Security, privacy and data integrity

A-Level Computer Science

Security, privacy and integrity — three different ideas

These sound alike but mean different things:

- **security** 安全 — protecting data from **unauthorised** 未授权 access, change or destruction.
- **privacy** 隐私 — an individual's right to **control who sees their personal data**, with consent and a clear purpose.
- **integrity** 完整性 — the data being **accurate and complete** — not corrupted or accidentally changed.

A file can be secure (only the right people can open it) but lack integrity (a typo corrupted it); or accurate but not private (anyone can read it). All three are needed.

The differences the scheme wants, one sentence each: **security** is keeping the data safe from loss and from unauthorised access; **privacy** is keeping the data confidential, so that only those with the right to see it can; **integrity** is the data being correct, consistent and complete. So "the difference between security and privacy": security is about protecting the data from being accessed, changed or lost by people who should not; privacy is about the individual's right to decide who may see their personal data. "The difference between security and integrity": security protects the data from unauthorised access; integrity is about the data being accurate and up to date, which validation and verification protect.

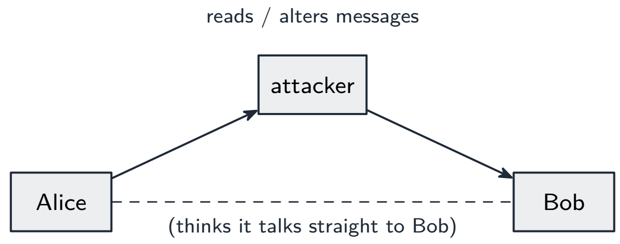
Why security matters

Two things to protect: the **data** itself (keep it confidential, intact and available) and the **computer system** (a compromised system can attack others, steal credentials, or be held to ransom).

"Why does the school need to keep both secure?" Data: it is personal and confidential, so it must not be read, changed or deleted by an unauthorised person, and its loss would stop the school working. System: an intruder who reaches the computer system can install malware, use it to attack other systems, damage the hardware or software, or lock it with ransomware; a secure system is the first line of defence for the data on it.

Threats from networks and the internet

Threats fall into three groups.



A man-in-the-middle attacker sits between the two parties

1. **Malware** 恶意软件 (malicious software) — harmful programs:

- **virus** 病毒 — self-copying code that attaches to other programs and spreads when they run.
- **worm** 蠕虫 — self-copying code that spreads over **networks** 网络 with no user action.
- **Trojan horse** 木马 — looks useful but hides malicious code.
- **spyware** 间谍软件 — secretly collects information (keystrokes, passwords).
- **ransomware** 勒索软件 — encrypts your files and demands payment.
- **adware** 广告软件 — pushes unwanted adverts.

2. Tricking people (social attacks):

- **phishing** 网络钓鱼 — fake emails/sites that trick users into giving credentials.
- **pharming** 域名欺骗 — redirects a user to a fake site even when they type the correct address.
- **social engineering** 社会工程 — tricking people into giving up information.

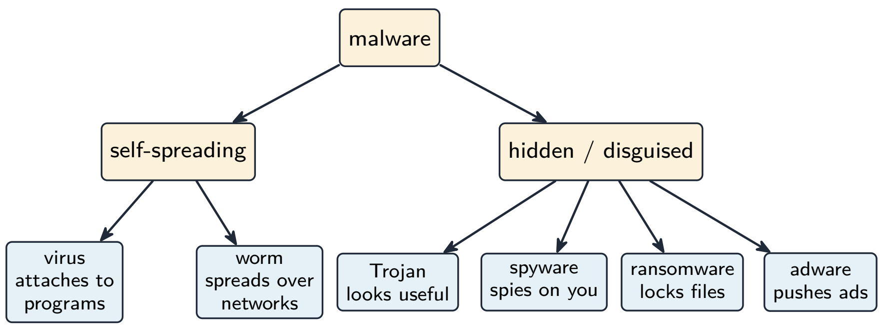
The scheme's descriptions of the four named threats: a **virus** is malicious software that replicates (copies itself), attaches itself to other files and deletes or corrupts data; **spyware** is malicious software that records the user's key presses and actions and sends them to a third party, to obtain passwords and personal data; a **phishing** email pretends to come from a legitimate organisation and contains a link to a fake website where the user is asked for personal or bank details; **pharming** is malicious code installed on the user's computer or on a web server that redirects the user to a fake website even though they typed the correct address. Similarities of spyware and a virus: both are malware, both are installed without the user's knowledge, both can send data to a third party or damage the system; the difference is that a virus replicates itself while spyware records and transmits information. Phishing and pharming both lead the user to a fake website that collects their data; phishing needs the user to click a link in an email, pharming works through code on the computer or the DNS server and needs no email.

