

Cambridge IGCSE · Computer Science 0478 · Notes

Network hardware

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Read first: [Number systems](#), [Types and methods of data transmission](#)

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What you need to know

By the end of this topic you should be able to:

1. **Say why a computer needs a network interface card (NIC):** without one it can't connect to, or send and receive data on, a network.
2. **Explain what a MAC (media access control) address is and what it is for,** and describe its **structure:** it is given to the NIC when it is made, it is usually written in hexadecimal, and it is made of a manufacturer code followed by a serial code.
3. **Explain what an IP (internet protocol) address is and what it is for:** an address the **network** gives a device, which can be **static** or **dynamic**.
4. **Know the two types of IP address, IPv4 and IPv6:** what each looks like, and how they are alike and how they differ.
5. **Describe the role of a router:** it sends data to the right destination on a network, it can give devices their IP addresses, and it can connect a local network to the internet.

How packets are built and routed across the internet (packet switching) is in the transmission methods topic; converting between binary, denary and hexadecimal is in number systems. Both turn up inside questions on this topic, so they are recapped where needed.

Understand it

The network interface card (NIC)

A computer on its own has no way of talking to other computers. The **network interface card (NIC)** is the hardware component that connects it to a network. In most devices it is a chip built into the main circuit board rather than a separate card; a **wireless NIC (WNIC)** connects to a Wi-Fi network instead of through a cable.

The NIC:

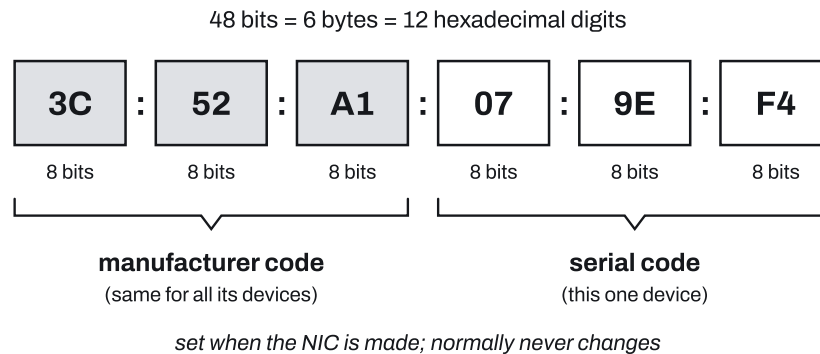
- gives the device its **physical connection** to the network (a cable socket, or a radio for Wi-Fi);
- **sends** the computer's data out onto the network and **receives** data sent to it;
- **converts** data between the form the computer uses and the form that travels over the network;

- carries the device's **MAC address**, so the device can be identified on the network.

Once connected, the device is also given an **IP address** by the network.

MAC addresses

Every NIC is given a **media access control (MAC) address** by its **manufacturer**, at the point it is made. Its purpose is to **identify the device uniquely** on a network: no two NICs in the world should have the same one. A MAC address is normally **static**: it stays with the NIC for its whole life.



The **structure** of a MAC address:

- it is **48 bits** (6 bytes) long;
- it is written in **hexadecimal**, as **12 digits** in **6 pairs**, each pair one byte;
- the pairs are separated by **colons** or **hyphens**: 3C:52:A1:07:9E:F4 or 3C-52-A1-07-9E-F4;
- the **first half** is the **manufacturer code** (the same for every NIC that company makes);
- the **second half** is the **serial code**, the number of this one device.

Hexadecimal is used because it is much shorter and easier for people to read than 48 binary digits, and each pair converts straight to one byte: 9E is 1001 1110 in binary, which is 158 in denary.

IP addresses

An **internet protocol (IP) address** is given to a device by the **network** it connects to (usually by the router, or by the internet service provider). Its purpose is to **identify the device on the network**, so that data can be sent to it, like a postal address. When a web page is requested, it is sent back to the requesting device's IP address.

IP addresses can be:

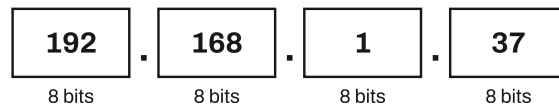
- **static**: the address stays the same every time the device connects. It is set once and doesn't change. Web servers use static addresses, so they can always be found at the same address.
- **dynamic**: a new address is given to the device **each time it connects** to the network, so it **can change** from one connection to the next. Most phones and laptops get dynamic addresses, usually from the router. While it is connected, a dynamic address still uniquely identifies the device.

