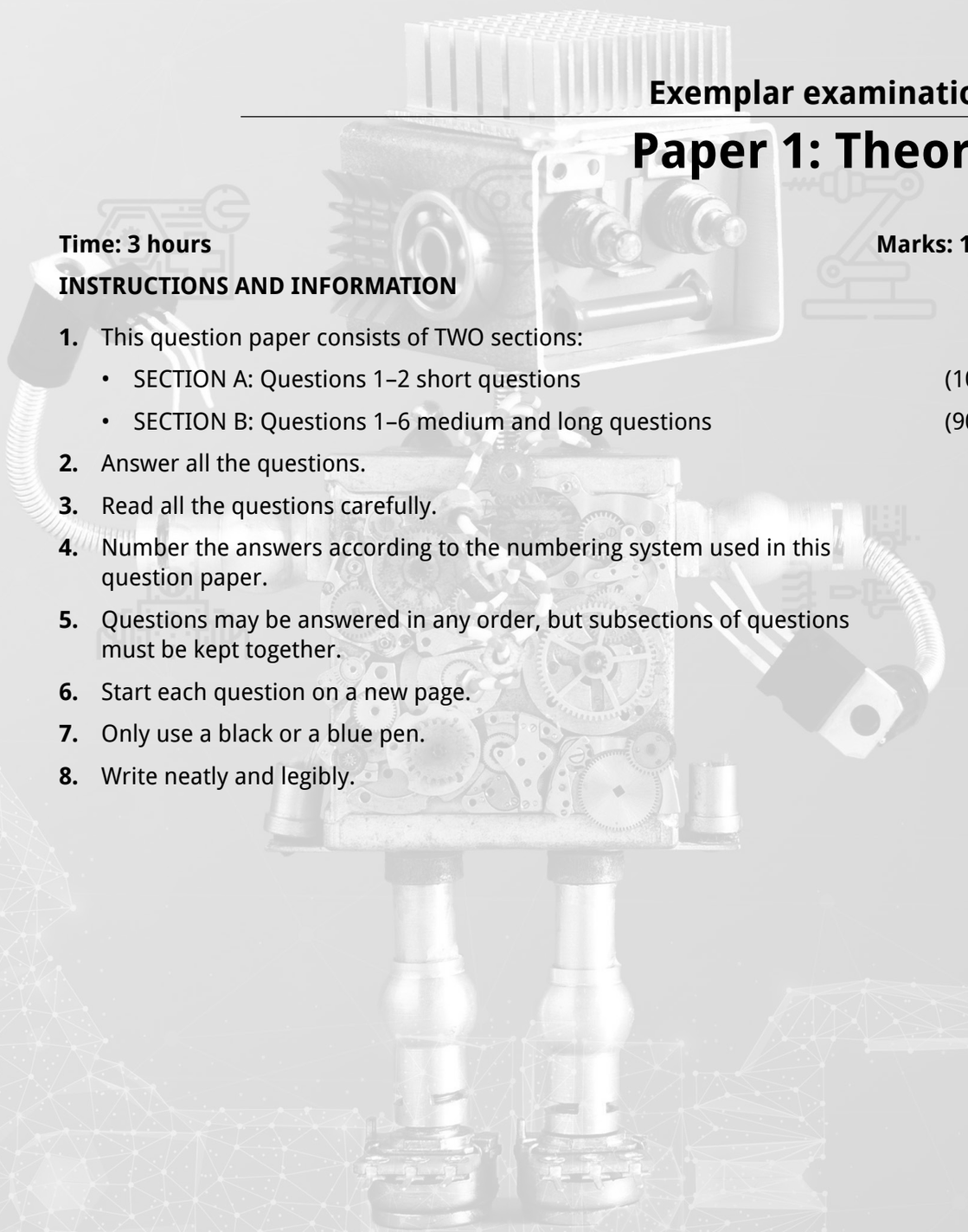


Exemplar examination

Paper 1: Theory

Time: 3 hours **Marks: 100**

INSTRUCTIONS AND INFORMATION

1. This question paper consists of TWO sections:
   - SECTION A: Questions 1–2 short questions (10)
   - SECTION B: Questions 1–6 medium and long questions (90)
2. Answer all the questions.
3. Read all the questions carefully.
4. Number the answers according to the numbering system used in this question paper.
5. Questions may be answered in any order, but subsections of questions must be kept together.
6. Start each question on a new page.
7. Only use a black or a blue pen.
8. Write neatly and legibly.

SECTION A: Short questions

QUESTION 1: Multiple choice

Only write the question number and the corresponding letter: e.g. 1.6 E

1.1 The traditional definition of a robot is a machine that can:

A. sense, reason, act
B. feel, think, emote
C. feel, reason, interact
D. sense, analyse, emote (1)

1.2 What type of component typically provides signal input in robotics projects?

A. Actuator
B. Motor controller
C. Sensor
D. Display component (1)

1.3 3D printing is also known as:

A. Summative building
B. Additive manifolding
C. Additive manufacturing
D. Additional manufacturing (1)

1.4 In electronics, voltage is a measure of:

A. Electromotive force
B. Potential difference
C. EMF
D. All of the above. (1)

1.5 What does the acronym SBC stand for?

A. Single-Base Computer
B. Single-Board Computer
C. Simple Branch Compiler
D. Serial Basic Compiler (1)

QUESTION 2: TRUE or FALSE

Decide whether the following statements are true, only write the question number and TRUE or FALSE.