3. Attacks on the network:

- **hacking** 黑客入侵 by **hackers** 黑客 — unauthorised access, often via weak passwords or software flaws.
- **denial of service** 拒绝服务 (DoS/DDoS) — floods a server so real users cannot reach it.
- **eavesdropping** 窃听 — capturing data in transit (a risk on open Wi-Fi).
- **man-in-the-middle** 中间人攻击 — an attacker secretly relays or alters messages between two parties.

Worked example. Identify and describe two threats to the data on a school network, and give a different prevention method for each.

Threat 1, malware: a virus copied onto a computer from an email attachment or a download replicates itself and corrupts or deletes files; prevention: anti-virus software that scans files and is kept up to date. Threat 2, hacking: an unauthorised person gains access to the network, for example by guessing a weak password, and reads or changes the data; prevention: a firewall that blocks unauthorised connections, or strong passwords with two-factor authentication. A third pair, phishing: an email leads a user to a fake site that collects their login; prevention: training users to check the sender and the URL, and filtering email. The measure must match the threat: encryption does not stop a virus, and anti-virus software does not stop phishing.



Malware by behaviour: self-spreading (virus, worm) versus hidden/disguised (Trojan, spyware, ransomware, adware)

Security measures

Measures protect both the **security of data** (against loss, theft or corruption) and the **security of the computer system** (its hardware, software and network).

A standalone PC

- a strong password; **antivirus** kept up to date; prompt **software updates**; **backup** 备份 to separate media; full-disk **encryption** 加密; a locked screen.

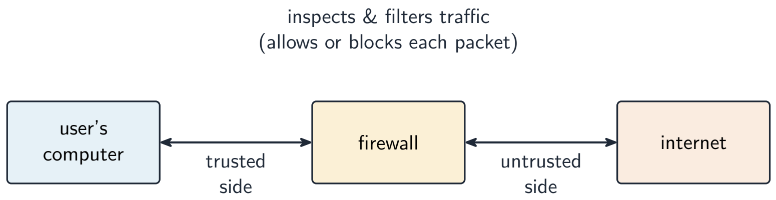
A networked PC

All the above, plus a **firewall** 防火墙, per-user **permissions** (admin rights only for admins), central management of **user accounts** 用户账户, and **audit logs** 审计日志 (who logged in, what they touched).

How the measures work, in the wording the scheme awards:

- **firewall**: examines every incoming and outgoing transmission and compares it with set criteria (a whitelist or blacklist of addresses, ports and protocols); blocks any that do not meet the criteria; can prevent access to certain sites and warn of unauthorised access attempts.
- **encryption**: the data is scrambled (encoded) with a key into ciphertext, so an intercepted copy cannot be understood without the key; the receiver uses a key to decrypt it. It protects data in transmission and in storage, but it does not stop the data being intercepted or deleted.
- **passwords and user accounts**: only a user who knows the password can log in; a strong password (long, mixed characters, changed regularly) cannot be guessed; accounts lock after repeated failures; each account carries its own access rights.
- **anti-virus and anti-spyware software**: scans files and programs against a database of known malware signatures, checks behaviour, quarantines or deletes what it finds, and must be updated so that new malware is recognised.
- **access rights**: each user (or group) is given permissions for each file or table, such as read-only or read and write, so a user cannot see or change data that is not theirs; a database can also present each user with a view containing only the fields they need.
- **biometrics**: the device captures an image of the face, fingerprint or iris, converts it to digital data, compares it with the stored data for that user and allows access only on a match; it cannot be forgotten, lent or guessed like a password.
- **backups**: a copy of the data on separate media, kept off-site, so that lost or corrupted data can be restored.

To restrict the risks of malware, in three marks: install anti-malware software and keep it updated; use a firewall; do not open attachments or download files from unknown sources; keep the operating system and applications patched; and train users.