(IP addresses can also be **public**, used on the internet, or **private**, used only inside a local network.)

IPv4 and IPv6

There are two versions of IP address in use.

IPv4 4 denary numbers, 0 to 255, separated by dots: 32 bits



IPv6 8 groups of 4 hex digits, 0000 to FFFF, separated by colons: 128 bits



zero groups in a row can be written once as :: → 2A03:0B40::0007

IPv4, the older version:

- is **32 bits** long;
- is written as **4 groups of denary** numbers, each from **0 to 255** (one byte each), separated by **dots**, for example 192.168.1.37;
- gives 2^{32} , about 4.3 billion, different addresses, which is no longer enough for every device in the world;
- has two parts: the **network prefix** (which network) and the **host number** (which device on it).

A number above 255, a colon instead of a dot, or the wrong number of groups makes an IPv4 address **invalid**: 192.168.300.4, 192:168:1:4 and 10.4.7 are all invalid.

IPv6, the newer version, was brought in because IPv4 addresses were running out:

- is **128 bits** long;
- is written as **8 groups of 4 hexadecimal digits**, each from **0000 to FFFF** (16 bits each), separated by **colons**, for example 2A03:0B40:0000:0000:0000:0000:0000:0007;
- a run of groups that are all zero can be replaced by a **double colon ::**, but **only once** in an address, so the address above can be written 2A03:0B40::0007 (the leading zeros in a group can also be dropped: 2a03:b40::7);
- gives 2^{128} , about 3.4×10^{38} , different addresses, enough to never run out.

	IPv4	IPv6
Length	32 bits (4 bytes)	128 bits (16 bytes)
Written in	Denary	Hexadecimal
Groups	4 groups, each 0 to 255	8 groups, each 0000 to FFFF
Separated by	Dots	Colons
Shortening	None: every group is written	:: can replace a run of zero groups, once

	IPv4	IPv6
Number of addresses	About 4.3 billion	About 3.4×10^{38}

Similarities: both identify a device on a network, both are unique on that network, both can be static or dynamic, both can be public or private, and both can be assigned by a router.

MAC address or IP address?

A device has both, and they do different jobs.

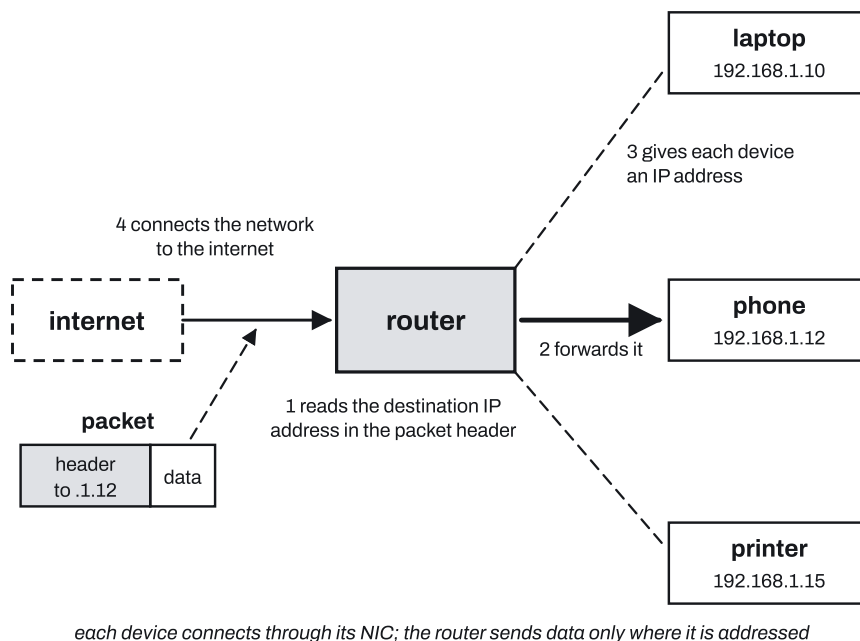
	MAC address	IP address
Given by	The manufacturer, when the NIC is made	The network (router or ISP), when the device connects
Changes?	Normally never (static)	Can change, if it is dynamic
Written in	Hexadecimal	Denary (IPv4) or hexadecimal (IPv6)
Groups	6 pairs	4 (IPv4) or 8 (IPv6)
Size	48 bits	32 bits (IPv4) or 128 bits (IPv6)
Contains	Manufacturer code and serial code	Network prefix and host number; no manufacturer code

Both are unique, both identify a device, both belong to the device's hardware, and both can be written in hexadecimal.

