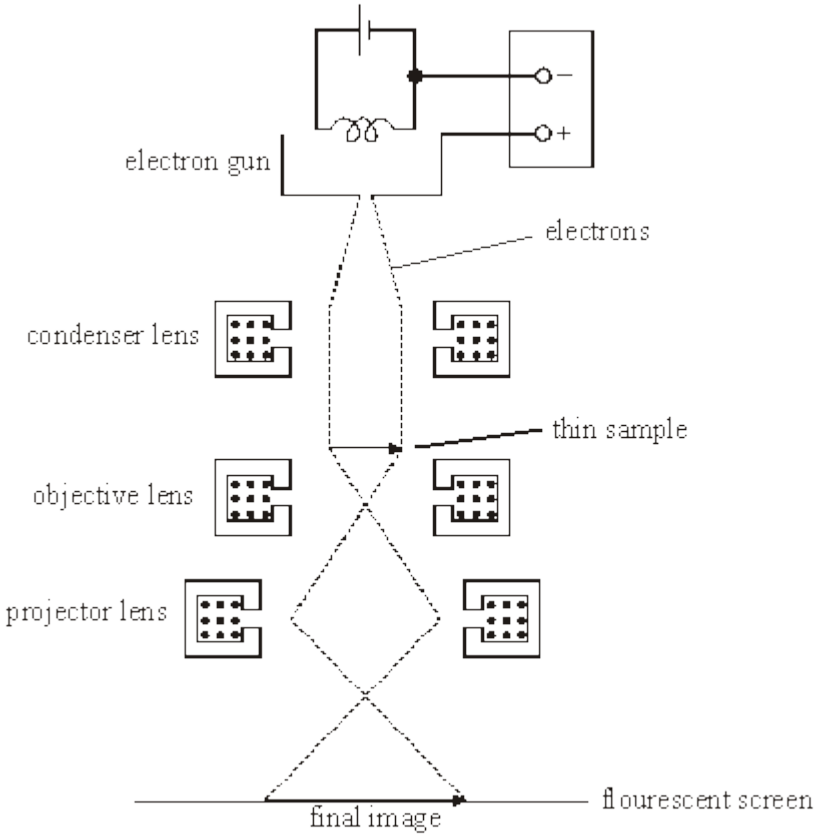
1 In a transmission electron microscope, electrons from a heated filament are accelerated through a certain potential difference and then directed in a beam through a thin sample. The electrons scattered by the sample are focused by magnetic lenses onto a fluorescent screen where an image of the sample is formed, as shown in the figure below.



(a) State and explain **one** reason why it is important that the electrons in the beam have the same speed.

.....

.....

.....

.....

(2)

(b) When the potential difference is increased, a more detailed image is seen. Explain why this change happens.

.....

.....

.....

.....

.....

.....

(3)
(Total 5 marks)

2 (a) **MOSFETs are commonly used in circuits where low power consumption is important to extend battery life.**

State and explain the property of MOSFET devices that makes them useful in these circuits.

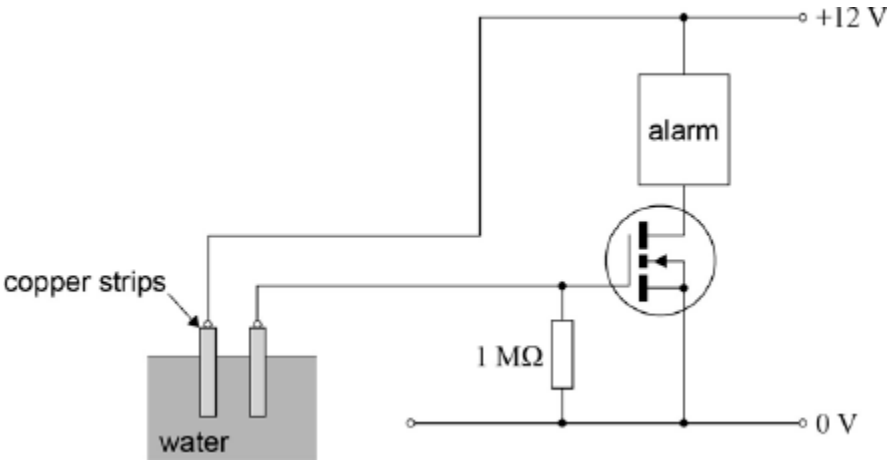
.....