2.1 Robotics uses aspects of computer science, mechanical design and genetic engineering. (1)

2.2. Robots can only be made of metal and plastic. (1)

2.3 A 3D printer works by reproducing physical objects. (1)

2.4 A microcontroller is defined as a compact integrated circuit (IC). (1)

2.5 The formula V = IR is an expression of Ohm's Law. (1)

[10]

SECTION B

QUESTION 1: Robots and our lives

1.1 Explain why the logic controller is called the "brain" of the robot. (3)

1.2 Name FOUR different types of robots in terms of their purposeful design and give examples of their uses. (8)

1.3 Sensors are known as the "eyes" and "ears" of the robot. Explain this statement, describing what sensors may be used on a robot. (4)

[15]

QUESTION 2: 3D printing

2.1 An FDM printer is the most commonly used 3D printer. What does FDM stand for? (1)

2.2 Explain what is meant by the terms "cold end" and "hot end" on an FDM printer. (4)

2.3 3D printers may be classified according to the print materials they use. Name the THREE main forms of 3D printing materials. (3)

2.4 Briefly describe the 3D printing process from design to final product. (6)

[14]

QUESTION 3: Electronics for robotics

3.1 Calculate the power in a circuit that draws 5 A of current from a 12-V battery. (2)

3.2 Imagine an outside tap with a hose attached. When you open the tap, water flows into the hose and there is water pressure in the hose.

Explain the flow of electrical current using the above water tap and hose as an analogy. (8)

3.3 Name the most important component in any electrical circuit. Explain your answer. (4)

3.4 List FOUR electrical properties that you could measure with a multimeter. (4)

[18]

QUESTION 4: Electronic components of a robot

4.1 Identify the type of processor you would use to control a simple mobile robot that is able to move within a defined space. (1)

4.2 Briefly explain what a breadboard is used for in electronic prototyping. (4)

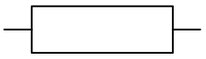
4.3 Microcontrollers and SBCs have GPIO pins.

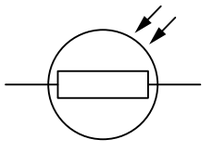
4.3.1 What does GPIO stand for? (1)

4.3.2 Briefly discuss the purpose and use of GPIO pins. (8)

4.4 List THREE ways to supply power to a development board or SBC. (3)

4.5 Identify the following symbols commonly used in circuit diagrams.

4.5.1 

4.5.2 

(2)

4.6 List THREE components commonly used in circuits. (3)

[22]

QUESTION 5: Programming

5.1 Explain what is meant by *physical computing*? (4)

5.2 The IPO cycle is the basis of most computer programs. Identify the steps in the IPO cycle. (3)

5.3 You will be using IDEs when programming microcontrollers and SBCs.

5.3.1 Write the term IDE in full. (2)

5.3.2 Briefly describe what an IDE is. (3)

5.3.3 List THREE typical features of an IDE. (3)

[15]

QUESTION 6: Practical robotics

Problem: Design a robotic arm that can lift a one-kilogram weight and move it in three dimensions.

6.1 Analyse the given problem and list the various components required for the design. (3)

6.2 Explain how THREE of your components will be used in the design. (3)

6.3 Write out the steps for the required design. (4)

[10]

TOTAL: 100

Exemplar examination

Paper 2: Design-related

Time: 4 hours **Marks: 80**

INSTRUCTIONS AND INFORMATION

1. Your QUESTION PAPER must be printed in full colour.
2. You will not be allowed access to the internet during this examination.
3. Any design software that you will need to complete these questions will be available on your computer. Ensure that you have all the software installed before you start the paper.
4. The following software is recommended:
   - Fritzing for circuit diagrams
   - Draw.io, or other suitable diagramming software for flowcharts and simple electrical diagrams
   - Any applicable Python IDE (such as MU or Thonny) for Python version 3 and above
   - MS Word
5. You may not submit handwritten code or hand drawn diagrams. All drawings must be clear and neat with labels.
6. Read all the questions carefully.
7. Answer all the questions.
8. Number the answers according to the numbering system used in this question paper.
9. Questions may be answered in any order, but subsections of questions must be kept together.

The following scenario is the basis of this examination.

Scenario

You are an engineer for an automation company. You have been tasked with building a robot required to perform two functions.

- Function 1: Turn on an electric fan when motion is detected.
- Function 2: Read in temperature using a temperature sensor and output to an RGB LED. The LED will change colour depending on the current temperature.

QUESTION 1: Robots and our lives

1.1 Where could a system like this be used in the real world? (1)

1.2 Name TWO advantages of using a system like this in order to automate simple tasks. (2)

[3]

QUESTION 2: 3D printing

2.1 How could 3D printing be incorporated into this device? (1)

2.2 What material parameters should you consider for printing a device that will be used in an outdoor setting? (1)

2.3 Once you have chosen to 3D print a part of your device, you will need to slice the design. A typical instruction is to:

"Slice using default settings."

