Grade 13 A/L ICT

Lesson 11: Internet of Things

- 11.1 Microprocessor Development Systems
- 11.2 Internet of Things (IoT)

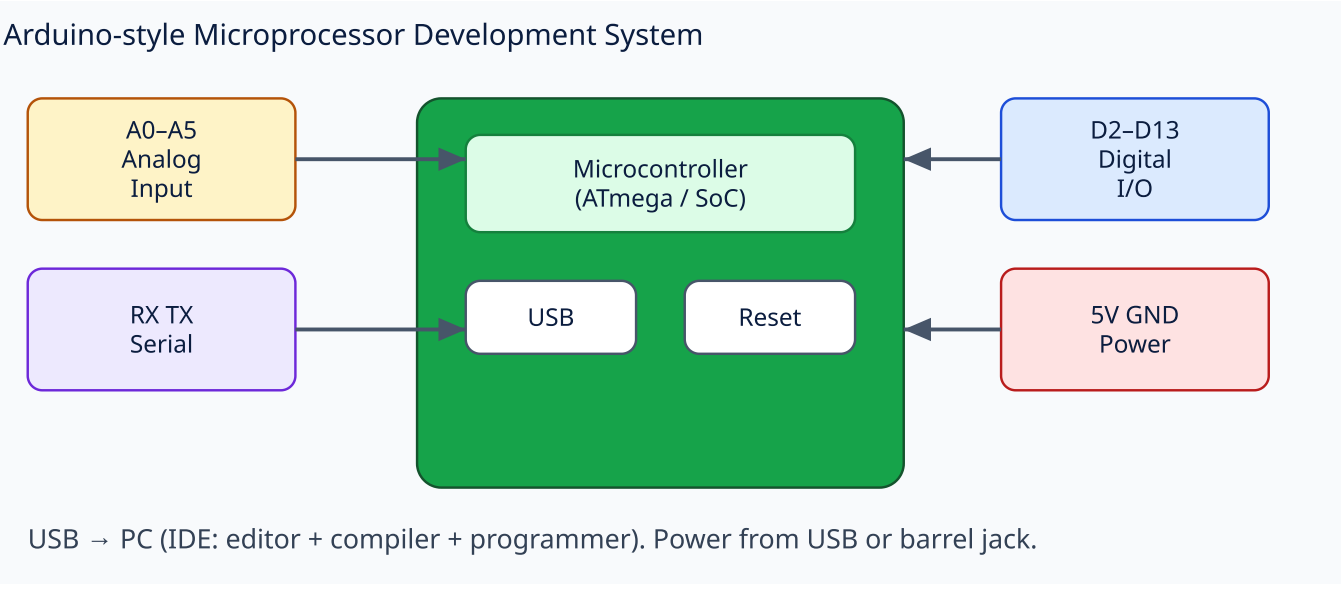
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Grade 13 A/L ICT · Lesson 11