The router

A **router** is the device that joins networks together and sends data where it needs to go. It has three roles:

1. **It sends data to the correct destination.** Data travels in packets, and each packet's header holds the **destination IP address**. The router **reads** that address and **forwards** the packet to the device on its network with that address or, if the destination is on another network, sends it on towards it by the best route. On the internet, each packet passes through many routers, and each one chooses the next step of its route.
2. **It can assign IP addresses.** When a device joins the network, the router can automatically give it a (dynamic) IP address.
3. **It can connect a local network to the internet.** A home or school network reaches the internet through its router.



This is the kind of diagram asked for when a question says "draw and annotate a diagram to represent the role of a router": the router, what it joins, a packet, and a note of each thing it does.

Key facts and formulas

There are no formulas in this topic. These are the facts to learn; nothing here is given in the exam.

Fact	Status
A device needs a NIC to connect to a network; the NIC sends and receives data and gives the physical connection	Learn it
MAC address: given by the manufacturer; unique; usually static; identifies the device	Learn it
MAC structure: 48 bits, 12 hex digits in 6 pairs, colons or hyphens; manufacturer code + serial code	Learn it
IP address: given by the network; identifies the device so data can be sent to it; static or dynamic	Learn it
Dynamic IP: a new address each time the device connects, so it can change	Learn it
IPv4: 32 bits, 4 denary groups 0–255, dots; about 2^{32} addresses	Learn it
IPv6: 128 bits, 8 hex groups 0000–FFFF, colons; :: replaces zero groups once	Learn it
Router: forwards data to its destination IP address, assigns IP addresses, connects a network to the internet	Learn it

Fact	Status
Hex digit = 4 bits; two hex digits = 1 byte; denary 0–255 = 8 bits	Learn it

How to do it

In the Paper 1 questions we have tagged for this topic (16 questions, 2021–2025), the types came up this often. 7 of the 16 questions mix more than one type, so the counts add up to more than 16.

Question type	Questions
The role of a router	8
MAC addresses: who assigns them, features and structure	7
IP addresses: IPv4 and IPv6, static and dynamic	7
The NIC	3
Compare MAC and IP addresses	2
Convert the numbers in an address	2

1. The role of a router (8 questions)

1. **Name it** when a question describes it: "the device that forwards data towards its correct destination", "the device that can connect several devices and automatically give them an IP address", "the device that assigns an IPv4 address" (in a tick list with DNS, NIC and web server) are all **router**.
2. **Describe what it does**, one point per mark:
 - it reads the **destination IP address** in each packet's **header**;
 - it **forwards** each packet to that destination, choosing the **route** (the fastest or most efficient one);
 - it **assigns IP addresses** to devices when they connect;
 - it **connects devices** and **connects networks**, such as a local network to the internet.

Variations you will meet:

- **"Draw and annotate a diagram to represent the role of a router"** (4 marks). Draw a box labelled "router", lines to two or three devices and one to the internet, and a packet arriving. Annotate: the router **examines** the packet; it looks at the **packet header**; it reads the **destination IP address**; it sends the packet **towards its destination** by the best route; it **connects** the devices or networks; it **assigns IP addresses** to the devices. Each annotation is a mark, so write at least four. The third diagram in "Understand it" is a model.
- **"Give the purpose of a router in packet switching"** (1 mark): it controls the route each packet takes, sending each packet on towards its destination.

- **A definition table** ("router: ..."): say what it does with data, for example "it reads the destination IP address of each packet and passes the packet on towards that address". Examiners say few candidates define a router well: "it connects to the internet" is not enough.
- **Connecting a computer to a router in another room**: the connection itself is a transmission question: there is no mark for choosing serial or parallel, only for reasons that fit your choice (serial works well over a longer distance; parallel is faster, and the next room may be close enough), and the packet header items (destination address, sender's address, packet number) come from transmission methods.

2. MAC addresses: who assigns them, features and structure (7 questions)

1. **Who assigns it** (tick or 1 mark): the **manufacturer**. Not the router, the network or the user, and not "the product".
2. **Features or characteristics** (usually 3 marks), from this list:
 - written in **hexadecimal**;
 - **6 pairs** (groups) of hex digits, **12 digits**, **48 bits**, 6 bytes;
 - pairs separated by **colons** or **hyphens**;
 - contains the **manufacturer code** and the **serial code** (device number);
 - it is **unique** and **assigned by the manufacturer**;
 - it is **static**: it normally doesn't change.
3. **Name it** from a description: "assigned by the manufacturer and used to uniquely identify the device" is a **MAC address**.