Explain how you would slice the design and what is the result of slicing in this context. (2)

[4]

QUESTION 3: Electronics for robotics

3.1 The fan you are given is rated for 150 W power and runs off a 50 V power supply. Calculate the current draw for this type of fan. (2)

3.2 Could we drive the fan output directly from an output of the Raspberry Pi? Give a reason for your answer. (2)

3.3 What alternative method could be used to power the fan from a Raspberry Pi output? (1)

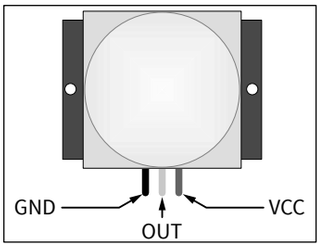
3.4 Draw a suitable circuit using Draw.io, Fritzing or any other appropriate software that will allow the Raspberry Pi to power and control the fan. (6)

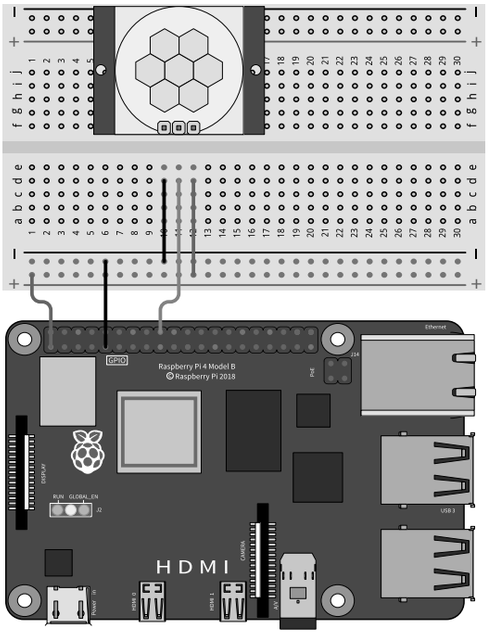
3.5 The following circuit is meant to connect the PIR sensor to GPIO 16 on the Raspberry Pi.

3.5.1 Explain how the circuit should be connected in order to detect movement. (4)

3.5.2 Using the pinouts below, identify FOUR mistakes on our circuit. (4)

Circuit:





Pinout:

3V3 power	1	○	2	5V power
GPIO 2 (I2C1 SDA)	3	○	4	5V power
GPIO 3 (I2C1 SCL)	5	○	6	Ground
GPIO 4 (GPCLK0)	7	○	8	GPIO 14 (UART TXD)
Ground	9	○	10	GPIO 15 (UART RXD)
GPIO 17	11	○	12	GPIO 18 (PCM CLK)
GPIO 27	13	○	14	Ground
GPIO 22	15	○	16	GPIO 23
3V3 power	17	○	18	GPIO 24
GPIO 10 (SPIO MOSI)	19	○	20	Ground
GPIO 9 (SPIO MISO)	21	○	22	GPIO 25
GPIO 11(SPIO SCLK)	23	○	24	GPIO 8 (SPIO CE0)
Ground	25	○	26	GPIO 7 (SPIO CE1)
GPIO 0 (EEPROM SDA)	27	○	28	GPIO 1 (EEPROM SCL)
GPIO 5	29	○	30	Ground
GPIO 6	31	○	32	GPIO 12 (PWM0)
GPIO 13 (PWM1)	33	○	34	Ground
GPIO 19 (PCM_FS)	35	○	36	GPIO 16
GPIO 26	37	○	38	GPIO 20 (PCM_DIN)
Ground	39	○	40	GPIO 21 (PCM_DOUT)

[19]

QUESTION 4: Electronic components of a robot

4.1 List EIGHT key components that would be needed to make up a system that can handle both functions mentioned above. Provide a short description of each component. (8)

4.2 Consider just the function that turns on the fan. Break down the system into the FOUR main categories that make up a robot. Identify a key component used in each category.

Category	Component
Sensor	
Logic controller	
Actuator	
End effector	

(4)

4.3 What does it mean to deploy your code when building programs for a Raspberry Pi based microprocessor? (2)

[14]

QUESTION 5: Programming

5.1 Name TWO modules from GPIOZero that are needed in order to make both functions work. (2)

5.2 How will the Raspberry Pi read a value from the PIR Motion sensor? Write some code that will show how this will work. (1)

5.3 What setup function do you need to call in order to configure an IO pin to output to the fan circuit? What code would you then call to turn the fan on? (2)

5.4 Open a Python IDE on your Raspberry Pi and write a simple program that will turn on the fan when motion is detected from the PIR sensor. Make sure that all pin numbers are defined as well. The program must wait for the PIR sensor to detect motion. When it detects motion, it must turn on the fan and then wait for 5 seconds. After 5 seconds, it will wait for the PIR motion detector to turn off before turning off the fan. Save the program as "motion_sensor.py" and make sure it is able to run. (8)

[13]

QUESTION 6: Practical robotics

Open the following code in a Python IDE on your Raspberry Pi

```
#Import Libraries
import RPi.GPIO as GPIO
import MCP3008
from gpiozero import LED
import time import sleep

#Declare GPIO devices
red = LED(16)
green = LED(20)
blue = LED(21)
tmp = MCP3008(channel=0, device=0)
#Main loop of the program
while True:
temp = (tmp.value * 3.3)*100
print("Current Temperature {} degrees".format(temp))
if temp > 20
    red.on()
    green.off()
    blue.off()
```

```
elif temp < 10
    red.off()
    green.off()
    blue.on()
else
    red.off()
    green.on()
    blue.off()
SLEEP(1)
```

