Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

November 2025

Computer science

Higher level

Paper 1

23 pages

Subject details: **Computer science HL paper 1 markscheme**

Mark allocation

Section A: Candidates are required to answer **all** questions. Total 25 marks.
Section B: Candidates are required to answer **all** questions. Total 75 marks.
Maximum total = 100 marks.

General

A markscheme often has more specific points worthy of a mark than the total allows. This is intentional. Do not award more than the maximum marks allowed for that part of a question.

When deciding upon alternative answers by candidates to those given in the markscheme, consider the following points:

Each statement worth one point has a separate line and the end is signified by means of a semi-colon (;).

An alternative answer or wording is indicated in the markscheme by a "/"; either wording can be accepted.

Words in (…) in the markscheme are not necessary to gain the mark.

If the candidate's answer has the same meaning or can be clearly interpreted as being the same as that in the markscheme then award the mark.

Mark positively. Give candidates credit for what they have achieved and for what they have got correct, rather than penalizing them for what they have not achieved or what they have got wrong.

Remember that many candidates are writing in a second language; be forgiving of minor linguistic slips. In this subject effective communication is more important than grammatical accuracy.

Occasionally, a part of a question may require a calculation whose answer is required for subsequent parts. If an error is made in the first part then it should be penalized. However, if the incorrect answer is used correctly in subsequent parts then **follow through** marks should be awarded. Indicate this with "**FT**".

General guidance

Issue	Guidance
Answering more than the quantity of responses prescribed in the questions	In the case of an "identify" question, read all answers and mark positively up to the maximum marks. Disregard incorrect answers. In the case of a "describe" question, which asks for a certain number of facts *eg* "describe two kinds", mark the first two correct answers. This could include two descriptions, one description and one identification, or two identifications. In the case of an "explain" question, which asks for a specified number of explanations *eg* "explain two reasons …", mark the first two correct answers. This could include two full explanations, one explanation, one partial explanation *etc*.

Section A

1. *Award [2 max].*

fixed vocabulary/ a set of words (keywords) of computer languages is constrained (and standardised);
consistent grammar/ the way different elements (statements, keywords, operators, punctuation) are combined is precisely stated/ordered (so that when they are combined, they create meaningful instructions/ always act in the same way);
consistent syntax/ the arrangement of various elements (statements, keywords, operators, punctuation) in code is uniform (and predictable)/ unique rules that control the structure of the code;
unambiguous meaning/ each method(function/statement) has one clear meaning/ corresponds to a single specific operation (that can be uniquely recognised by the computer);

2. *Award [1 max].*

to hold data that will be stored into or fetched from the primary memory;

3. *Award [2 max].*

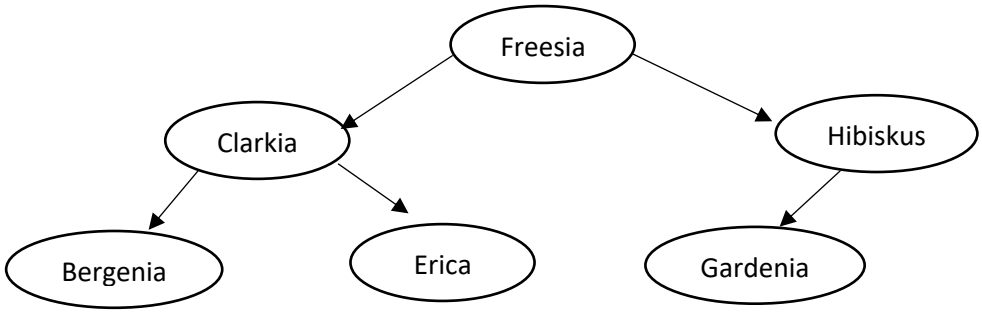
reliable/ strong signal transfer/ signals traveling via a fibre optic cable are immune from (electromagnetic/ radiofrequency/ high voltage) interference;
fast transfer of data;
high transmission rate and bandwidth;
huge data capacity;
less maintenance;
transmit data as pulses of light;
low latency;
secure transmission;
difficult to install (more difficult than other types of cables (such as copper cables));
expensive (more expensive than other types of cables (such as UTP cable));

4. (a) *Award [1 max].*
01111010;

(b) *Award [1 max].*
1C;

5. (a) *Award [3 max].*
Award [1] for the root, [1] for the left subtree and [1] for the right subtree.