Variations you will meet:

- **"Identify three characteristics"** after the question has said what a MAC address is for: give features of **the address itself** (hexadecimal, 6 pairs, colons, 48 bits, manufacturer code + serial code). Examiners say many candidates wrote what it is used for ("to identify a computer"), which doesn't count as a characteristic.
- **A multiple-choice statement**: "It is assigned by the manufacturer" is true; "it can be static or dynamic" and "it is made of three parts" are false (it has two parts).

3. IP addresses: IPv4 and IPv6, static and dynamic (7 questions)

1. **Name it** from a description: "assigned by the network and used to identify a device on the network" or "the address given to a device when it connects to the internet" is an **IP address**.
2. **Characteristics of IPv4** (up to 4 marks): denary; each number 0 to 255; 32 bits; 4 groups; separated by dots. Extra accepted points: unique, static or dynamic, public or private, contains a network prefix and a host number. Examiners say many candidates gave general IP facts: give the **IPv4-specific** ones first.
3. **Characteristics of IPv6**: 128 bits (16 bytes); hexadecimal; 8 groups of 4 characters; separated by colons; :: can replace consecutive zero groups, only once.
4. **Differences between IPv4 and IPv6** (usually 4 marks for two): write each as a **pair** with "whereas":
 - IPv4 is 32-bit, **whereas** IPv6 is 128-bit;

- IPv4 is written in denary, **whereas** IPv6 is written in hexadecimal;
- IPv4 uses dots, **whereas** IPv6 uses colons;
- IPv4 has 4 groups, **whereas** IPv6 has 8;
- IPv4 groups go from 0 to 255, **whereas** IPv6 groups go from 0000 to FFFF;
- IPv4 writes every group, **whereas** IPv6 can use **::** for zero groups;
- IPv4 has fewer possible addresses, **whereas** IPv6 has far more.

5. **A similarity:** both identify a device on a network; both are unique; both can be static or dynamic; both can be assigned by a router; both can be public or private.

Variations you will meet:

- **"Tick the valid IPv4 address":** check four things: dots (not colons), exactly 4 numbers, every number 0 to 255, only denary digits. 3.162.74.3 is valid; 8.0.257.6.8 fails (257, and five groups), 1.30.2FF.A9 fails (hex letters), 110:255:2:1 fails (colons).
- **"Give an example of an IPv4 address":** four numbers from 0 to 255 with dots, such as 10.245.3.99. Check every number is at most 255.
- **"Describe what is meant by a dynamic IP address"** (3 marks): it identifies the device on the network; it can change; a new one is given each time the device connects. Examiners say some candidates described IPv4 or IPv6 instead: answer about **dynamic**.
- **"Which device automatically gives a computer an IP address each time it connects?":** a router.

4. The NIC (3 questions)

1. **Name it:** "the component needed to access a network" is a **network interface card (NIC)** (or WNIC for wireless). The most common wrong answer is "router": the router is a separate device, the NIC is **inside** the computer.
2. **Its purposes** (2 marks, beyond "provides the MAC address"): it gives the physical connection to the network; it sends and receives data over the network; it converts data between the computer's form and the network's form; it is how the device gets an IP address.
3. **A definition table** ("NIC: ..."): the hardware inside a computer that joins it to a network, so it can send and receive data.

5. Compare MAC and IP addresses (2 questions)

1. **Similarities** (1 or 2 marks): both are unique; both identify a device on a network; both are assigned to hardware; both can be written in hexadecimal.
2. **Differences** (2 marks): each must state **both sides**. Examiners warn that one side only earns nothing.
 - a MAC address is assigned by the manufacturer, **whereas** an IP address is assigned by the network (router or ISP);
 - a MAC address normally never changes, **whereas** an IP address can change if it is dynamic;
 - a MAC address has 6 groups, **whereas** an IP address has 4 (IPv4) or 8 (IPv6);
 - a MAC address is 48 bits, **whereas** an IP address is 32 or 128 bits;

- a MAC address contains the manufacturer's code and a serial number, **whereas** an IP address doesn't;
- a MAC address is in hexadecimal, **whereas** an IPv4 address is in denary.

6. Convert the numbers in an address (2 questions)

The address is only the setting; the skill is from number systems.