6.1 Find and fix THREE errors in this program. (3)

6.2 Based on the code, when will the RGB LED turn red? (1)

6.3 What colour will the RGB LED turn if the temperature is 15 degrees? (1)

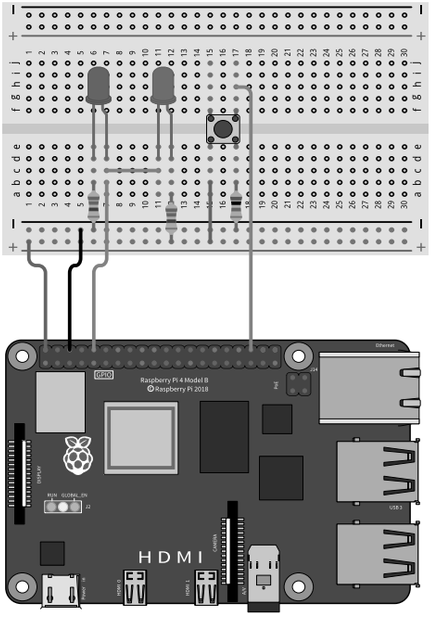
6.4 Create a breadboard diagram for the code in Fritzing, using a Raspberry Pi, RGB LED, LM35 temperature sensor, and an MCP3008. (9)

6.5 Identify the document that should accompany the completed device or artefact. (1)

[15]

QUESTION 7: Breadboards and Circuits

7.1 Consider the following breadboard circuit. Draw a circuit diagram for this circuit in Draw.io or using any other suitable software.

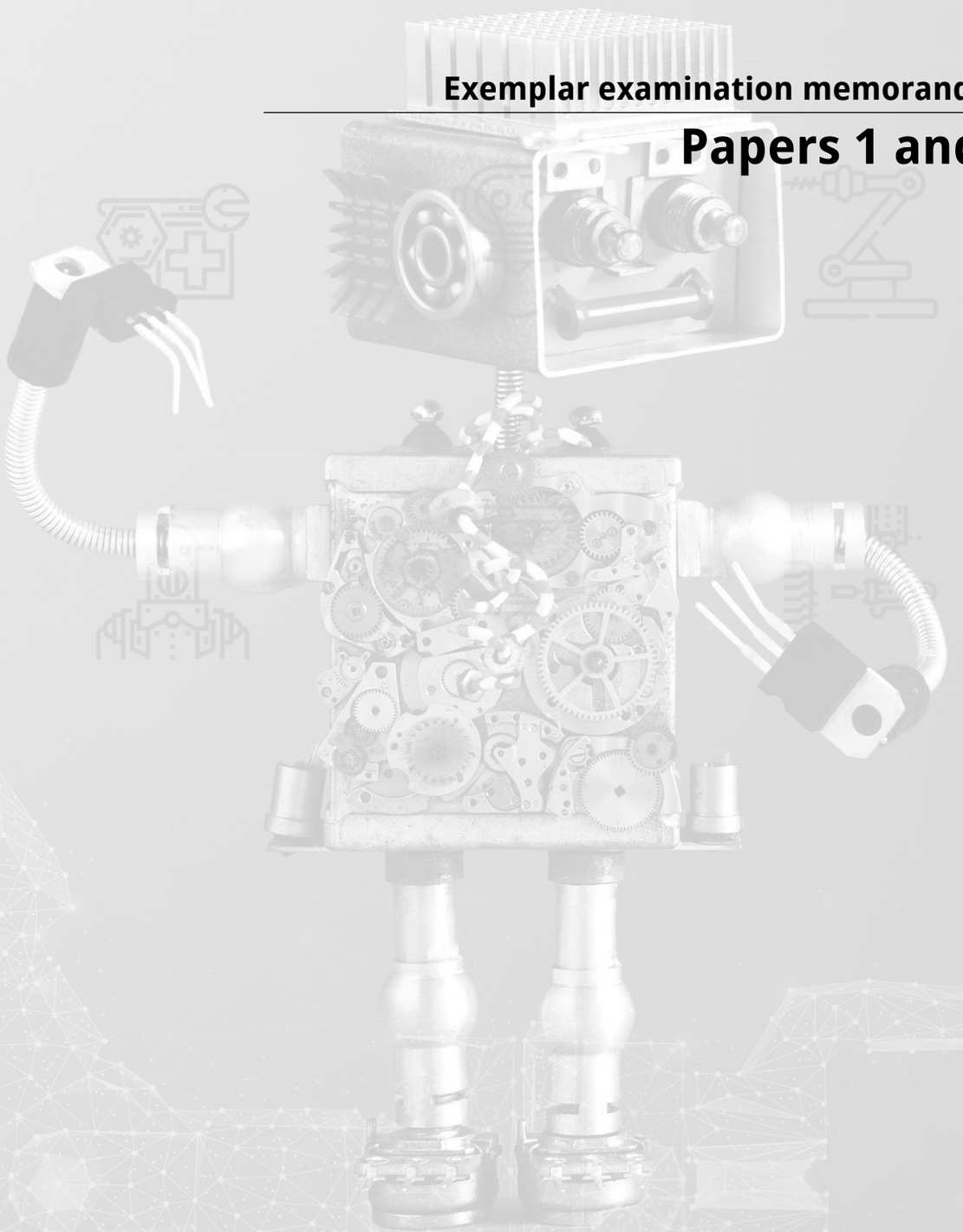


(6)