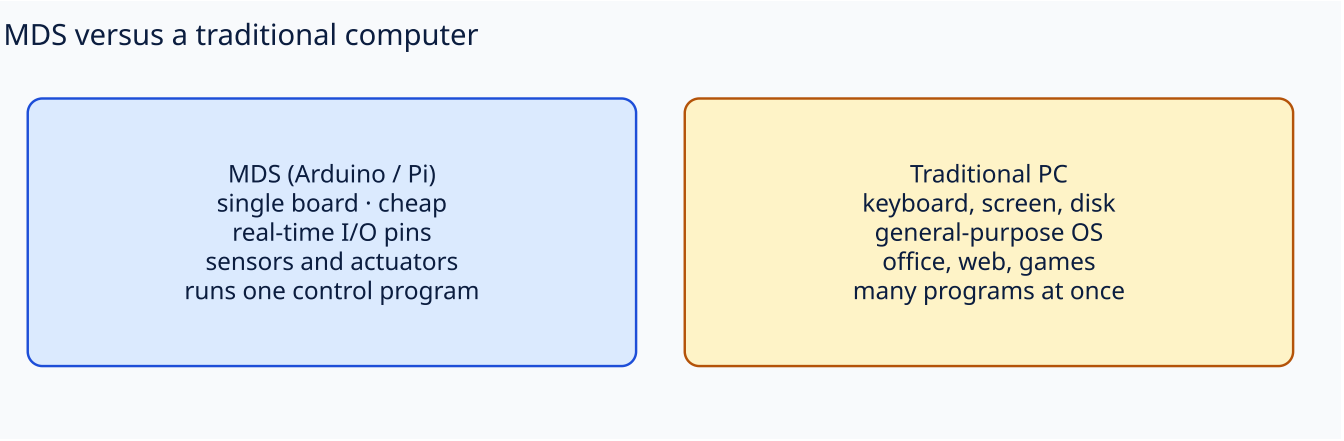
11.1 Microprocessor Development Systems

Syllabus 11.1. A **Microprocessor Development System (MDS)** is a single board (Arduino, Raspberry Pi and similar boards) with a **microcontroller**, **I/O pins** and ports you can program. Unlike a traditional PC, an MDS is cheap, talks directly to **sensors** and **actuators**, and runs one control program in real time. You write a sketch in an **IDE** (editor, compiler, programmer), upload it over **USB**, and build simple applications: LEDs, LDR lighting, temperature fans and magnetic door switches.

1. What is an MDS?



Arduino-style board and its main parts



MDS compared with a traditional computer

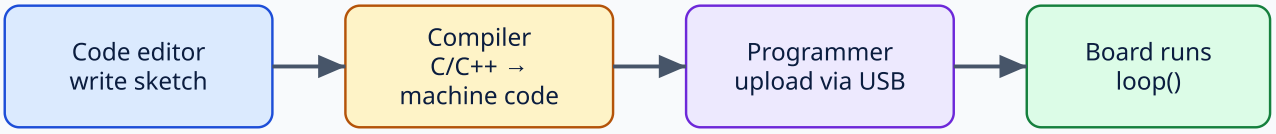
- **Microcontroller** – the “brain” that runs your program.
- **Analog input** (A0–A5) – reads voltages from sensors (0–5 V → 0–1023).
- **Digital input / output** (D2–D13) – HIGH or LOW for buttons, LEDs, relays.

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- **RX / TX** – serial communication; **USB** – power and programming; **Reset** – restart; **Power** – 5 V / 3.3 V / GND.

2. Connecting and the IDE

Arduino IDE toolchain



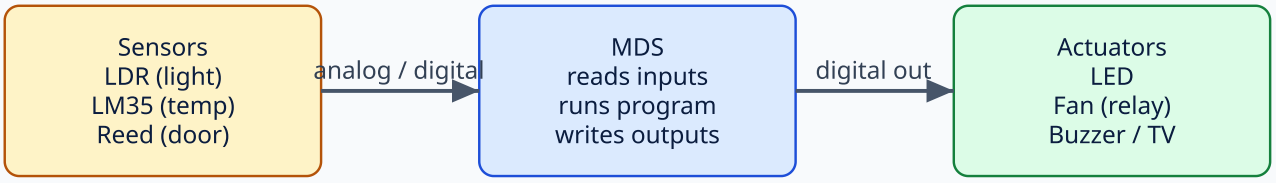
Download the IDE free from the Internet; select the board and the COM/serial port.

Editor, compiler and programmer

- Download the free **Arduino IDE** (or similar) from the Internet.
- Connect the board to the PC with a **USB** cable; select the board and the COM/serial port.
- Write the sketch → **Verify/Compile** → **Upload**. setup() runs once; loop() runs forever.

3. Sensors, actuators and numbers

Sensors → MDS → actuators

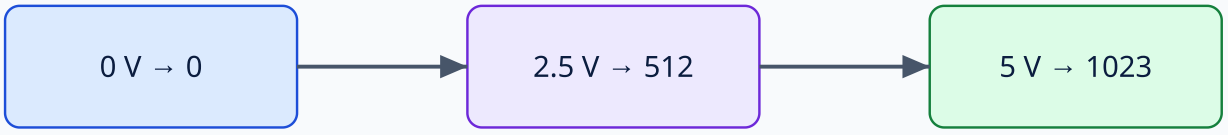


Analog input (A0): 0–5 V → ADC → 0–1023. Digital I/O: HIGH ≈ 5 V, LOW ≈ 0 V.

LED resistor R = (Vcc − Vf) / I. Example: (5 − 2) / 0.02 = 150 Ω.

From sensors through the MDS to actuators

10-bit ADC: voltage to a number



Step = Vref / 1024 ≈ 4.88 mV. V = raw × 5 / 1024.