.....

.....

(2)

The figure below shows an N-channel enhancement mode MOSFET, being used as part of a circuit for the water level alarm in a garden pond.
When the gap between the copper strips is filled with water the MOSFET turns on and the alarm sounds.



(b) Explain the reason for the 1 MΩ resistor in this application.

.....

.....

.....

(2)

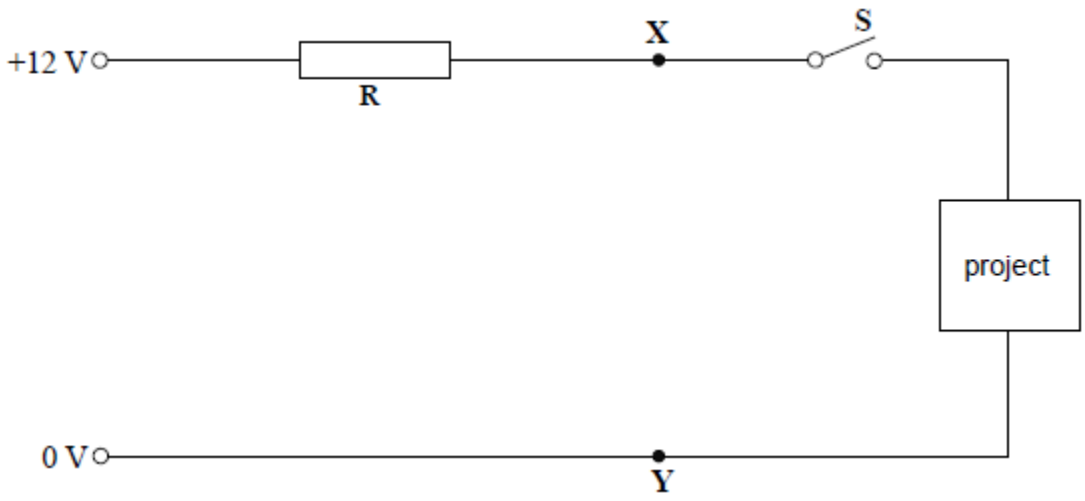
(c) The circuit is tested by immersing the copper strips in the water, and bringing them closer together until the alarm sounds.
V_{th} for the MOSFET in the figure above is 2.4 V.

Determine the resistance of the water between the copper strips when the alarm sounds.

resistance = ... MΩ

(2)
(Total 6 marks)

3 A Zener diode is used to produce a stabilized 5.1 V from an unregulated 12 V supply to power a project that requires 80 mA.
Part of the circuit is shown in the diagram.



(a) Draw on the diagram the Zener diode connected correctly between points **X** and **Y**.

(2)

(b) The Zener diode requires at least 5 mA to maintain its Zener voltage of 5.1 V.

(i) Calculate the minimum current flowing through **R** when switch **S** is closed.

.....

(1)

(ii) Calculate the voltage across resistor **R** under these conditions.

.....

.....

(1)

(iii) Calculate the value of resistor **R**.

.....

.....

.....

(2)

(c) The circuit in the diagram above is now constructed using a value of 75 Ω for resistor **R**.

(i) Show that the power dissipated in the resistor is approximately 0.6 W.

.....

.....

.....

(2)

(ii) The project is disconnected by turning switch **S** off, but the 12 V supply remains connected.

Calculate the current that now flows through the Zener diode.

.....

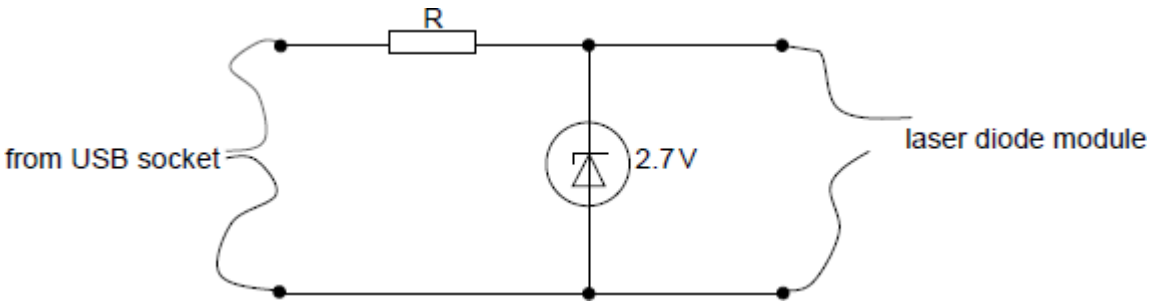
.....