7.2 Write a Python program that will turn on the red LED when the button is pressed, and turn on the blue LED when the button is not pressed. (6)

[12]

TOTAL: 80



Exemplar examination memorandum

Papers 1 and 2

Paper 1: Theory

Time: 3 hours Marks: 100

SECTION A: Short questions

QUESTION 1: Multiple choice

1.1 A. sense, reason, act (1)

1.2 C. Sensor (1)

1.3 C. Additive manufacturing (1)

1.4 D. All of the above. (1)

1.5 B. Single-Board Computer (1)

QUESTION 2: TRUE or FALSE

2.1 False (1)

2.2 False (1)

2.3 False (1)

2.4 True (1)

2.5 True (1)

[10]

SECTION B

QUESTION 1: Robots and our lives

1.1 In robots the CPU will be within the programmable logic controller (PLC). This is the robot's "brain". ✓ It manages and controls all aspects of the robot. ✓ The PLC is programmed ✓ to tell a robot how to use its different parts to complete a specific task. (3)

1.2 (Any four and any reasonable example)

- Emergency services robots – bomb disposal; ✓✓
- Social robots – assist students with autism or learning difficulties, social companion for elderly; ✓✓
- Swarm robots – individual robots communicate with each other to coordinate their movements; ✓✓
- Robotic medical assistants – monitor vital statistics, perform surgery; ✓✓
- Telepresence robots – allows someone to attend an event or a meeting without physically being there themselves; ✓✓
- Research robots – collect and analyse data; ✓✓
- Exploration robots – sent into natural or artificial environments where people cannot go or do not want to go; ✓✓
- Entertainment robots – toy-like gadgets, interactive point-of-purchase sites; ✓✓
- Educational robots – interdisciplinary learning environment based on the use of robots and electronic components. ✓✓ (8)

1.3 Sensors turn physical measurements into electrical signals. ✓ The CPU will then use the signal data and allow the robot to interact with its environment. ✓ Common sensors found within robots include distance sensors, light detectors, cameras for image recognition, movement sensors, microphones and many others. ✓✓ (4)

[15]

QUESTION 2: 3D printing

2.1 Fused Deposition Modelling ✓ (1)

2.2 The extruder, ✓ also known as the cold end, is the part responsible for feeding the filament ✓ through the hot end and out the nozzle.

The hot end is the section of the printer where the filament is melted ✓ and extruded through the nozzle. ✓ (4)

2.3 Solid, ✓ liquid, ✓ powder ✓ (3)

2.4 (Accept any valid description, the steps design, slice, print must be included)

Design: The first step in printing a part is creating a digital model. ✓✓

Slice: The second step is to import the STL file into the slicing software. This is where the model is positioned on the print bed, supports are added and the printer settings specified. ✓✓

Print: The third step is the production of the part. The G-code file must be sent to the printer. It is important to make sure that the print area is clear, the print bed is level, there is proper ventilation and there is enough filament loaded into the printer. Once everything is ready, the print can start. ✓✓ (6)

[14]

QUESTION 3: Electronics for robotics

3.1 $P = I \times V$ ✓

$= 5\ A \times 12\ V$

$= 60\ W$ ✓ (2)

3.2 In this analogy, the tap is the battery, ✓ supplying water (voltage or pressure) ✓ to the hose (the circuit). ✓ This water must go through the hose to pour into the ground, just like all electricity must flow from its source to ground (from positive to negative). ✓

If you block the end of the hose, or cut through the hose, the water stops flowing through it, much like electricity will stop flowing if you break the circuit ✓ (either with a switch or by disconnecting something).

The thickness of the hose controls how much water can flow at a time, ✓ and the amount of water per second is like the amount of charge flowing in a circuit (current). ✓ Water cannot flow into the hose faster than water is flowing out of the hose, so the total water flow (the current) will always be the same in a single hose (single loop). ✓ (8)

3.3 The power source ✓ or source of electrical energy.

A power source, whether it is a battery or main-line electricity, creates the force, known as voltage or potential difference, ✓ that pushes an electric charge through the circuit and creates a flow of current. ✓ Any other components will only function if there is a current flowing. ✓ (4)

3.4 (Any four)

voltage, ✓ resistance, ✓ current, ✓ continuity. ✓

Some multimeters allow for measurement of temperature ✓ and capacitance ✓ (4)

[18]

QUESTION 4: Electronic components of a robot

4.1 A microcontroller ✓ would be ideal for a simple obstacle-avoidance robot. (1)

4.2 Creating ✓ and testing ✓ quick prototypes of a circuit ✓ without damaging or permanently attaching components ✓ (4)

4.3 **4.3.1** General Purpose Input Output ✓ (1)