LM35: 10 mV/°C → T (°C) = V × 100.

How the 10-bit ADC turns voltage into a number

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Quantity	Value
ADC levels (10-bit)	1024
Voltage step (5 V / 1024)	≈ 0.005 V
raw 820 → voltage	4.004 V
LDR divider in light (2 kΩ + 10 kΩ)	4.167 V
LDR divider in dark (50 kΩ + 10 kΩ)	0.833 V
LED series resistor (5 V, Vf 2 V, 20 mA)	150 Ω
PWM duty 64/255	25.1% → 1.25 V avg

🧱 **Worked example: Why does raw 820 mean about 4.004 V, and which LED resistor do you need?**
V = raw × Vref / 1024 = 820 × 5 / 1024 ≈ **4.004 V**. For a red LED, R = (Vcc − Vf) / I = (5 − 2) / 0.02 = **150 Ω**.

4. Application 1 – Blink an LED

🔌 Blink an LED on pin 13

```
// Blink LED on pin 13 (built-in LED on many Arduino boards)
const int LED = 13;

void setup() {
  pinMode(LED, OUTPUT);   // digital output
}

void loop() {
  digitalWrite(LED, HIGH);  // LED on
  delay(1000);              // wait 1 second
  digitalWrite(LED, LOW);   // LED off
  delay(1000);
}
```

▶ Simulated run

```
LED 13 = HIGH
delay 1000 ms
LED 13 = LOW
delay 1000 ms
(loop repeats)
```

5. Application 2 – Ambient light (LDR) controls an LED

🔌 Switch LED on when it is dark (LDR)

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```
// LDR on A0 (voltage divider with 10 kΩ); LED on pin 8
const int LDR = A0;
const int LED = 8;
const int THRESHOLD = 400;   // below this = dark

void setup() {
  pinMode(LED, OUTPUT);
  Serial.begin(9600);
}

void loop() {
  int light = analogRead(LDR);   // 0–1023
  Serial.print("Light: ");
  Serial.println(light);
  if (light < THRESHOLD) {
    digitalWrite(LED, HIGH);     // dark → LED on
  } else {
    digitalWrite(LED, LOW);      // bright → LED off
  }
  delay(500);
}
```

▶ Simulated run

```
Light: 820
LED 8 = LOW
delay 500 ms
Light: 180
LED 8 = HIGH
delay 500 ms
```

> 🧱 **Worked example: At raw 820 the LED is off; at raw 180 it turns on. Why?**
> 820 is above the threshold 400 (bright → LED LOW). 180 is below 400 (dark → LED HIGH).

6. Application 3 – Temperature sensor runs a fan

🔌 Run a fan when temperature is high

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```
// LM35 on A1 (10 mV/°C); fan relay on pin 7
const int TEMP = A1;
const int FAN = 7;
const float ON_C = 28.0;
const float OFF_C = 26.0;
int fanOn = 0;

void setup() {
  pinMode(FAN, OUTPUT);
  Serial.begin(9600);
}

void loop() {
  int raw = analogRead(TEMP);
  float volts = raw * (5.0 / 1024.0);
  float celsius = volts * 100.0;   // LM35: 10 mV per °C
  Serial.print("Temp: ");
  Serial.print(celsius);
  Serial.println(" C");
  if (celsius >= ON_C) {
    digitalWrite(FAN, HIGH);
    fanOn = 1;
  } else if (celsius <= OFF_C) {
    digitalWrite(FAN, LOW);
    fanOn = 0;
  }
  // between OFF_C and ON_C keep previous state (hysteresis)
  delay(1000);
}
```

▶ Simulated run

```
Temp: 24.9 C
FAN 7 = LOW
delay 1000 ms
Temp: 29.8 C
FAN 7 = HIGH
delay 1000 ms
Temp: 26.9 C
FAN 7 stays HIGH (hysteresis)
delay 1000 ms
Temp: 25.4 C
FAN 7 = LOW
delay 1000 ms
```

🧱 Worked example: Trace the four readings [24.9, 29.8, 26.9, 25.4] °C. When does the fan change?

24.9 ≤ 26 → fan **LOW**. 29.8 ≥ 28 → fan **HIGH**. 26.9 is between 26 and 28 so hysteresis keeps it **HIGH**. 25.4 ≤ 26 → fan **LOW** again. LM35: T = V × 100 with V = raw × 5 / 1024.

