Structure of book

<table>
<thead>
<tr>
<th>Section</th>
<th>Number of questions</th>
<th>Number of questions to be answered</th>
<th>Number of marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
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<td>B</td>
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<td>29</td>
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<td>Total</td>
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</table>

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers and one scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or white out liquid/tape.

Materials supplied
- Question and answer book of 23 pages including formulas on page 23.
- Answer sheet for multiple-choice questions.

Instructions
- Write your student number in the space provided above on this page.
- Check that your name and student number as printed on your answer sheet for multiple-choice questions are correct, and sign your name in the space provided to verify this.
- All calculations must show appropriate formulas and working.
- All written responses must be in English.

At the end of the examination
- Place the answer sheet for multiple-choice questions inside the front cover of this book.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

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SECTION A – Multiple-choice questions

Instructions for Section A

Answer all questions in pencil on the answer sheet provided for multiple-choice questions. Choose the response that is correct for the question. A correct answer scores 1, an incorrect answer scores 0. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question. A formula sheet is provided on page 23. Unless indicated diagrams are not to scale.

Question 1
The figure below shows a pair of tin snips.

Which of the following shows the correct positions of the effort, load and fulcrum?

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>fulcrum</td>
<td>load</td>
</tr>
<tr>
<td>B.</td>
<td>effort</td>
<td>load</td>
</tr>
<tr>
<td>C.</td>
<td>fulcrum</td>
<td>effort</td>
</tr>
<tr>
<td>D.</td>
<td>load</td>
<td>fulcrum</td>
</tr>
</tbody>
</table>

Question 2
What class of lever are the tin snips?

A. class 1 only
B. class 2 only
C. class 3 only
D. both class 1 and class 2
Question 3
In the diagram below
pulley A has a radius of 4 cm
pulley B has a radius of 8 cm
pulley C has a radius of 4 cm
pulley D has a radius of 16 cm.

If pulley A rotates at 16 rpm, pulley D will rotate at
A. 1 rpm
B. 2 rpm
C. 4 rpm
D. 16 rpm
Questions 4 and 5 refer to the diagram below.

**Question 4**
The motion of the piston in the bicycle pump when pumping can best be described as
A. linear.
B. rotary.
C. oscillating.
D. reciprocating.

**Question 5**
A force of 100 N is applied to the pump handle. The area of the piston is 0.001 square metres.
What pressure is produced within the cylinder?
A. 10 kpa
B. 100 kpa
C. 10 000 kpa
D. 100 000 kpa

**Question 6**
A 20 cm long spanner is used to produce a torque of 60 Nm.
The force applied to the spanner is
A. 3 N
B. 12 N
C. 120 N
D. 300 N
**Question 7**
Gear A rotates at 12 rpm in the hydraulic pump below.

![Gear Configuration Diagram]

Gear B will rotate at
A. 10 rpm
B. 12 rpm
C. 14.2 rpm
D. 120 rpm

**Question 8**

![Lever Diagram]

The mechanical advantage of this lever is
A. 0.25
B. 4
C. 10
D. 40

**Question 9**
Which capacitance value is the smallest?
A. 10 farads
B. 47 microfarads
C. 220 millifarads
D. 100 nanofarads
Question 10
The four switches, S1 to S4, in the circuit shown below are in the OFF position.

![Circuit diagram](image)

When turned ON, which pair of switches will allow the motor to operate?
A. S1 and S2  
B. S1 and S3  
C. S1 and S4  
D. S3 and S4

Question 11
Batteries can be connected in series or in parallel.
The main advantage of connecting batteries in parallel is to increase the
A. current drawn.  
B. voltage available.  
C. internal resistance.  
D. external resistance.
**Question 12**

Below is the display on a cathode ray oscilloscope.

Given that the horizontal scale is 0.01 seconds per division and the vertical scale is 2 volts per division, the voltage and frequency of the above signal are

A. 3 volts and 1 Hz  
B. 3 volts and 2 Hz  
C. 6 volts and 50 Hz  
D. 6 volts and 100 Hz

**Question 13**

The total resistance between points X and Y is

A. 4 R  
B. 12 R  
C. 18 R  
D. 36 R
Question 14

The number of output windings in the diagram above is
A. 16
B. 18
C. 4320
D. 4608

Question 15

Which of the truth tables below represents the circuit above?
A.  
B.  
C.  
D.  

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Question 16

In an electronic circuit, the main purpose of an electromagnetic relay switch is to allow
A. a small output current using a large input current.
B. a small output current using a small input current.
C. a large output current using a large input current.
D. a large output current using a small input current.