4.3.2 GPIO pins are programmable pins that can be used to control circuits and other hardware. ✓

They can be used to interact with the physical world. ✓

The purpose of GPIOs is to provide a way for the microprocessor to control external devices (such as LEDs, motors, sensors, etc.) ✓ or to receive inputs from external devices. ✓

They are digital pins that can be programmed as either an input or an output, ✓ and the state of the pin (high or low) ✓ can be read or written by the software running on the device. ✓

They can be used to control lights, read sensor data, drive motors and perform many other functions. The flexibility of GPIOs make them a crucial part of many electronics, robotics and embedded systems where they control complex systems. ✓ (8)

4.4 (Any three)

- Micro-USB power supply
- DC barrel jack
- USB port
- Battery
- GPIO pins (3)

4.5 **4.5.1** resistor

4.5.2 photo resistor (2)

4.6 (Any three)

power sources, capacitor, resistor, inductor, push-button switch, photoresistor, LED, RGB LED, transistor, temperature sensor, passive infrared (PIR) sensor, relay, analogue-to-digital converter, buzzer (3)

[22]

QUESTION 5: Programming

5.1 Physical computing is the application of physical, ✓ embedded ✓ interactive ✓ systems with microcontrollers ✓ that can sense their environment and/or control outputs such as lights, screens and motors. (4)

5.2 input, processing, output (3)

5.3 **5.3.1** Integrated development environment ✓✓ (2)

5.3.2 An IDE is software ✓ used for building applications that combine common developer tools ✓ into a single graphical user interface. ✓ (3)

5.3.3 Source code editor, ✓ Local build automation, ✓ Debugger ✓ (3)

[15]

QUESTION 6: Practical robotics

6.1 0 marks – no components listed

1 mark – 1-3 components listed

2 marks – 4-5 components listed

3 marks – 6-7 components listed

The components required for this design include motors, sensors, actuators, control boards, jumper wires, power sources, and a frame or body to hold all the components together. (3)

6.2 Only THREE marks for three components explained.

The motors will provide power and torque necessary to lift the one-kilogram weight. ✓ Sensors will provide feedback on position and movement. ✓ Actuators will allow for precise movement of the robotic arm. ✓ Control boards will provide instructions for operation of all components. Jumper wires will connect all components together. ✓ A power source will provide energy for operation of all components. ✓ A frame or body will hold all these components together securely. ✓ (3)

6.3 0 marks – four or more steps missing

1 mark – missing three important steps

2 marks – missing two important steps

3 marks – missing one important step

4 marks – steps fully outlined

Example answer:

Step 1: Design a frame or body that can securely hold all the necessary components.

Step 2: Choose two motors that can provide enough power and torque to lift a one-kilogram weight.

Step 3: Choose/design two actuators that can allow precise movements in three dimensions.

Step 4: Choose/design two sensors that can provide feedback on position and movement.

Step 5: Design a control board that can provide instructions for operation of all other components.

Step 6: Connect all necessary components with jumper wires.

Step 7: Select an appropriate power source for operation of all other components.

Step 8: Test each component individually before assembling them into a single unit. (4)

[10]

TOTAL: 100

Paper 2: Design-related

Time: 4 hours Marks: 80

QUESTION 1: Robots and our lives

1.1 (Any one) ✓ home automation, industrial automation (1)

1.2 (Any two reasonable) ✓✓
Increased system efficiency,
Less required human interaction (2)
[3]

QUESTION 2: 3D printing

2.1 (Any one) ✓
You could 3D print a structure to house the entire device components in a single body.
You could also 3D print brackets to hold the sensors or the LEDs to allow for mounting in a different location to the controller. (1)

2.2 (Any one) ✓
Melting temperature; UV resistance (1)

2.3 Click the "slice" button in the software ✓ to generate G-code ✓ for the design. (2)
[4]

QUESTION 3: Electronics for robotics

3.1 (One mark for formula, one for correct answer)

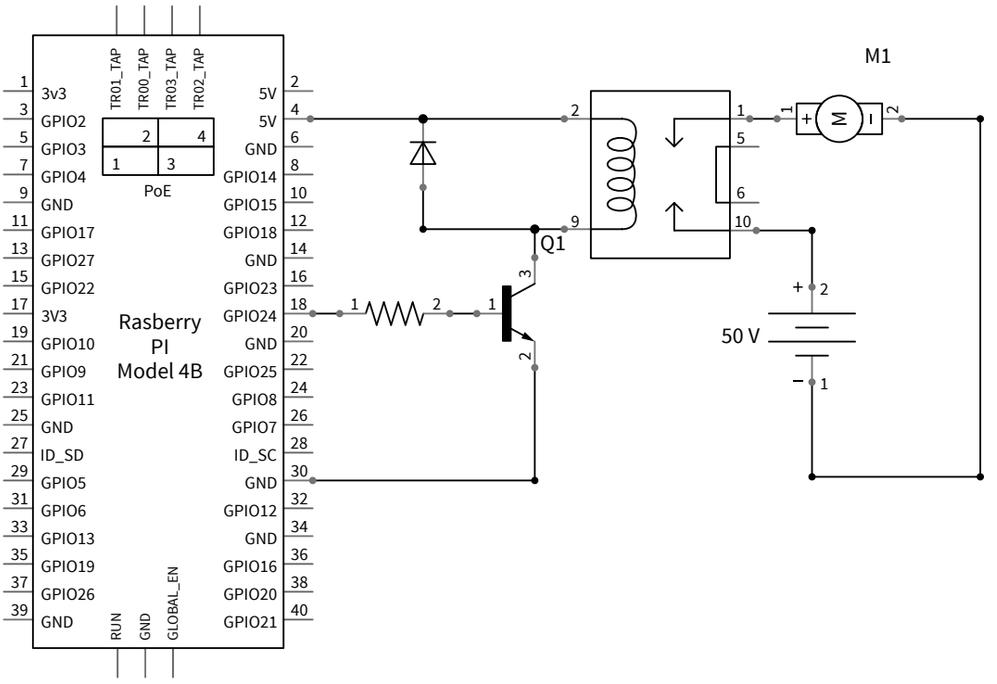
$$\text{Current} = \frac{\text{power}}{\text{voltage}} \checkmark$$
$$= \frac{150\ \text{W}}{50\ \text{V}}$$
$$= 3\ \text{A} \checkmark$$ (2)