.....

(2)

(Total 10 marks)

4 The circuit shown below uses a 2.7 V Zener diode to convert the voltage supply from a USB socket on a PC to power a laser diode module.



Specifications for the laser diode module and the USB output are:

Laser diode module current: 88 mA
USB socket supply output: 4.40 V - 5.25 V

(a) If the voltage from the USB socket is 4.40 V, the current through the Zener diode is 10 mA and the laser diode module is connected, calculate the required value of series resistor, R.

.....

.....

.....

.....

(4)

(b) State what the Zener diode current will be if the laser diode module is now disconnected from the circuit.

.....

(1)

(c) Zener diodes are available with ratings of $\frac{1}{8}$W, $\frac{1}{4}$W and $\frac{1}{2}$W. Using a calculation determine which one should be used.

.....

.....

.....

(3)

(d) Explain, without using calculations, what will happen in the circuit if the USB socket voltage rises to its maximum of 5.25 V.

.....

.....

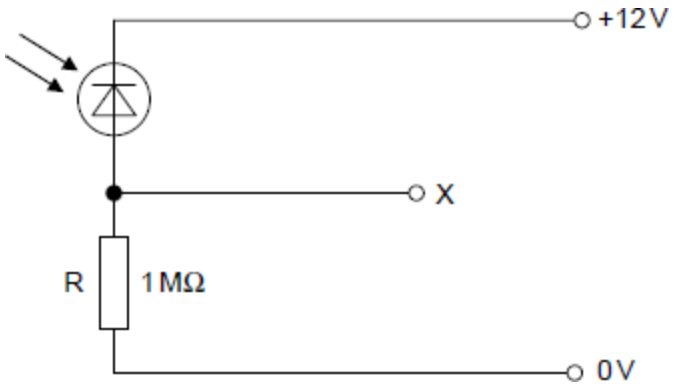
.....

(3)
(Total 11 marks)

5 Part of a data sheet for a PIN photodiode intended for an optical fibre communication system is shown below.

Reverse leakage dark current	max 5nA
Sensitivity (reverse current caused by light)	0.6 A/W
Capacitance (at zero bias)	10 pF
Response time (to 95% amplitude)	5 ns

(a) The PIN photodiode is used in the following circuit which converts an optical signal travelling along a fibre into an electrical signal.



(i) In what bias direction is the photodiode connected?

.....

(1)

(ii) Calculate the maximum voltage at X that exists when the photodiode is in the dark.

.....

.....

(2)

(iii) Sensitivity is the reverse current caused by the light power that hits the active area of the device.

Calculate the current through the photodiode and then the voltage at X when light of power 1μW hits the active area of the photodiode.

Current .....

.....

Voltage at X .....

.....

(3)

(iv) Calculate the time constant of the circuit assuming the photodiode acts as a simple capacitor.

.....

.....

(2)

(v) Suggest a reason why the response time of the photodiode given in the datasheet is much less than the value you have calculated in part (iv).

.....

.....

(1)

(vi) The output voltage at X is low even when an optical signal is present. Suggest **two** ways of increasing the output voltage.

.....

.....

(2)

(b) The power of the optical signal received at the photodiode, after passing through the optical fibre, is found to be less than the transmitted power.

Describe and explain **two** possible causes of this.

.....

.....

.....

.....

.....

.....

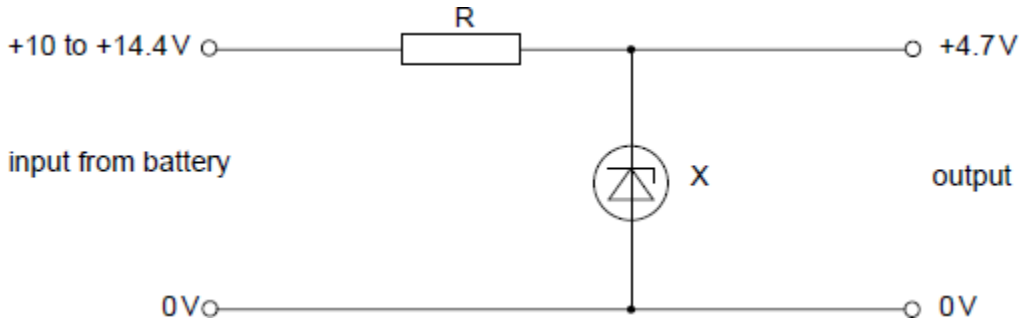
.....