1. **Hex pair** → **8-bit binary**: convert each hex digit to 4 bits and join them: C9 → 1100 and 1001 → 11001001.
2. **Hex pair** → **denary**: first digit $\times 16$ + second digit: C8 → $12 \times 16 + 8 = 200$.
3. **Denary (an IPv4 number)** → **8-bit binary**: use the place values 128, 64, 32, 16, 8, 4, 2, 1: $167 = 128 + 32 + 4 + 2 + 1 = 10100111$.

Always give **8 bits**, with leading zeros: hex 14 is 00010100, not 10100.

Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **B1** mark for a correct result on its own, with no method needed.
-

Example 1

A laptop is connected to a school network.

- (a) Identify the component in the laptop that is needed to connect to the network. **[1]**
- (b) The component has the MAC address 3C:52:A1:07:9E:F4. Describe the structure of a MAC address. **[3]**
- (c) Convert the hexadecimal value 9E from the MAC address into 8-bit binary and into denary. **[2]**
- (d) Explain why the MAC address of the laptop is not expected to change. **[2]**

(a) Network interface card (NIC). **B1**

(b) Any three:

- it is written in hexadecimal **B1**;
- it has 6 pairs of digits (12 digits, 48 bits) **B1**;
- the pairs are separated by colons (or hyphens) **B1**;
- the first half is the manufacturer code and the second half is the serial code of the device.

(c) $9 = 1001$, $E = 1110$, so 10011110 **B1**. Denary: $9 \times 16 + 14 = 158$ **B1**.

(d) It is assigned by the manufacturer when the NIC is made **B1**, and it is a static address that identifies that NIC uniquely, so it stays the same whatever network the laptop joins **B1**.

Example 2

The laptop is also given an IP address.

(a) Tick (✓) **one** box to show the valid IPv4 address. **[1]**

	Address
A	172.16.300.4
B	10.0.0.255
C	192:168:1:2
D	12.4.7

(b) Describe **two** differences between IPv4 and IPv6 addresses. **[4]**

(c) The laptop's IP address is dynamic. Describe what is meant by a dynamic IP address. **[2]**

(d) Convert the denary value 172 into 8-bit binary. **[1]**

(a) B. (A has $300 > 255$, C uses colons, D has only 3 groups.) **B1**

(b) Any two paired differences, one mark for each side:

- IPv4 is 32 bits **B1**, whereas IPv6 is 128 bits **B1**;
- IPv4 is written as denary numbers separated by dots **B1**, whereas IPv6 is written as hexadecimal separated by colons **B1**.

(Also accepted: 4 groups whereas 8 groups; 0–255 whereas 0000–FFFF; fewer addresses whereas many more; no shortening whereas :: for zero groups.)

(c) Any two: it is given to the laptop by the network each time the laptop connects **B1**; so it can change from one connection to the next **B1**; it still identifies the laptop on the network while it is connected.

(d) $172 = 128 + 32 + 8 + 4$, so 10101100. **B1**

Example 3

A customer's phone joins the Wi-Fi network in a café. The phone then streams a video from a web server, and the video arrives at the café's router as packets addressed to the phone.

(a) Describe how the café's router deals with each packet of the video. **[3]**

(b) Identify **one** other task the router carries out when the phone joins the network. **[1]**

(a) Any three:

- it reads the header of each packet **B1**;
- it finds the destination IP address in the header, which is the phone's IP address **B1**;
- it sends the packet on to the phone, the device on the café network with that address **B1**;
- it does this for every packet, so the whole video reaches the phone and no other customer's device.

(b) It gives the phone a (dynamic) IP address. **B1** (Also accepted: it connects the phone to the internet.)

The third diagram in "Understand it" shows the same steps for a home network.

Example 4

Write the name of the network item that each statement describes. **[4]**

(a) Its twelve hexadecimal digits are split into a part that identifies the company that made it and a part that identifies this one device.

(b) Four denary numbers, none larger than 255, with a dot between each pair.

(c) Hardware built into a laptop that turns the laptop's data into signals for the network cable or Wi-Fi, and back again.

(d) A device that looks at where each packet is going and passes it on towards that address.

(a) MAC address **B1**. (b) IPv4 address **B1**. (c) Network interface card (NIC) **B1**. (d) Router **B1**.