3.2 No. ✓ The Raspberry pi operates at only 3.3 V ✓ and is not able to output the required amount of electrical current. (2)

3.3 You could use a relay in order to increase the power. ✓ (1)

3.4 Circuit diagram:
1 point for each of the following:

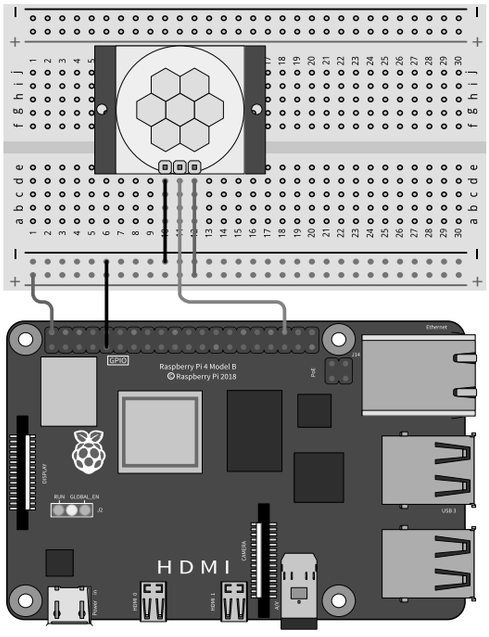
- Relay
- Transistor
- 1k transistor
- Diode
- Fan (or fan motor)
- Power supply



(6)

3.5 **3.5.1** The PIR sensor would be connected to 5V, ground, ✓ and a GPIO pin on the Raspberry Pi ✓ between You can then test the GPIO pin to detect voltage ✓ which shows the sensor has detected motion ✓ (4)

3.5.2 Circuit (4 marks: correct wire to 5V (not 3v3), correct position of sensor, allowing it to connect to the wires from the Pi, correct wire to the power rail connected to 5V, output pin connected to the correct GPIO pin.)



(4)

[19]

QUESTION 4: Electronic components of a robot

4.1 PIR Motion detector - Detects motion to turn on the fan
LM35/Temperature sensor – sensor that outputs an analogue value based on temperature
MCP3008 – Analog to digital converter
Resistors – resists current flow
Raspberry Pi/Microprocessor – the main logic controller
RGB LED – a multi colour Light emitting diode
Relay – interface for the light
Fan – end effector (8)

4.2

Category	Component
Sensor	PIR Motion Detector ✓
Logic controller	Raspberry Pi/ Microprocessor ✓
Actuator	Fan Motor ✓
End effector	Fan Blades ✓

(4)

4.3 Deploying your code means preparing your code for use in its real-world scenario. ✓ For a Raspberry Pi this means making sure that the code is being run when the device is powered on. ✓ (2)

[14]

QUESTION 5: Programming

5.1 (Any two) LED ✓ MCP3008 ✓ DigitalOutputDevice ✓ MotionSensor ✓ (2)

5.2 The motion sensor has a function called “wait_for_motion” that will pause the program until motion is detected

```
    pir.wait_for_motion()
```

✓ (1)

5.3

```
relay = OutputDevice(RELAY_PIN)
```

✓ (2)

Turn the relay on:

```
relay.on()
```

✓ (2)

5.4

```
from gpiozero import MotionSensor
from gpiozero import DigitalOutputDevice
from time import sleep
 ✓
# Define the GPIO pin number for the PIR motion sensor
PIR_PIN = 17
RELAY_PIN = 18
 ✓
# Create a MotionSensor object for the PIR motion sensor
pir = MotionSensor(PIR_PIN)
# Create an OutputDevice object for the relay module
relay = OutputDevice(RELAY_PIN)
 ✓
```

```
while True
    pir.wait_for_motion() ✓
    print("Relay On")
    relay.on() ✓

    sleep(5000) ✓

    pir.wait_for_no_motion() ✓
    relay.off() ✓
    print("Relay Off")
```

(8)

[13]