7. Application 4 – Magnetic door switch

🔌 Door open/close with a magnetic switch

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```
// Reed (magnetic) switch on pin 2 with INPUT_PULLUP; alarm LED on pin 9
// Magnet near switch → pin reads HIGH (closed); magnet away → LOW (open)
const int DOOR = 2;
const int ALARM = 9;

void setup() {
  pinMode(DOOR, INPUT_PULLUP);
  pinMode(ALARM, OUTPUT);
  Serial.begin(9600);
}

void loop() {
  int state = digitalRead(DOOR);
  if (state == LOW) {
    Serial.println("Door OPEN");
    digitalWrite(ALARM, HIGH);
  } else {
    Serial.println("Door CLOSED");
    digitalWrite(ALARM, LOW);
  }
  delay(200);
}
```

▶ Simulated run

```
Door CLOSED
ALARM 9 = LOW
delay 200 ms
Door OPEN
ALARM 9 = HIGH
delay 200 ms
```

💡 Use INPUT_PULLUP for a reed switch so the pin is HIGH when the door is closed (magnet present) and falls LOW when it opens.

🚀 **Beyond the syllabus (2026 update)** *Not required for the exam – read for interest.* In 2026 school MDS boards often ship with Wi-Fi (ESP32) already on the board, so the same LED and sensor sketches can talk to a phone app with a few extra lines.

Key Words

MDS – Microprocessor Development System – a programmable single board.

Microcontroller – Chip that runs the control program on the board.

Analog input – Pin that measures a voltage as a number.

Digital I/O – Pin that is either HIGH or LOW.

ADC – Analog-to-digital converter (e.g. 10-bit, 0–1023).

Sensor – Device that measures a physical quantity.

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Actuator – Device the MDS drives – LED, motor, relay, buzzer.

LDR – Light-dependent resistor used to sense light.

LM35 – Temperature sensor that outputs 10 mV per °C.

Reed switch – Magnetic switch used to detect a door open/close.

IDE – Software with editor, compiler and programmer.

USB – Cable/port used to power and program the board.

Sample Q&A

1. MDS vs traditional PC – one difference?

> **Answer:** MDS talks directly to sensors/actuators; a PC is general-purpose.

2. What does the 10-bit ADC return for 5 V?

> **Answer:** 1023 (0–1023).

3. Voltage for raw 820?

> **Answer:** About 4.004 V.

4. LED resistor for 5 V, Vf 2 V, 20 mA?

> **Answer:** 150 Ω.

5. When does the LDR sketch turn the LED on?

> **Answer:** When analogRead is below 400 (dark).

6. Why use hysteresis on the fan?

> **Answer:** Stops the fan switching on/off rapidly near the threshold.

MCQ

1. An Arduino board is an example of a

A. web server
B. hard disk
C. Microprocessor Development System
D. desktop PC
E. router only

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2. Pins A0–A5 are mainly used for

A. USB power
B. reset
C. crystal clocks
D. Wi-Fi only
E. analog input

3. A 10-bit ADC maps 0–5 V to

A. 0–1023
B. 0–100
C. 0–5
D. 0–255
E. 0–65535

4. raw 820 equals about

A. 1.000 V
B. 2.500 V
C. 5.000 V
D. 4.004 V
E. 0.500 V

5. LED series resistor (5 V, Vf 2 V, 20 mA) is

A. 220 Ω
B. 50 Ω
C. 150 Ω
D. 100 Ω
E. 1 kΩ

6. In the LDR sketch, raw 180 makes the LED

A. LOW (off)
B. HIGH (on)
C. reset
D. blink
E. TX

7. LM35: 10 mV/°C. Near 29.8 °C the fan turns

A. HIGH (on)
B. reset
C. TX only
D. LOW forever
E. compile error

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8. A magnetic reed switch on a door is a

A. actuator
B. router