Question 17

A globe has a power rating of 24 watts. The globe has 200 mA passing through it.
What is the voltage?
A. 120 mV
B. 4.8 V
C. 48 V
D. 120 V
**Question 18**
A design brief is best described as which of the following?
A. the process of designing a product  
B. the process of constructing a product  
C. the instruction to a designer from a client  
D. the plan for constructing a product

**Question 19**

The system in box X is best described as
A. a closed-loop system.  
B. an open-loop system.  
C. a control system.  
D. a feedback loop.

**Question 20**
The flow chart below is for the operation of a flashing LED on a programmable integrated circuit. High 0 turns the LED on. Low 0 turns the LED off. Wait 1 gives a 1-second time delay.

Which of the following is true?
A. It is a closed-loop circuit where the flashing LED has a period of 1 second.  
B. It is an open-loop circuit where the flashing LED has a period of 1 second.  
C. It is a closed-loop circuit where the flashing LED has a period of 2 seconds.  
D. It is an open-loop circuit where the flashing LED has a period of 2 seconds.
Forklifts are used in many industries including supermarkets and manufacturing. They may be used to move materials. The forklift below is powered by an electric motor and hydraulics are used to raise and lower the load.

Figure 1

**Question 1**
Explain why this forklift is an integrated system.

1 mark

**Question 2**
Is the forklift an open-loop system or a closed-loop system? Explain your answer.

1 mark

**Question 3**
It is unsafe to drive a forklift while the load is raised high.
Give two valid safety reasons why this is so.

i.  

ii.  

2 marks
Figure 2 is a diagram of the mast and hydraulic system of a forklift.

![Diagram of mast and hydraulic system](image)

**Figure 2**

**Question 4**
If the hydraulic arm is extended 500 mm from its current position, what distance is the 2000 N load raised?

__________________________

1 mark

**Question 5**
Given that the effort applied to the hydraulic arm and cylinder is 4000 N, calculate the mechanical advantage of the system.

__________________________

1 mark

A 2000 N load is raised a distance of 600 mm.

**Question 6**
Calculate, in joules, the work done. Show working and include units.

__________________________

__________________________

__________________________

2 marks
The hydraulic cylinder has a diameter of 150 mm. The hydraulic arm has a diameter of 30 mm.

Question 7
Given that this hydraulic pump produces a pressure of 100 000 Pa, calculate the maximum force that acts on the hydraulic piston as the arm is forced up. Show working and include units.

3 marks
Figure 4a shows the original hydraulic cylinder. This cylinder developed a fault and a service person replaced it with another type of cylinder as shown in Figure 4b.

**Figure 4a**

**Figure 4b**

**Question 8**

Give two negative effects of using the replacement cylinder rather than the original cylinder. (Note the design configuration of the replacement cylinder.)

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

2 marks
The drive of the forklift is powered by an electric motor that is connected to a battery power pack. The motor requires 48 volts and draws a current of 200 amps.

**Question 9**
Calculate the power of the electric motor. Show working and include units.

---

**Question 10**
The battery power pack consists of a number of 12-volt batteries connected in series and/or parallel.

On the diagram below, draw the connections between the battery terminals to produce a 48-volt supply across the terminals A(+) and B(−).

---

Using 4 batteries, the forklift can run for 2.5 hours before a recharge is necessary. To increase the operating time, 8 batteries could be used.

**Question 11**
On the diagram below, draw the connections between all the batteries to produce a 48-volt supply across terminals A(+) and B(−).

---

SECTION B – continued
The electric motor of the forklift is found to be running slowly. A service person suspects there is an open-circuit battery. Each battery is isolated before being tested.

**Question 12**
a. Name a diagnostic test instrument that can be used to test the voltage output of the batteries.

b. One of the batteries is found to be open circuit. What is the expected reading on the diagnostic test instrument?

The electric motor of the forklift must power the forklift so it can move forwards or backwards.

**Question 13**
Explain what would happen if the motor was connected as shown in each of the following cases.

---

1 mark

1 mark

3 marks
The electric motor drives the axle and wheels of the forklift via a gearbox and differential assembly as shown in Figure 5.

![Figure 5: Differential assembly diagram](image)

**Question 14**
Name the type of gears that are used in the differential assembly.

1 mark

**Question 15**
Give the main function of the differential assembly as shown in Figure 5.

1 mark
Gear A has 12 teeth and gear B has 36 teeth as shown in Figure 6.

The forklift is moving in a straight line.

**Question 16**
If the wheel axle rotates at 100 rpm, calculate the rpm of the drive shaft. Show working.

The circumference of the wheel (Figure 5) is 1 m.

**Question 17**
What is the speed of the forklift? Show working and include units.
The motor to drive shaft needs to have a reduction ratio of 12:1.