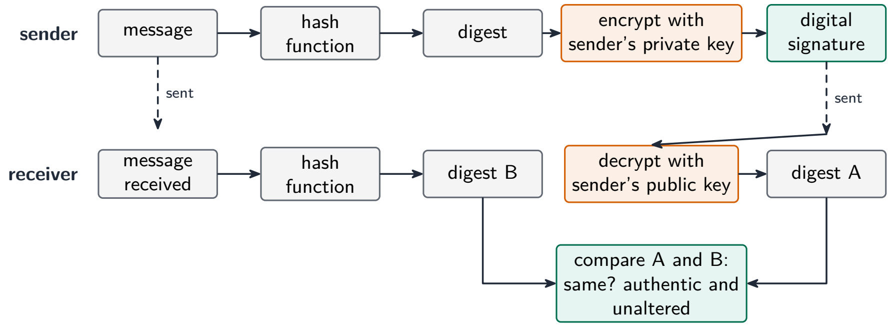


A firewall sits between the user's computer and the internet

Across the internet

- **VPN** 虚拟专用网 — encrypts traffic between the user and the corporate gateway.
- **HTTPS / TLS** — encrypt web traffic.
- **digital signatures** 数字签名 — prove who sent a message and that it was not altered in transit.
- intrusion detection — watches traffic for known attack patterns.

How a digital signature authenticates a document (five marks): the sender puts the message through a hash function to produce a digest; the sender encrypts the digest with their **private key**, and that encrypted digest is the digital signature; the message and the signature are sent together; the receiver decrypts the signature with the sender's **public key** to recover the digest; the receiver hashes the received message and compares the two digests; if they match, the message came from the sender (only they hold the private key) and was not altered in transmission. A signature proves who sent the message and that it is intact; it does not hide the contents, which is what encryption of the message is for.



A digital signature: a hash of the message, encrypted with the sender's private key, checked by the receiver against a fresh hash

Matching measures to threats

- **interception in transit** → **encrypt** the data (HTTPS, VPN). Intercepted ciphertext is useless without the key.
- **unauthorised access** → strong **authentication** 身份验证 (long passwords; **two-factor authentication** 双因素认证 with a phone code or key); user **authorisation** 授权; lock-out after failed logins.
- **malware** → **anti-virus software** and **anti-spyware** 反间谍软件 with real-time scanning; patching; avoid untrusted downloads.
- **phishing** → user training; email filtering; check the URL before entering credentials.
- **internal threats** → the **least-privilege** 最小权限 principle (give each user only what they need); auditing.
- **DDoS** → rate limiting and traffic filtering.

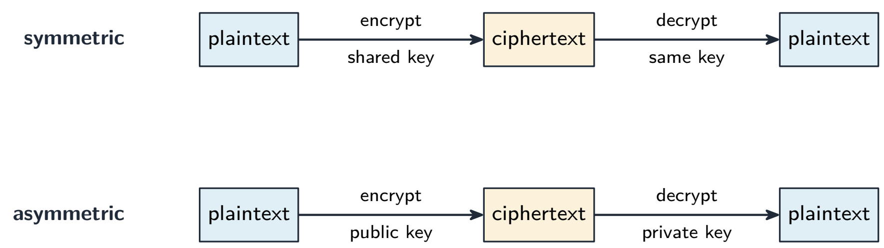
For confidential data crossing the internet, the scheme's method is **encryption**: the data is encoded with a key into ciphertext, so that an unauthorised person who intercepts it cannot read it, and only the intended receiver, who has the key, can decode it. For a program file sent by email for testing, the same answer applies (encrypt the file, or send it over an encrypted connection), together with a password on the file itself.

Protecting the data itself

- **encryption** — turn **plaintext** 明文 into **ciphertext** 密文 with a key. **Symmetric encryption** 对称加密 (AES) uses one shared key; **asymmetric encryption** 非对称加密 (RSA) uses a **public key** 公钥 and a **private key** 私钥. Protects data at rest and in transit.

- **access control** 访问控制 — file permissions (read/write/execute) and **access rights** 访问权限, enforced by the OS.
- **authentication** — **authentication techniques** verify the user: something you know (password), have (token, phone), or are (**biometrics** 生物识别 — fingerprint, face, iris); strongest combined.
- **backups** — keep copies (some **off-site**) so loss or corruption is recoverable.
- **physical security** — locked server rooms, cable locks.