C. sensor
D. compiler
E. power supply

9. Which term means: “Microprocessor Development System – a programmable single board”?

A. IDE
B. LDR
C. Sensor
D. Analog input
E. MDS

10. Which term means: “Chip that runs the control program on the board”?

A. USB
B. Microcontroller
C. Actuator
D. Digital I/O
E. LM35

11. Which term means: “Pin that measures a voltage as a number”?

A. ADC
B. LDR
C. MDS
D. Reed switch
E. Analog input

12. Which term means: “Pin that is either HIGH or LOW”?

A. LM35
B. IDE
C. Sensor
D. Digital I/O
E. Microcontroller

13. Which term means: “Analog-to-digital converter (e.g. 10-bit, 0–1023)”?

A. Actuator
B. Analog input
C. USB
D. ADC
E. Reed switch

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14. Which term means: “Device that measures a physical quantity”?

A. Sensor
B. Digital I/O
C. IDE
D. LDR
E. MDS

15. Which term means: “Device the MDS drives – LED, motor, relay, buzzer”?

A. Actuator
B. LM35
C. USB
D. Microcontroller
E. ADC

16. Which term means: “Light-dependent resistor used to sense light”?

A. Analog input
B. MDS
C. Reed switch
D. Sensor
E. LDR

17. Which term means: “Temperature sensor that outputs 10 mV per °C”?

A. Digital I/O
B. LM35
C. IDE
D. Actuator
E. Microcontroller

18. Which term means: “Magnetic switch used to detect a door open/close”?

A. ADC
B. Analog input
C. Reed switch
D. LDR
E. USB

19. Which term means: “Software with editor, compiler and programmer”?

A. LM35
B. IDE
C. Sensor
D. MDS
E. Digital I/O

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20. Which term means: “Cable/port used to power and program the board”?

A. ADC
B. Reed switch
C. Actuator
D. USB
E. Microcontroller

Structured Questions

1. Compare an MDS with a traditional computer (three points). *(4 marks)*

> Board vs PC; I/O pins; real-time control; cost/size.

2. List the main features of an Arduino-style board. *(6 marks)*

> Analog in; digital I/O; MCU; RX/TX; USB; power; reset.

3. Explain how the IDE gets a sketch onto the board. *(4 marks)*

> Editor; compile; USB upload/programmer; board and port.

4. Calculate V for raw 820 and the LED resistor for 20 mA, Vf 2 V. *(2 marks)*

> 4.004 V; 150 Ω.

5. Describe the LDR, temperature-fan and door-switch applications. *(3 marks)*

> Threshold LED; LM35 with hysteresis fan; reed + alarm LED.

Summary

- An MDS is a programmable board for sensing and control.
- Features: analog/digital I/O, USB, RX/TX, power, reset.
- The IDE edits, compiles and uploads over USB.
- ADC: V = raw × 5 / 1024.
- Apps: LED, LDR, temperature fan, magnetic door.

MCQ answer key – 11.1

1. **C** – MDS.
2. **E** – Analog.
3. **A** – 2^10 − 1.
4. **D** – 820×5/1024.
5. **C** – (5−2)/0.02.
6. **B** – Below 400.
7. **A** – ≥ 28 °C.

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8. **C** – Senses open/close.
9. **E** – MDS – Microprocessor Development System – a programmable single board.
10. **B** – Microcontroller – Chip that runs the control program on the board.
11. **E** – Analog input – Pin that measures a voltage as a number.
12. **D** – Digital I/O – Pin that is either HIGH or LOW.
13. **D** – ADC – Analog-to-digital converter (e.g. 10-bit, 0–1023).
14. **A** – Sensor – Device that measures a physical quantity.
15. **A** – Actuator – Device the MDS drives – LED, motor, relay, buzzer.