Common mistakes

- **Answering "router" for the component inside the computer.** The component needed to access a network is the **NIC**; the router is a separate device the NIC connects to.
- **Saying the router or the user assigns the MAC address.** The **manufacturer** does, when the NIC is made. The router assigns **IP** addresses.
- **Giving what a MAC address is for when asked for its characteristics.** "To identify the computer" is its purpose. Characteristics are about the address: hexadecimal, 6 pairs, colons, 48 bits, manufacturer code and serial code.
- **One-sided differences.** "An IP address can change" earns nothing on its own; add "whereas a MAC address normally doesn't". Examiners mention this every year for MAC vs IP and IPv4 vs IPv6.
- **General IP facts for an IPv4 question.** "It identifies a device" is true of every address; the IPv4 marks are for denary, 0–255, 32 bits, 4 groups and dots.
- **Mixing up the two versions:** saying IPv4 uses colons or hexadecimal, or IPv6 is 64 bits. IPv4: 32 bits, dots, denary. IPv6: 128 bits, colons, hex.
- **Writing an "IPv4 address" with a number over 255,** such as 192 . 168 . 256 . 1. Each group is one byte, so 255 is the maximum.

- **Describing IPv4 or IPv6 when asked about a dynamic address.** "Dynamic" is about the address **changing**: a new one each time the device connects.
- **Vague router definitions**, such as "it connects to the internet" or "it gives you Wi-Fi". Say that it **forwards data packets to their destination** using the destination IP address.
- **Router diagrams with no annotations**, or annotations that don't say what the router does. Each mark is for a step: examine the packet, read the header, find the destination IP address, send it on by the best route.
- **Dropping leading zeros in a binary conversion.** Hex 14 is 00010100 as 8 bits.

How to get the marks

- **"Identify", "give", "state"** (1 mark each): the exact term: "NIC", "MAC address", "router", "manufacturer", "dynamic IP address". A tick list: tick exactly one box.
- **"Describe"** (characteristics or structure): one fact per mark, from the lists in "How to do it". Numbers help: 48 bits, 32 bits, 128 bits, 0 to 255, 6 pairs, 4 groups, 8 groups.
- **"Describe two differences"** (4 marks): two pairs, each with both sides joined by "whereas". Each side is a mark.
- **"Give one similarity"**: a fact true of **both**: "both identify a device on a network", "both are unique".
- **"Draw and annotate"**: the drawing only has to be clear; the marks are in the annotations, one per step. Write at least as many annotations as there are marks.
- **Tables of terms and definitions**: one mark per row; a definition must say what the thing **does** or is **for**, not just where it is.
- **Read what the question already gives.** If it says the NIC provides the MAC address, give its **other** purposes; if it names one part of an address, give the others.
- **Conversions**: 8 bits for each byte, with leading zeros; show the place values if there is working space.

Quick check

1. Which **two** of these are valid IPv4 addresses? 8.8.4.4, 256.1.1.1, 10.20.30, 192.168.0.1
2. Write the IPv6 address 2C0F:0000:0000:0000:0000:0010:0001 in a shorter form using a double colon.
3. Give **two** differences between a MAC address and an IP address.
4. A device has the MAC address A4:5E:60:C2:19:0D. (a) Which part is the manufacturer code? (b) Convert C2 to denary and to 8-bit binary.
5. Describe **three** things a router does in a home network.

Answers

1. 8.8.4.4 and 192.168.0.1. (256.1.1.1 has a number over 255; 10.20.30 has only 3 groups.)
2. 2C0F::0010:0001. The five zero groups in a row become ::; the double colon can only be used once.
3. Any two, both sides each time: a MAC address is assigned by the manufacturer, whereas an IP address is assigned by the network; a MAC address normally doesn't change, whereas a dynamic IP address can; a MAC address is 48 bits, whereas an IP address is 32 or 128 bits; a MAC address has 6 pairs of hex digits, whereas an IPv4 address has 4 denary numbers; a MAC address contains a manufacturer code, whereas an IP address doesn't.
4. (a) A4:5E:60, the first three pairs. (b) $12 \times 16 + 2 = 194$; c = 1100, 2 = 0010, so 11000010.
5. Any three: it reads the destination IP address in each packet's header; it forwards each packet to the device with that address (or towards it by the best route); it assigns an IP address to each device when it connects; it connects the home network to the internet.

Past questions to try

- 0478/13/O/N/23 Q8: draw and annotate the role of a router.
- 0478/13/M/J/23 Q9: a similarity and two differences between IPv4 and IPv6.
- 0478/13/O/N/22 Q8: similarities and differences between MAC and IP addresses.
- 0478/13/M/J/21 Q1: who assigns a MAC address, then converting its hex pairs.