

**UNIVERSITY OF GREATER MANCHESTER**

**SCHOOL OF ENGINEERING AND BUILT  
ENVIRONMENT**

**MSc Biomedical Engineering**  
**MSc Electrical and Electronic Engineering**  
**MSc Mechanical Engineering**  
**MSc Robotics, Autonomous Systems and  
Telecommunications**

**Semester One Examination 2025/2026**

**SMART ENGINEERING SYSTEMS**

**MODULE NO: MSE7013**

Date: Friday 16<sup>th</sup> January 2026

Time: 2pm – 4:30pm

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**INSTRUCTIONS TO CANDIDATES:**

There are 5 questions.

Answer any 4 questions.

All questions carry equal marks.

Marks for parts of questions are shown  
in brackets.

This examination paper carries a total of  
100 marks.

All working must be shown. A  
numerical solution to a question  
obtained by programming an electronic  
calculator will not be accepted.

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**Question 1**

- (a) Critically evaluate the distinction between **Smart Devices**, **Edge Devices**, and **Wireless Sensor Networks (WSNs)** in terms of functionality, interoperability, and system intelligence. **(7 marks)**
- (b) Examine how **data governance frameworks** and **security architectures** influence **privacy and trust** in large-scale IoT ecosystems. Propose and justify improvements based on emerging standards or technologies. **(8 marks)**
- (c) Evaluate the main **ethical and societal challenges** associated with the proliferation of **app-based IoT systems**, including user consent, data ownership, and algorithmic transparency. **(6 marks)**
- (d) With the use of an example, explain the significance of the **Physical Layer** within the **OSI model** in maintaining IoT network resilience and performance. **(4 marks)**
- (Total 25 marks)**

**Question 2**

- (a) Critically explain the function of **CSMA/CD** in Ethernet networks. Evaluate how this mechanism manages data collisions and the limitations it imposes on network scalability. **(6 marks)**
- (b) Compare the design philosophy and scalability mechanisms of IPv4 and IPv6 in the context of smart engineering systems that demand massive device connectivity. Evaluate how IPv6 features (such as address autoconfiguration and header simplification) contribute to system resilience and security in industrial IoT environments. **(5 marks)**
- (c) Analyse how the **IEEE 802.11 standard** improves collision management in wireless networks through its **CSMA/CA mechanism**. Comment on the trade-offs involved. **(7 marks)**
- (d) Rationalise the **role of configuration management** in the growth of IoT. Discuss the benefits and potential risks associated with **self-configurable IoT architectures**. **(7 marks)**

**(Total 25 marks)**

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### Question 3

(a) A communications satellite with a mass of 800 kg is in a circular orbit around the Earth at a distance of 42,000 km from the Earth's center. The Earth's mass is  $5.97 \times 10^{24}$  kg and the gravitational constant  $G = 6.67 \times 10^{-11} \text{N}\cdot\text{m}^2/\text{kg}^2$ .

(i) Calculate the gravitational force  $F_1$  acting on the satellite.

(ii) Using the force balance condition  $F_1 = F_2$ , find the orbital velocity of the satellite. **(12 marks)**

(b) An earth station is located at Latitude  $40^\circ$  North and Longitude  $80^\circ$  West. It needs to point its antenna at a geostationary satellite parked at Longitude  $99^\circ$  West.

(i) Calculate the geostationary arc angle  $G$ .

(ii) Substitute the values into the formula and compute the azimuth angle  $\beta$  (in degrees).

(iii) Based on the earth station's location and the satellite's position, determine the correct quadrant for the azimuth and state the final azimuth direction with respect to True North. **(13 marks)**

**(Total 25 marks)**

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#### Question 4

- (a) Draw a UML Use Case Diagram for the Elevator Control System as described in Figure Q4. Your diagram should identify all key actors, interactions, and system boundaries.

Critically discuss how your diagram supports functional completeness and stakeholder traceability within the system's requirements. **(10 marks)**

- (b) Develop a UML Class Diagram for the Elevator Control System described in Figure Q4. Show all major classes, their relationships, attributes, and methods.

In addition to the diagram, justify your design choices in terms of modularity, encapsulation, and maintainability, and explain how the model supports scalability or fault tolerance in complex system environments. **(15 marks)**

**Question 4 continued over page 5**

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PAST EXAMINATION

**Question 4 continued**

A software system must control one elevator for a building with 20 floors. The elevator contains a set of buttons, each corresponding to a desired floor. These are called floor request buttons, because they indicate a request to go to a specific floor. The elevator also has a current floor indicator above the door. Each floor (except the highest and lowest) has two buttons for requesting elevators, called elevator request buttons, because they request the elevator.