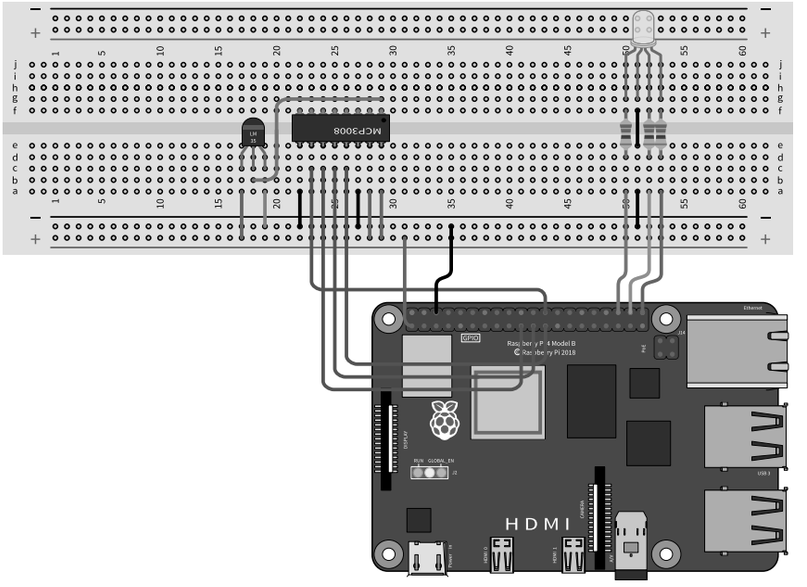
QUESTION 6: Practical robotics

6.1 "SLEEP" should be "sleep"
No indent after the "While True:"
"import MCP3008" should be "from gpiozero import MCP3008" (3)

6.3 The RGB Led will turn red if the temperature goes above 20 degrees (1)

6.3 The RGB Led will turn green at 15 degrees. (1)

6.4 1 mark for getting the LM35 pin correct to the MCP3008
2 marks for wiring the MCP correctly to the Pi
1 mark for wiring the LED with 3 resistors
3 marks for power connections and components
2 marks for downloading to the board



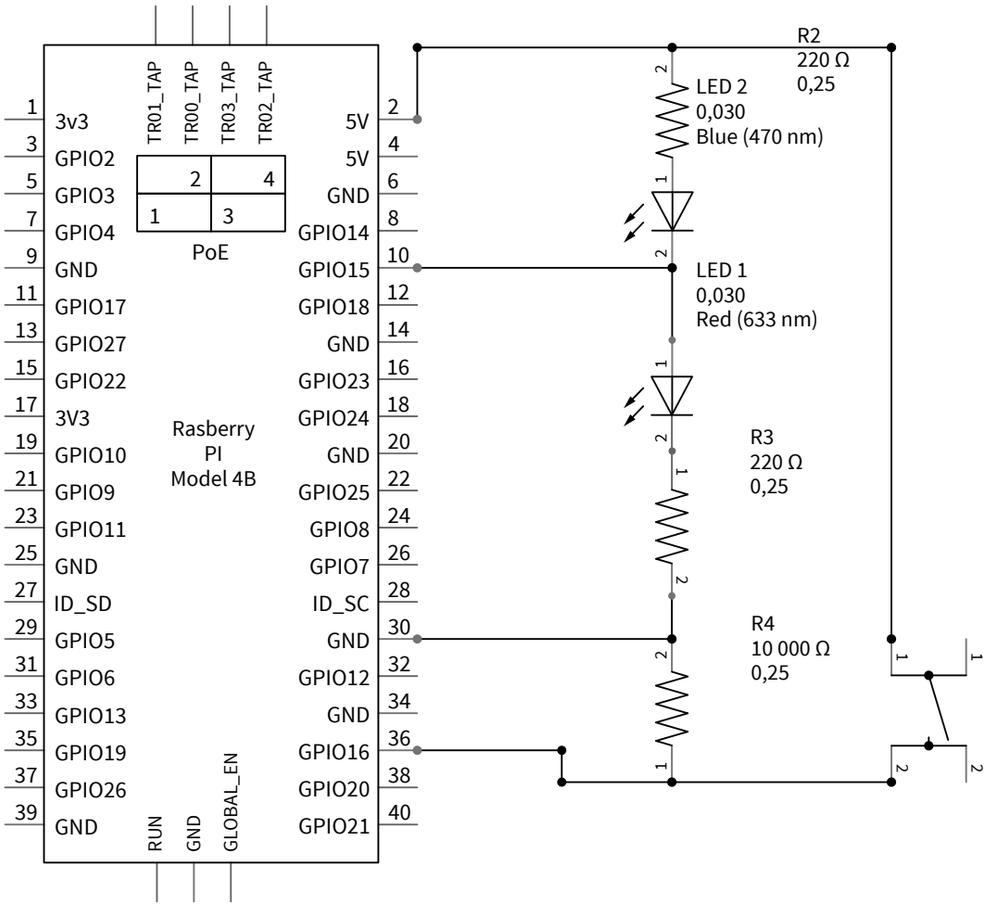
(9)

6.5 The user manual (1)

[15]

QUESTION 7: Breadboards and Circuits

7.1 Answer should resemble this:



(6)

7.2 Sample code:

```
#Program to turn ON/OFF the lights using Raspberry Pi
from gpiozero import LED
from gpiozero import Button

#declaring the leds variable
leds = LED(15)
buttonToggle = button(16)

#Turning On/Off the lights using a sequence
buttonToggle.when_pressed = ledToggle.toggle()
```

(6)

[12]

TOTAL: 80