**Question 18**
Design a functional gearbox to give the needed ratio. Clearly show the number of teeth of each gear.

**Note:** The gearbox is big enough to have a maximum gear size of 50 teeth. A spur gear will not work with less than 8 teeth.
The operators of the forklift discuss whether to use solar energy to recharge the batteries.

**Question 19**
Complete the following table. Give the input form of energy and output form of useful energy for each subsystem.

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Input form of energy</th>
<th>Output form of useful energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar cells</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Battery</td>
<td></td>
<td></td>
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<tr>
<td>Motor</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A typical solar cell is 18% efficient.

**Question 20**
If 450 joules of energy fall on the solar cell, how much useful output energy is produced? Show working.

2 marks

**Question 21**
Give two negative impacts on the environment that are due to the life cycle of a solar cell.

2 marks
The forklift operators decide to use solar energy to recharge the batteries. Each lead-acid battery that powers the forklift is recharged using solar energy. An electronic circuit between the solar panel and the battery allows for voltage regulation and isolation. This circuit is shown in Figure 8.

![Figure 8](image)

An analogue ammeter is connected to the battery to monitor the charging current.

**Question 22**
On Figure 8 draw an ammeter to measure the charging current of the battery.

1 mark

Component R₁ in Figure 8 is a $\frac{1}{4}$ watt resistor with a value of 180 ohms and a tolerance of 5%.

**Question 23**
Write down the four colours (in order) that are found on the resistor R₁.

1 mark

Components R₂ and R₃ are both 330 ohm resistors.

**Question 24**
What is the combined resistance of R₂ and R₃ as connected in this circuit?

1 mark

**Question 25**
Name the component D₁ and explain its function in the circuit.

2 marks
Large electric currents can pass through power transistors $Q_1$ and $Q_2$ when the battery is being charged. Such large currents may destroy the transistors.

**Question 26**
What modification can be made to keep these transistors functioning under the condition described above.

1 mark

The transistor $Q_1$ is a BD649.

<table>
<thead>
<tr>
<th>Transistor</th>
<th>Type</th>
<th>Polarity</th>
<th>Power</th>
<th>Collector current</th>
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<tbody>
<tr>
<td>1</td>
<td>BD649 (not available)</td>
<td>NPN</td>
<td>60 W</td>
<td>8 A</td>
</tr>
<tr>
<td>2</td>
<td>BD650</td>
<td>PNP</td>
<td>60 W</td>
<td>8 A</td>
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<td>3</td>
<td>MJE2995</td>
<td>PNP</td>
<td>75 W</td>
<td>10 A</td>
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<td>6</td>
<td>TIP41C</td>
<td>NPN</td>
<td>65 W</td>
<td>6 A</td>
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</table>

**Question 27**
$Q_1$ stops working and needs to be replaced. A replacement BD649 is not available. Select a transistor from the table above that would be the most suitable replacement.

Transistor number

1 mark
The recharging circuit for the batteries and an incomplete circuit board are shown below.

Question 28
On the diagram of the printed circuit board above, draw the two missing tracks.

1 mark

Question 29
a. Identify two processes in the construction of a circuit board where people may be exposed to the risk of injury.

i. ____________________________  ii. ____________________________  
2 marks

b. Explain a practical solution for reducing the likelihood of injury for the processes identified above.

i. ____________________________

ii. ____________________________  

2 marks
Work done = force × distance moved

Gear ratio final = gear ratio 1 × gear ratio 2

Efficiency = \(\frac{\text{output energy}}{\text{input energy}}\) × 100%

Voltage = current × resistance

Resistance in parallel = \(\frac{R_1 \times R_2}{R_1 + R_2}\)

Colour codes

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<th>Value</th>
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<tr>
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<tr>
<td>silver</td>
<td>10%</td>
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</table>

Resistance in series = \(R_1 + R_2\)

\(V = \frac{P}{I}\)

Area of circle = \(\pi r^2\) \(\pi = 3.14\)

Force = pressure × area

gear A rpm = number of teeth gear B

\(\text{gear B rpm} = \frac{\text{number of teeth gear A}}{\text{radius of pulley B}}\)

\(\text{pulley B rpm} = \frac{\text{radius of pulley A}}{\text{radius of pulley B}}\)

\(V_{\text{in}} = \frac{N_{\text{in}}}{N_{\text{out}}}\)

Speed = \(\frac{\text{distance}}{\text{time}}\)

Gear ratio = \(\frac{\text{number of teeth on driven gear}}{\text{number of teeth on driver gear}}\)

Mechanical advantage = \(\frac{\text{load}}{\text{effort}}\)

Torque = force × distance