Each floor has a sliding door for the shaft arranged so that two door halves meet in the centre when closed. When the elevator arrives at the floor, the door opens at the same time the door on the elevator opens; these two sets of doors can be treated as one door since the two only ever open together. The door has both pressure and optical sensors to prevent closing when an obstacle is between the two door halves. If an obstruction is detected by either sensor, the door shall open. The door shall automatically close after a timeout period of five seconds after the door opens. The detection of an obstruction shall restart the door closure time after an obstruction is removed. There is a speaker on each floor that "pings" in response to the arrival of an elevator.

On each floor (except the highest and lowest), there are two elevator request buttons, one for UP and one for DOWN. On each floor, above the elevator door, there is an indicator that specifies the floor the elevator is currently at and another indicator for its current direction. The system shall respond to an elevator request by sending the elevator if it is already going in the requested direction, or if the elevator is idle. If the elevator is travelling in the opposite direction, the request shall pend until the elevator meets the above criterion. Once pressed, the request buttons are backlit to indicate that a request is pending. Pressing an elevator request button when a request for that direction is already pending shall have no effect. When an elevator arrives to handle the request, the backlight shall be removed. If the button is pressed when the elevator is on the floor to handle the request, then the door shall stop closing and the door closure timer shall be reset.

To enhance safety, a cable tension sensor monitors the tension on the cable that controls the elevator. In the event of a failure in which the measured tension falls below a critical value, then four external locking clamps connected to running tracks in the shaft stop the elevator and hold it in place.

**Figure Q4**

**(Total 25 marks)**

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### Question 5

(a) For a complex, remotely located system like a large-scale offshore wind turbine:

- i) Provide one clear functional requirement and one critical non-functional requirement.
- ii) Analyse a potential conflict that could arise between your chosen non-functional requirement and other system requirements (functional or non-functional).
- iii) Suggest a systems engineering approach to resolve this conflict.

**(9 marks)**

(b) A company that traditionally manufactures individual elevator components is transitioning to become a provider of fully integrated, smart elevator systems. Critically assess how the adoption of the processes in ISO/IEC 15288 could help this company manage the increased complexity and risks associated with this strategic shift. Identify one potential challenge in its implementation.

**(7 marks)**

(c) Considering the six general principles of Design for Reliability:

- i) The control system for an elevator's emergency brake is a critical safety element. Explain why Diversity is a more appropriate principle than Redundancy alone for this specific subsystem.
- ii) Propose a specific design for a diverse emergency brake control system, specifying the different technologies or methods for the primary and diverse backup paths.
- iii) Briefly explain how the principle of Minimum Complexity must be balanced against the need for this diversity.

**(9 Marks)**

**(Total 25 marks)**

**END OF QUESTIONS**

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## Formula sheet

These equations are given to save short-term memorisation of details of derived equations and are given without any explanation or definition of symbols; the student is expected to know the meanings and usage.

### Newton's Law of Universal Gravitation

$$F_1 = \frac{GMm}{R^2}$$

### Centripetal Force Equation

$$F_2 = \frac{mv^2}{R}$$

### Satellite Look Angle (Elevation Angle)

$$\beta = \tan^{-1} \left( \frac{\cos G \cdot \cos L - 0.151}{\sqrt{1 - \cos^2 G \cdot \cos^2 L}} \right)$$

### Geocentric Angle Between Two Points on Earth

$$\cos \psi = \sin \varphi_g \sin \varphi_s + \cos \varphi_g \cos \varphi_s \cos \Delta \lambda$$

### Distance Between Ground Station and Satellite

$$r = \sqrt{R_e^2 + R_s^2 - 2R_e R_s \cos \psi}$$

### Downlink Carrier-to-Noise Ratio

$$\left( \frac{C}{N} \right)_{\text{dB}} = EIRP + G_r - L_p - L_s - (10 \log_{10}(k) + 10 \log_{10}(T_s) + 10 \log_{10}(B))$$

### Antenna Gain Formula

$$G = \eta \left( \frac{4\pi A}{\lambda^2} \right)$$

**END OF PAPER**