.....

(5)

(Total 16 marks)

6 A stable power supply voltage of 4.7 V at a maximum current of 100 mA is needed to power an MP3 player in a car.
The problem is that the car battery voltage can vary from as low as 10 V when the car is started on a cold day, up to 14.4 V when it is charging as the engine is running. The circuit below is designed to produce a constant 4.7 V output.



(a) (i) What is component X?

.....

(1)

(ii) What voltage rating should be chosen for X?

.....

(1)

(iii) In which bias direction is component X placed?

.....

(1)

(b) The minimum current through component X is 5 mA. The maximum output current from this circuit is 100 mA.
R must be calculated when the value of the input voltage is at its lowest.

Calculate

(i) the total current flow through R under these conditions

.....

(1)

(ii) the voltage across R when the input voltage is at its lowest

.....

(1)

(iii) the required value of R.

.....

(2)

(iv) Which preferred value should be chosen for R if the minimum current through X is not to fall below 5 mA?

.....

(1)

(c) The preferred value of resistor determined in part (b)(iv) is not available, but a 33 Ω resistor is used. With the circuit powered up, and the engine running, the MP3 player is disconnected. Component X is then found to be hot.

(i) Calculate the current through component X.

.....

.....

(2)

(ii) Calculate the power dissipated by component X.

.....

.....

(1)
(Total 11 marks)

7 A student designs an electronic system to control a ventilation fan for a greenhouse. The fan should be switched on only when both the temperature and humidity exceed certain levels that can each be set independently.

(a) Choosing appropriate input, process and output subsystems from the list below, draw a labelled block diagram to show a possible design for the system.

Choose from:

AND gate	**comparator**	**driver**	**humidity sensor**
fan motor	**temperature sensor**	**voltage divider**	

(7)

(b) In which subsystem would:

(i) a MOSFET be used .....

(1)

(ii) an op-amp be used .....

(1)

(iii) a thermistor be used? .....

(1)

(c) The controller circuit operates from a 12 V power supply and draws a current of 25 mA under all conditions.
The fan motor requires a current of 450 mA when switched on and operates from the same 12 V power supply.

Calculate:

(i) the total current drawn by the whole system when the fan motor is switched on

.....

(1)

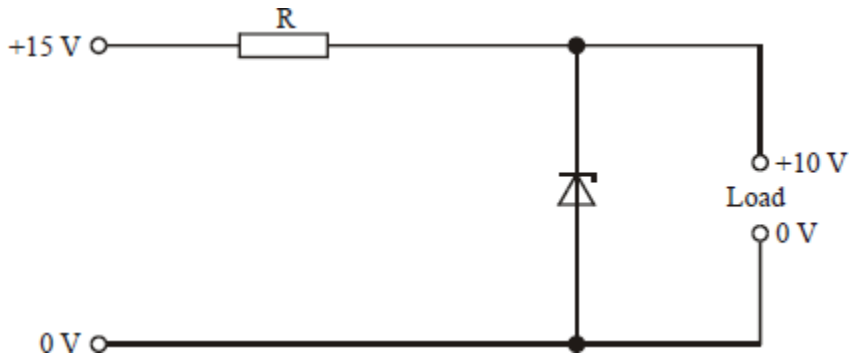
(ii) the input power to the whole system when the fan motor is switched on.

.....

(2)

(Total 13 marks)

8 The diagram below shows a zener diode used to produce a stabilised output of 10 V from a nominal 15 V supply.



The maximum output current supplied to the load is 100 mA. The zener diode must have a minimum current of 10 mA passing through it to maintain its voltage.

(a) Calculate the ideal value of the resistor R.

.....

.....

(2)

(b) Calculate the power dissipated by R under these conditions.

.....

.....

(2)

(c) State, giving a reason, the best value resistor to use from the E24 range.

.....