16. **E** – LDR – Light-dependent resistor used to sense light.
17. **B** – LM35 – Temperature sensor that outputs 10 mV per °C.
18. **C** – Reed switch – Magnetic switch used to detect a door open/close.
19. **B** – IDE – Software with editor, compiler and programmer.
20. **D** – USB – Cable/port used to power and program the board.

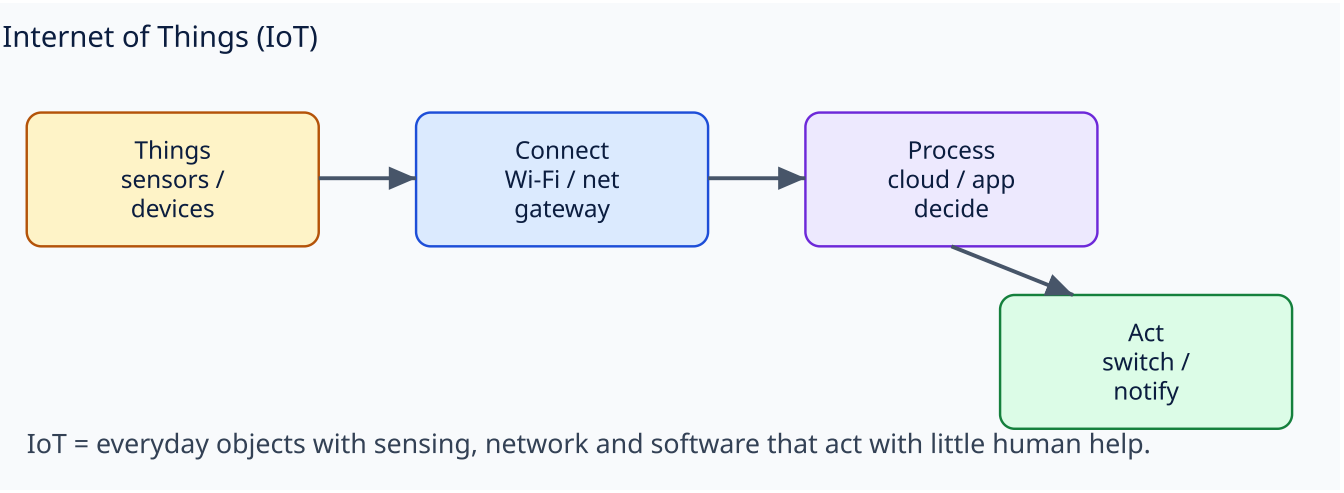
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Grade 13 A/L ICT · Lesson 11

11.2 Internet of Things (IoT)

Syllabus 11.2. The **Internet of Things (IoT)** connects everyday **things** (sensors, appliances, meters) to the **Internet** so they can be monitored and controlled with little human help. You learn the **definition**, the **needs** it meets, typical **applications**, the **enabling technologies**, and you design a simple **remote switch** that turns a device such as a television ON or OFF through the Internet.

1. What is IoT?



Things, connect, process, act

- **Definition**: a network of physical objects (“things”) that sense, connect to the Internet and act – often automatically.
- **Needs**: remote control, continuous monitoring, automation, energy saving, safety and convenience.
- Without IoT you must be next to the device; with IoT you use a phone or web page from anywhere.

2. Applications

Smart home
Lights, fans, TVs and locks controlled from a phone.

Smart farm
Soil moisture and weather guide irrigation pumps.

Health care
Wearables report heart rate to a clinic.

Transport & cities
Traffic lights, parking sensors, fleet tracking.

Industry
Machines report faults before they break.

Environment
Air and water quality monitored online.

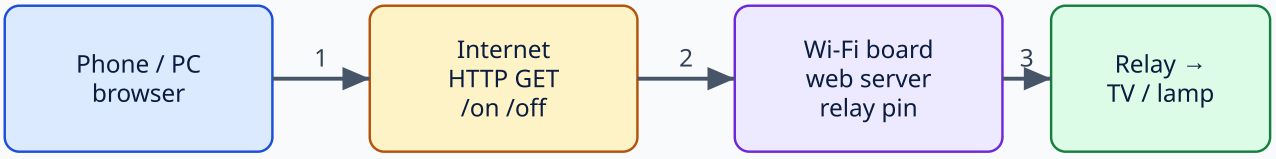
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3. Enabling technologies

Technology	Role in IoT
Microcontrollers / MDS	Run the local sensing and control program
Sensors and actuators	Measure the world and change it
Connectivity (Wi-Fi, cellular, LPWAN)	Link things to the Internet
Cloud and databases	Store readings and run logic
Mobile / web apps	Human interface to watch and command

4. Simple IoT application – remote ON/OFF switch

Simple IoT remote switch



Enabling technologies: microcontrollers, sensors, actuators, Wi-Fi/Internet, cloud, mobile apps.

Needs: remote control, monitoring, automation, energy saving, safety.

Applications: smart home, farm, health, transport, industry, cities.

Browser → Internet → Wi-Fi board → relay → TV

🔌 Remote ON/OFF switch over the Internet

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```
// Simple IoT remote switch (ESP8266 / WiFi board style)
// Browser → http://device-ip/on  or  /off  → relay on pin 5
#include <ESP8266WiFi.h>
#include <ESP8266WebServer.h>

const char* ssid = "SchoolWiFi";
const char* password = "secret123";
const int RELAY = 5;
ESP8266WebServer server(80);

void handleOn() {
  digitalWrite(RELAY, HIGH);
  server.send(200, "text/plain", "TV ON");
}
void handleOff() {
  digitalWrite(RELAY, LOW);
  server.send(200, "text/plain", "TV OFF");
}

void setup() {
  pinMode(RELAY, OUTPUT);
  digitalWrite(RELAY, LOW);
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) { delay(500); }
  server.on("/on", handleOn);
  server.on("/off", handleOff);
  server.begin();
}

void loop() {
  server.handleClient();   // wait for HTTP requests
}
```

