Embedded systems

Embedded systems are specialised computers built into everyday objects, designed to perform specific tasks and control a device's functionality based on sensor input and programmed instructions. Many of them operate in real-time. Eg. monitoring the temperature in a washing machine or the insulin levels in a patient's blood.

Consumer Electronics:	**Home Appliances:**	**Industrial Applications:**	**Everyday Items:**
Smartphones and wearables Eg. sensing heart rate, or 'steps' and outputting info on a screen or via sound	**Microwave ovens**: Manages cooking time, power levels, and displays. Inputs usually buttons but could also be voice-activated using a microphone	**Traffic light controllers:** Manages traffic flow based on sensor data and pre-programmed timing. Inputs may be sensors in the road, or cameras.	**Calculators**: Performs mathematical operations based on user input.
Handheld gaming device. Takes inputs from buttons or touchscreen. Outputs are via speakers or screen	**Washing machines:** Optimises washing cycles based on sensor data and user settings. Controls water temperature, spin cycles, water levels. Inputs usually via buttons but also if a smart machine could be via an app or even via voice/mic.	**Factory robots**: Executes precise movements and actions based on control programs. Inputs via cameras, sensors or external controls.	**Modern cars:** Manages the engine, braking system, airbag control, automatic wipers/lights, help with reversing/parking, cruise control, alerts a driver if they come out of their lane. A wide range of sensors and cameras involved.
Televisions. Inputs may be via a camera, touch screen, microphone or remote control.	**Smart thermostats**: Learns your temperature preferences and controls heating/cooling automatically. Inputs remotely via an app, via buttons or via temperature sensors to adjust room temperature automatically.	**Medical devices**: Monitors vital signs or delivers controlled medication dosages. Inputs may be sensors or external control. Eg. pacemakers, insulin pumps	**Security systems**: Monitors sensors for alarms, controls cameras, and sends alerts. Inputs may be motion sensors, pressure sensors and/or cameras

Embedded systems follow **the input-process-output** model of all computers. The processor is known as a **microprocessor**.

Questions

1. Embedded systems are specialized computers designed for:

(a) General-purpose computing tasks
(b) Running complex operating systems
(c) Performing specific tasks within a device
(d) High-performance gaming applications

2. Which of the following is **NOT** a typical characteristic of an embedded system?

(a) Limited processing power
(b) Low power consumption
(c) Ability to connect to networks
(d) Designed for a specific purpose

3. An embedded system in a fitness tracker might receive input from:

(a) Keyboard and mouse
(b) Motion sensors and heart rate monitor
(c) Webcam and microphone
(d) All of the above

4. An embedded system in a smart thermostat might use sensor data to:

(a) Play music and videos
(b) Adjust room temperature automatically
(c) Run complex calculations
(d) Display a variety of websites

5. Embedded systems often rely on pre-programmed instructions called:

(a) Web applications
(b) Operating systems
(c) Firmware
(d) Word processing software

6. Explain the key differences between an embedded system and a personal computer like a laptop.

7. Describe two situations where embedded systems are used in everyday life.

8. Why is it important for an embedded system to be energy-efficient?

9. A baby monitor uses a microphone to record sound.
Describe how an embedded system within a baby monitor can be used to alert parents about changes in room temperature.

10. One example of an embedded system in a car is automatic headlights.
Explain how an embedded system could control the headlights of a car.

11. Explain one function of the embedded system in a washing machine.

ANSWERS

1. (c) Performing specific tasks within a device

2. c) Ability to connect to networks

3. (b) Motion sensors and heart rate monitor

4. (b) Adjust room temperature automatically

5. (c) Firmware

6. An embedded system is a low-power, low-storage computer system that is designed to do one set of specialised tasks, often within a larger system.Embedded systems have a set of pre-programmed instructions that cannot be changed, whereas laptops use complex operating systems that can load many different types of software. A laptop will have a higher power consumption and greater memory and storage. A laptop is a general-purpose computer and is able to perform a wide-range of different tasks.

7. You could use any number of examples from the table given and from your own knowledge. Here is just an example:
   Smartwatch Health Tracking: A smartwatch relies on an embedded system to process data from sensors like a heart rate monitor and accelerometer (senses the position of the watch – used for measuring steps). It analyses this information to track steps, calories burned, and even sleep patterns. **Microwave Cooking**: The brains behind a microwave are an embedded system. It controls the power level, cooking time, and displays information. It takes input from the buttons pressed and uses pre-programmed settings to generate the precise amount of microwave radiation for the chosen cooking task.

8. Many embedded systems rely on batteries for power. High energy consumption would drain batteries quickly, requiring frequent replacements. This is not desirable and not always practical. Eg. an insulin pump or pacemaker inserted into a patient. Embedded systems are often compact and integrated within devices with limited space. Low power consumption translates to less heat generation. This is crucial to prevent overheating and potential damage to the delicate components within the system itself or the surrounding device.

9. The input for the baby's rooom temperature monitor would be a temperature sensor. The microprocessor would check the temperature input via the sensor to a pre-programmed range. If the temperature was outside of this range, either too hot or too cold, an alert would be sent to parents. This could be visual via a screen (eg. flashing light) or via an app on a phone screen; or it could be an audible alarm – via speakers.

10. The input for the car's automatic headlight system could be a light sensor. The microprocessor would receive the input and compare the light levels to a preset range. If the levels are outside the preset range, the microprocessor would send a signal to turn on or off the headlights.

11. An embedded system controls the water temperature. The user selects a program which will include water temperature information. Heat sensors will detect the water temperature. The microprocessor will receive the temperature data and send a signal to adjust a heat element to get the water to the desired temperature and keep it there.