Access rights in a database, described for three marks: each user is given an account with a username and password; the database administrator assigns each account permissions for each table, such as read-only, read and write, or no access; users see only the tables and fields they are allowed to, so a customer cannot open the staff table and a clerk can read but not change the prices. The **DBMS** enforces this with its access rights and with **views**, and it can encrypt the stored data as well.



Symmetric uses one shared key; asymmetric uses a public key to encrypt and a private key to decrypt

A security token shows a changing code for two-factor authentication ("something you have")

A fingerprint reader checks "something you are" — a feature of the person, not a password

Data integrity

Data has integrity when it is accurate and complete. Two techniques: **data validation** (catch bad data before storing) and **data verification** (confirm data was entered or transferred correctly).

Validation — does the data make sense?

Validation 验证 checks data against sensible rules, automatically:

- **range check** — within limits (a month is 1–12).
- **limit check** — on the correct side of a single limit (e.g. age ≥ 18).
- **existence check** — the referenced item exists (e.g. a product code is in the table).
- **length check** — the right number of characters.
- **type / character check** — the right kind of data (a phone field allows only digits).
- **format check** — matches a pattern (an email must contain `@`).
- **presence check** — required fields are not empty.
- **check digit** 校验位 — an extra digit computed from the others (ISBN, card numbers) that spots transcription errors.

Worked example. In a simple check-digit scheme the check digit is the remainder when the sum of the digits is divided by 10, appended to the number. The number 4162 has digit sum 13, so it is stored as 41623. A user types 14623: the first two digits are swapped, but the sum is still 13, so the check digit still matches and the error is **not** caught. A user who types 41523 is caught, because $4 + 1 + 5 + 2 = 12$ gives check digit 2. A scheme that catches swapped digits weights each position differently, as the ISBN-13 check does (weights $1, 3, 1, 3, \ldots$, then the digit that makes the total a multiple of 10). A check digit is validation: it tests the number against a rule at the moment it is entered.

- **lookup check** and **consistency check** (e.g. delivery date ≥ order date).

Validation catches data that is wrongly **formatted**, but not data that is the right format yet factually wrong (“Bob” for “Bib”).

Worked example. Identify the validation check each piece of pseudocode performs.

Pseudocode	Check
`IF x < 0 OR x > 10 THEN OUTPUT "Invalid"`	range check: the value must lie between two limits
`IF x = "" THEN OUTPUT "Invalid"`	presence check: the field must not be empty
`IF NOT(x = "Red" OR x = "Yellow" OR x = "Blue") THEN OUTPUT "Invalid"`	lookup (existence) check: the value must be one of a list
`IF LENGTH(x) <> 6 THEN OUTPUT "Invalid"`	length check: the right number of characters
`IF MID(x, 1, 1) < "A" OR MID(x, 1, 1) > "Z" THEN OUTPUT "Invalid"`	format check: a particular character must be a letter

To validate a car registration number that must be one letter, three digits and two letters: a **format check** tests each position against its pattern, and a **length check** confirms six characters. To validate a date of birth: a format check (DD/MM/YYYY), a range check (the month is 1 to 12, the year is not in the future) and a presence check (it is not left blank). A mark between 0 and the maximum for the test needs a type check (an integer) and a range check, with the upper limit read from the test’s own record: that is how validation protects integrity, by refusing data that could not be correct.

Verification — was the data entered or transferred correctly?

Verification 核对 checks the data was not changed in moving from one place to another.

During entry: **double entry** (type it twice and compare, as for a new password) or **visual** check.

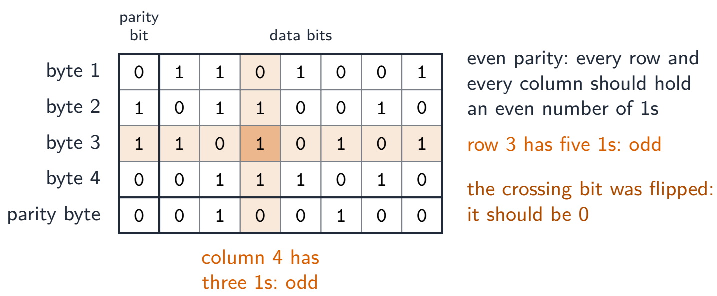
In the scheme’s words, **double entry** is entering the data twice, by the same person or by two people, and having the computer compare the two versions and report any difference; a **visual check** is the person comparing what is on the screen with the original source document and correcting any difference before saving. Both protect integrity by making sure the stored data matches the source. Even after validation and verification the data can still be wrong: it can be sensible and match the source, yet the source itself was wrong, or the user typed a different but valid value from the one intended.