▶ Simulated run

```
WiFi connected
Server listening on port 80
HTTP GET /on
RELAY 5 = HIGH
Reply: TV ON
HTTP GET /off
RELAY 5 = LOW
Reply: TV OFF
```

🧱 **Worked example: A student opens http://192.168.1.50/on on a phone. What happens step by step?**
The phone sends an **HTTP GET /on** over Wi-Fi/Internet. The board's tiny **web server** runs handleOn(), drives the **relay pin HIGH**, and replies "TV ON". The relay closes and the television (or lamp) receives power. /off does the opposite.

- Design: list the thing (TV), the actuator (relay), the MDS with Wi-Fi, the network and the user interface (browser links /on and /off).

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- Security note (interest): use a password or HTTPS on a real deployment – open switches on a public network are unsafe.
- The same idea works for a lamp, a fan or a school lab power socket.

💡 Build and test the relay on the desk with a lamp first; only then put the board on the school Wi-Fi.

🚀 **Beyond the syllabus (2026 update)** *Not required for the exam – read for interest.* In 2026 many school IoT kits use MQTT and free brokers instead of raw HTTP, and phone apps are built with no-code tools – the syllabus idea (sense → connect → act) is unchanged.

Key Words

IoT – Internet of Things – networked sensing and control of everyday objects.	**Thing** – Physical object with sensing and/or actuation.
Remote control – Operating a device from another place over a network.	**Monitoring** – Watching sensor readings continuously.
Automation – Acting on sensor data without a person each time.	**Enabling technology** – Hardware or software that makes IoT possible.
Wi-Fi board – MDS with a wireless network interface (e.g. ESP8266).	**HTTP request** – Message such as GET /on sent by a browser.
Web server (on device) – Tiny program on the board that answers HTTP.	**Relay** – Electrically controlled switch that can drive a TV or lamp.
Smart home – Home where appliances are monitored and controlled over a network.	**Cloud** – Remote servers that store IoT data and run logic.

Sample Q&A

1. Define IoT in one sentence.

> **Answer:** Networked things that sense, connect and act, often automatically.

2. Name three needs that IoT meets.

> **Answer:** Remote control, monitoring, automation (also energy saving, safety).

3. Give three IoT application areas.

> **Answer:** Smart home, farm, health, transport, industry, environment.

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4. List three enabling technologies.

> **Answer:** MDS/microcontrollers, sensors/actuators, Wi-Fi/Internet, cloud, apps.

5. What does GET /on do in the remote switch?

> **Answer:** Sets the relay HIGH and replies TV ON.

6. Why test the relay with a lamp first?

> **Answer:** Safer and easier debugging before going on the school network.

MCQ

1. IoT stands for

A. Internet of Things
B. Internal Office Tools
C. Internet of Televisions
D. Input of Transistors
E. Index of Tables

2. Turning a TV on from a phone over the Internet is mainly

A. formatting a disk
B. remote control
C. compiling
D. printing
E. word processing

3. Soil-moisture pumps on a farm are an IoT application in

A. agriculture / smart farm
B. only gaming
C. only CD-ROM
D. only cable TV
E. only desktop publishing

4. Which is an enabling technology for IoT?

A. CRT televisions only
B. vinyl records
C. Wi-Fi connectivity
D. punched cards
E. fountain pens

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5. In the remote-switch sketch the actuator is the

A. LM35
B. relay (to the TV)
C. reed switch
D. LDR
E. USB cable

6. The browser command that turns the device on is

A. FTP PUT /off
B. DNS lookup only
C. SMTP MAIL
D. HTTP GET /on
E. CSS hover

7. The board program that answers /on and /off is a

A. web server
B. spreadsheet
C. compiler only
D. word processor
E. paint program

8. A need met by IoT is

A. removing all sensors
B. avoiding all networks
C. writing novels by hand
D. banning mobile phones
E. automation of routine actions

9. Which term means: “Internet of Things – networked sensing and control of everyday objects”?

A. IoT
B. Enabling technology
C. Smart home
D. HTTP request
E. Remote control

10. Which term means: “Physical object with sensing and/or actuation”?

A. Cloud
B. Thing
C. Monitoring
D. Wi-Fi board
E. Web server (on device)

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11. Which term means: “Operating a device from another place over a network”?