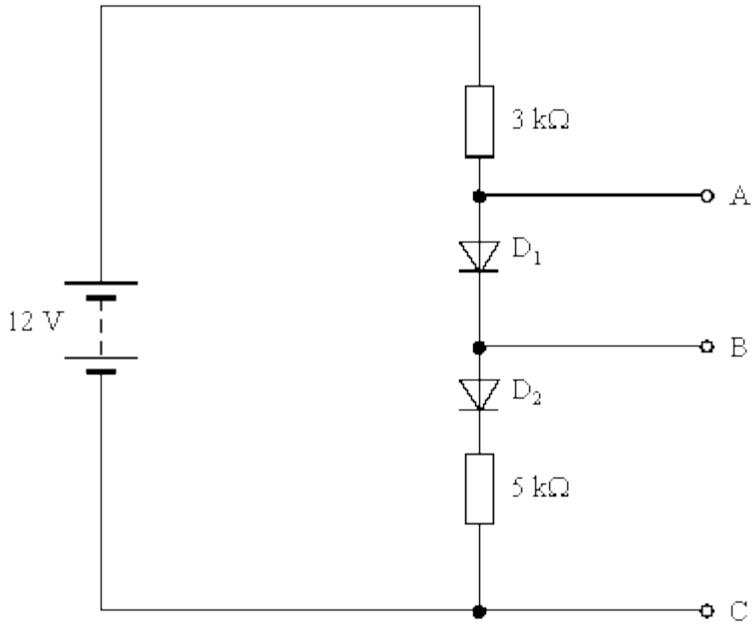
.....

.....

.....

(2)
(Total 6 marks)

9 The diagram below shows a series circuit containing resistors and silicon diodes.



(a) Calculate

(i) the voltage between A and C,

.....

.....

.....

.....

(ii) the voltage between B and C.

.....

.....

.....

.....

(4)

(b) A student connects diode D_2 the opposite way round to that shown in the diagram above.

State, giving reasons,

(i) the new voltage between A and C,

.....

.....

.....

.....

(ii) the new voltage between B and C.

.....

.....

.....

.....

(3)
(Total 7 marks)

Mark schemes

1

(a) force on an electron in a magnetic field depends on speed **(1)**
electrons at different speeds would be focussed differently so image would be blurred **(1)**
[or electrons at different speeds would have different (de Broglie) wavelengths
therefore resolution would be reduced]

2

(b) increase in pd increases speed **(1)**
increase in speed/momentum/E_k causes reduction of (de Broglie) wavelength **(1)**
reduced (de Broglie) wavelength gives better resolution **(1)**

3

[5]

2

(a) High input resistance ✓

low / no energy consumption when in the ON and OFF states✓
OR
No input current / control by pd only.

2

(b) Prevents static charge building up on gate (-source capacitor) ✓
Makes gate voltage 0 V when no water / nothing between probes ✓

2

(c) Identifies or attempts to use potential divider equation ✓

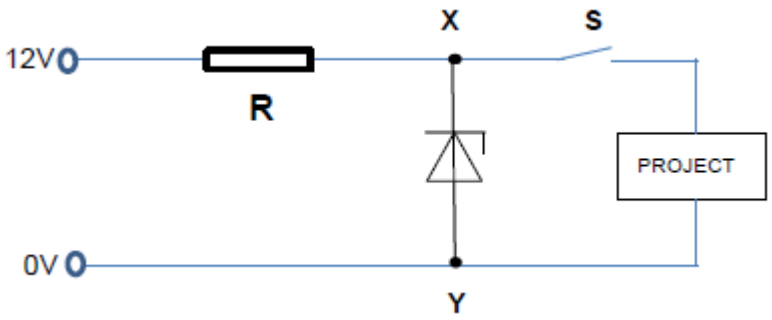
2.4 = 12 x 1 / (R_{probes} +1) leading to R_{probes} = 9.6 / 2.4 = 4 MΩ ✓

2

[6]

3

(a)



1 mark for Zener symbol
1 mark for orientation

2

(b) (i) 80mA + 5mA = 85mA

Answer − 1

1

(ii) 12V − 5.1 V = 6.9V

Calculation and answer − 1

1

(iii) R = 6.9V / 85mA = 81Ω

Calculation and answer − 2

2

(c) (i) $P = V^2 / R$ $P = (6.9 \times 6.9) / 75$ $P = 0.64W$
Hence P is approx. 0.6W