During transfer (bits can flip):

- **parity check** 奇偶校验 — an extra bit makes the number of 1s even (even parity) or odd. The receiver re-counts. Catches single-bit errors.
- **checksum** 校验和 — the sender sends a summary value of the data; the receiver recomputes it and compares.
- **cyclic redundancy check** 循环冗余校验 (CRC) — a stronger checksum using polynomial division, catching many more error types.

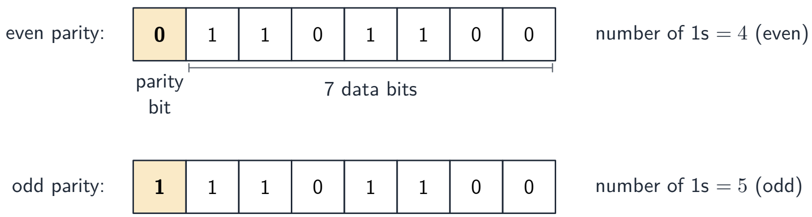
A **parity block check** 奇偶块校验 goes further and *locates* the error. Arrange the bytes in a grid: give each byte a **row** parity bit, then compute one extra **parity byte** whose bits are the **column** parity of the bytes above. A single flipped bit now fails **one row and one column** – their intersection pinpoints exactly which bit changed, so it can even be corrected.

Worked example. Four bytes are sent with even parity, followed by a parity byte. Find the bit that was corrupted.

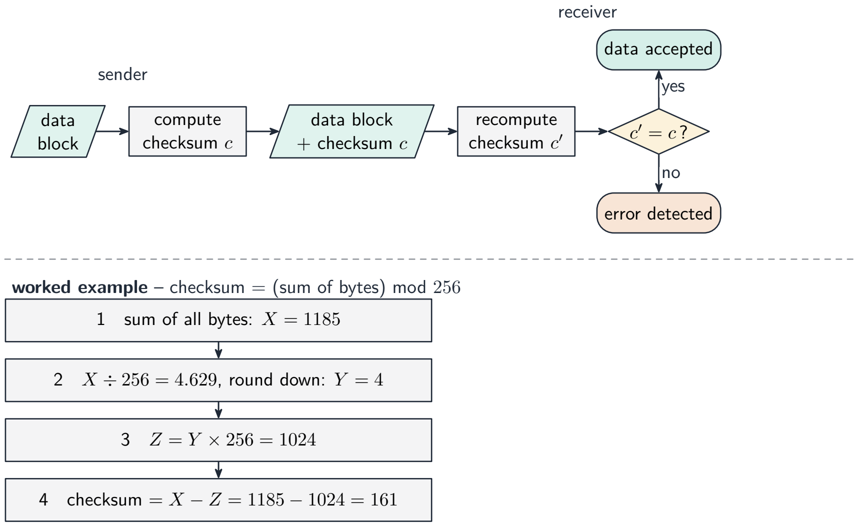


A parity block check: the row that fails and the column that fails cross at the flipped bit

Count the 1s in each row and each column. Every row and column should have an even number; byte 3 has five and column 4 has three. The bit where that row and that column cross is the one that changed, so it is reset from 1 to 0. A parity check on its own detects an error in a byte but cannot say which bit; two errors in the same byte cancel and pass unnoticed. A **checksum**, explained for three marks: the sender puts the block of data through an algorithm that produces a checksum value; the data and the checksum are sent together; the receiver runs the same algorithm on the data it received; if the two checksums match, the data is accepted, and if not, it is rejected and sent again.