A. HTTP request
B. Relay
C. Automation
D. Remote control
E. IoT

12. Which term means: “Watching sensor readings continuously”?

A. Web server (on device)
B. Thing
C. Enabling technology
D. Smart home
E. Monitoring

13. Which term means: “Acting on sensor data without a person each time”?

A. Remote control
B. Relay
C. Cloud
D. Wi-Fi board
E. Automation

14. Which term means: “Hardware or software that makes IoT possible”?

A. Smart home
B. Enabling technology
C. Monitoring
D. IoT
E. HTTP request

15. Which term means: “MDS with a wireless network interface (e.g. ESP8266)”?

A. Web server (on device)
B. Thing
C. Automation
D. Wi-Fi board
E. Cloud

16. Which term means: “Message such as GET /on sent by a browser”?

A. Relay
B. IoT
C. HTTP request
D. Enabling technology
E. Remote control

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17. Which term means: “Tiny program on the board that answers HTTP”?

A. Wi-Fi board
B. Thing
C. Monitoring
D. Web server (on device)
E. Smart home

18. Which term means: “Electrically controlled switch that can drive a TV or lamp”?

A. HTTP request
B. Cloud
C. Relay
D. Automation
E. Remote control

19. Which term means: “Home where appliances are monitored and controlled over a network”?

A. IoT
B. Web server (on device)
C. Smart home
D. Enabling technology
E. Monitoring

20. Which term means: “Remote servers that store IoT data and run logic”?

A. Relay
B. Thing
C. Automation
D. Wi-Fi board
E. Cloud

Structured Questions

1. Define IoT and state three needs it addresses. *(2 marks)*

> Definition (1); three needs (2).

2. Describe four IoT application areas with one example each. *(2 marks)*

> Home, farm, health, transport/industry/environment.

3. Explain five enabling technologies for IoT. *(5 marks)*

> MDS; sensors/actuators; connectivity; cloud; apps.

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4. Design a remote ON/OFF switch for a classroom lamp. *(4 marks)*

> Wi-Fi MDS; relay; /on /off; block diagram.

5. Trace what happens when a user opens /off in a browser. *(5 marks)*

> HTTP GET; handleOff; relay LOW; reply TV OFF; lamp off.

Summary

- IoT connects sensing things to the Internet to act.
- Needs: remote control, monitoring, automation, saving, safety.
- Applications: home, farm, health, transport, industry, environment.
- Enablers: MDS, sensors, networks, cloud, apps.
- A remote switch: browser → HTTP → Wi-Fi board → relay.

MCQ answer key – 11.2

1. **A** – Internet of Things.
2. **B** – Remote control.
3. **A** – Smart farm.
4. **C** – Connectivity.
5. **B** – Relay.
6. **D** – GET /on.
7. **A** – Tiny web server.
8. **E** – Automation.
9. **A** – IoT – Internet of Things – networked sensing and control of everyday objects.
10. **B** – Thing – Physical object with sensing and/or actuation.
11. **D** – Remote control – Operating a device from another place over a network.
12. **E** – Monitoring – Watching sensor readings continuously.
13. **E** – Automation – Acting on sensor data without a person each time.
14. **B** – Enabling technology – Hardware or software that makes IoT possible.
15. **D** – Wi-Fi board – MDS with a wireless network interface (e.g. ESP8266).
16. **C** – HTTP request – Message such as GET /on sent by a browser.
17. **D** – Web server (on device) – Tiny program on the board that answers HTTP.
18. **C** – Relay – Electrically controlled switch that can drive a TV or lamp.
19. **C** – Smart home – Home where appliances are monitored and controlled over a network.
20. **E** – Cloud – Remote servers that store IoT data and run logic.

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