Calculation and answer − 2

2

(ii) I = V / R I = 6.9 / 75 I = 92mA

Calculation and answer − 2

2

[10]

4

(a) 10mA + 88mA = 98mA✓; V across resistor = 4.4-2.7 = 1.7V✓; R=1.7 / 0.098 ✓= 17.3Ω✓

4

(b) 98mA✓

1

(c) P = I.V = 0.098 × 2.7✓ = 0.265W✓; use 0.5W✓

3

(d) Voltage across R will increase✓,
so current through R will increase. ✓
current through zener will increase ✓

3

[11]

5

(a) (i) reverse✓

1

(ii) use of V = IR✓
$5\times10^{-9} \times 10^{6} = 5\times10^{-3}$V or 5mV✓

2

(iii) use of current = sens × power✓
6×10^{-7}A or 0.6 μA✓
voltage = 6×10^{-7}A × 10^{6} = 0.6V✓

3

(iv) T = RC $10^{6} \times 10\times10^{-12}$ ✓= 10^{-5}s or 10μs✓

2

(v) capacitance given at zero bias, reverse bias decreases diode capacitance / use of smaller resistance than stated in question ✓

1

(vi) Increase R ✓
use op-amp✓

2

(b) Attenuation✓ due to absorption✓ and / or scattering of signal in fibre✓Radiation✓ due to signal loss from tight bends or fibre misalignment ✓

5

[16]

6

(a) (i) zener diode✓

1

(ii) 4.7V✓

1

(iii) reverse✓

1

(b) (i) 5 + 100 = 105mA✓

1

(ii) 10 - 4.7 = 5.3V✓

1

(iii) 5.3 ÷ 0.105✓ = 50.5Ω✓

2

(iv) 47Ω✓

1

(c) (i) 14.4- 4.7 = 9.7V✓ 9.7 ÷ 33 = 294mA✓

2

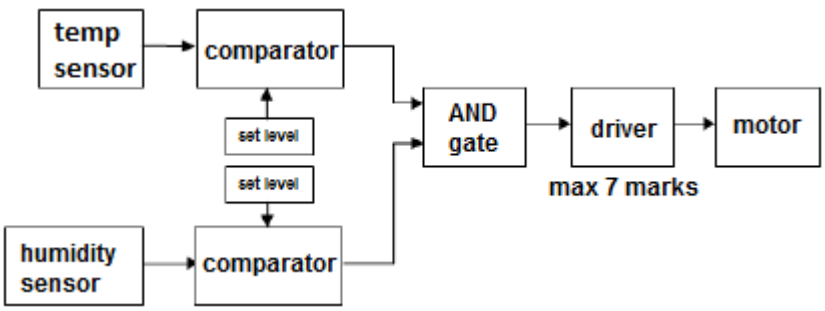
(ii) 4.7 × 0.294 = 1.38W✓

1

[11]

7

(a)



max 7 marks

7

(b) (i) driver✓

1

(ii) comparator✓

1

(iii) temperature sensor✓

1

(c) (i) 25 + 450 = 475mA✓

1

(ii) 12V × 475mA✓
= 5.7W✓

2

[13]

8

(a) $R = \frac{(15 - 10)}{110 \times 10^{-3}}$ **(1)**
= 45(.5) Ω **(1)**

2

(b) (use of $P = I^2R$ gives) $P = (110 \times 10^{-3})^2 \times 45$ **(1)**
= 0.54(5) W **(1)**
(allow C.E. for value of R from (a)

2

(c) 43 (Ω) **(1)**
(allow C.E. for value of R from (a)
go to lower resistor to ensure current through zener is > 10 mA **(1)**

2

[6]

9

(a) (i) pd across resistors = 12 – 1.4 = 10.6 (V) **(1)**

pd across 3 kΩ = $10.6 \times \frac{3}{8}$ = 4.0 (V) **(1)**

pd_{AC} (= 12 – 4) = 8.0 V **(1)**

(ii) pd_{BC} = 8.0 – 0.7 = 7.3 V **(1)**

(allow C.E. for value of pd_{AC} from (i))

4

(b) (i) diode D_2 in reverse mode, ∴ no current flow **(1)**
all pd dropped across D_2 **(1)**
pd_{AC} = 12 V **(1)**

(ii) pd_{BC} = 12 V **(1)**

max 3

[7]