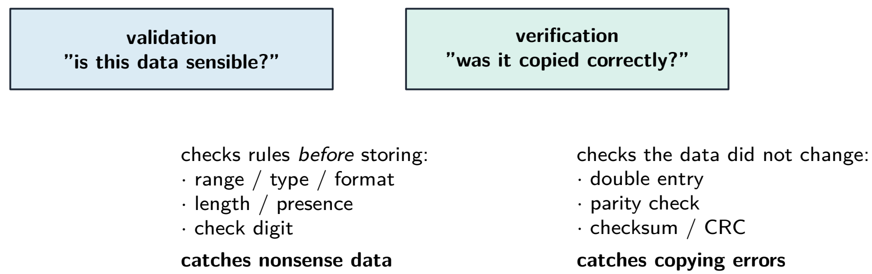
The parity bit is set to make the number of 1s even or odd



Working out a checksum for a block of data

Verification only proves what arrived matches what was sent — not that the data is correct, and not against deliberate tampering. **Validation** asks "is this sensible?"; **verification** asks "was this copied correctly?" — use both.

The table questions sort the methods by when they are used: **during data entry**, double entry and a visual check; **during data transfer**, a parity check (byte or block) and a checksum. Transferring video files from a camera to a server uses a checksum: the camera computes it, the server recomputes it, a mismatch means retransmit.



Validation checks the data makes sense; verification checks it was copied without change

Worked example. A user types their date of birth as 31/02/2009, and types their email address twice. Which check catches which error, and what is the difference? **Validation** asks "is this data **sensible**?" - the computer tests it against a rule, and a format or range check rejects 31/02/2009 because February never has 31 days. **Verification** asks "was this data **entered correctly**?" - typing the email twice is **double entry**, and comparing the two copies catches a typing slip. The limit is what makes this a favourite question: validation can never tell you the data is **right**, only that it is **possible** - 01/02/2009 passes every validation rule even if the user was actually born on a different day. Say what each check **can** and **cannot** catch.

Definitions the examiner accepts

A definition question is marked against fixed wording. Learn these exactly.

Term	Definition
data security	keeping data safe from loss and from unauthorised access, change or deletion
data privacy	keeping data confidential, so that it is seen only by those who have the right to see it
data integrity	the data being accurate, consistent and complete
malware	malicious software that is installed without the user's knowledge to damage a system or steal data
virus	malware that replicates itself, attaches to other files and corrupts or deletes data
spyware	malware that records the user's key presses or actions and sends them to a third party
phishing	an email pretending to be from a legitimate organisation that leads the user to a fake website to collect personal data

Term	Definition
pharming	malicious code that redirects the user to a fake website even when the correct address is entered
firewall	hardware or software that examines all traffic entering or leaving a system against set criteria and blocks what does not meet them
encryption	scrambling data with a key into ciphertext, so that it cannot be understood without the key to decrypt it
digital signature	a hash of a message encrypted with the sender's private key, used to prove who sent it and that it was not altered
data validation	an automatic check that entered data is reasonable and follows set rules
data verification	a check that data has been entered or transferred correctly, by comparing it with the source or with a recomputed value
check digit	an extra digit calculated from the other digits of a number and appended to it, so that an error in the number can be detected
parity check	an extra bit added to a byte so that the number of 1s is even (or odd), which the receiver recounts
checksum	a value calculated from a block of data by an algorithm and sent with it, recalculated by the receiver and compared

Exam tips

- Keep the three ideas separate: **security** (keeping data safe), **privacy** (who may see it), **integrity** (keeping it correct).
- Match each **threat** (malware, hacking, phishing, interception) to a **measure** (firewall, encryption, authentication, access rights).
- Encryption protects **confidentiality, not integrity** — use a checksum, parity or check digit for integrity.
- Distinguish a **virus, worm and Trojan** and how each spreads.

Common mistakes

- Giving the same measure for two threats, or a measure that does not fit the threat. Each threat in the table needs a different prevention that actually stops it.
- Naming a measure without saying how it works. "Firewall" scores when it is followed by "compares traffic with set criteria and blocks what fails".
- Calling validation a check that the data is correct. Validation checks that data is reasonable; verification checks that it matches the source. Neither proves it is true.

- Saying a digital signature encrypts the message. It encrypts a hash of the message with the private key; the receiver decrypts it with the public key and compares hashes.
- Describing a check digit as verification, or a parity check as validation. The check digit is a validation rule on entry; parity and checksums verify a transfer.
- Writing that a virus "sends data to a third party" and spyware "replicates". The replicating one is the virus; the recording one is spyware.