***Note**: Allow mirror image.*



(b) *Award [1 max].*
3;

6. *Award [2 max].*

Software corruption/ software malfunction/crash;
Theft; ***Note:*** a*ccept examples such as, a data storage device/ a laptop is stolen, or data can get stolen digitally through hacking.*
Computer viruses/ ransomware and other malware;
Hardware malfunction; ***Note:*** a*ccept examples such as hardware malfunction due to firmware corruption/ read or write failure/ corruption of bad sectors on disk.*
Power failure / sudden power failures can damage the hardware and operating system resulting in data loss;
Natural disasters (that can lead to data loss such as floods, earthquakes, hurricanes, cyclones, natural fires, and lightning);
Migration errors/ errors during data transmission;
Software or hardware incompatibilities (errors during system upgrade);

7. *Award [2 max].*
Award [1] for identification of purpose, and award [1] for matching description/expansion.

To enable processes to use virtual storage;
When a process tries to access a page that is not in RAM, the OS brings in the page from the secondary memory;

To improve the efficiency of memory management;
The OS moves pages in and out of memory as needed keeping only the frequently used pages (that reduces the number of page faults/ that improves system performance);

To enable an OS to transfer data between secondary and primary memory;
When the process requests memory, the OS allocates pages from the primary memory to the process and moves program pages from the secondary memory to the primary memory;

To allocate RAM for (large) processes even if there isn't enough (continuous) free space;
by allowing some pages stay on disk until needed;

To improve app isolation/ to prevent an app to access memory used by other apps;
by separating a memory used by an app into fixed-sized blocks and setting the page table of addresses/directory register;

Note: Reward other reasonable responses.

8. *Award **max** [4].*
Award [1] for every two correct rows.

A	B	C	X
0	0	0	**1**
0	0	1	**1**
0	1	0	**1**
0	1	1	**1**
1	0	0	**0**
1	0	1	**1**
1	1	0	**0**
1	1	1	**0**

9. *Award **max** [3].*

The microprocessor takes in inputs from various sensors (and selections made by the user);
continually (fetches, decodes and) executes instructions stored in the memory;
compares sensor measurements with predefined stored values;
to determine proper response to different externally produced interrupts (according to their priority);
sends signals to output transducers/ actuators (*that take these signals and convert them into another form of energy, for example, sounds an audible alarm, sends a phone call, text, or a notification on a mobile app)* to alert the home owner / alert a monitoring centre in case of professional monitoring);

10. (a) *Award [1 max].*
The process in which a function/sub-program calls itself;

(b)
(i) *Award [1 max].*
1;

(ii) *Award [1 max].*
2 * `NUMBER` + 1;

Section B

11. (a) *Award [3 max].*

Wireless router;
Wireless access points (WAP) *Accept access point (AP);*
Wireless antennas;
Client wireless adaptors / Network interface cards (NICs)
Wireless bridge/ repeater;
Wireless controller;
Network switches;
***Note**: the word wireless in front of the name of the component may not appear in candidates' answers.*

(b) *Award [4 max].*
*Award [1] for stating an advantage and award [1] for a suitable expansion, **x2**.*

Flexibility / mobility within the office;
Office-based employees can work without sitting at dedicated computers/ allow employees to remain online even if they move their laptop/ allow employees use of other mobile devices around the office/building;

Access/ availability;
Employees can communicate while on the move/ enable employees to share the network and hardware/ WLAN 'hotspots' offering guests access to internet/ employees can bring their own devices (and use full functionality of the network);

Increased collaboration;
employees can be located anywhere in the office and still access key documents and information/ can easily work in teams/groups;

Cost savings/ wireless networks can be cheaper to install / cheaper to extend;
because no need for buying additional hardware or cables to access the network / allows network access to areas where cabling was not cost-effective/ practical;

Simpler infrastructure/office organization/ office layout;
Desk locations are not dictated by wires and cables;

Scalability;
New employees can be added to the network easily and quickly;

***Note:** Reward other reasonable responses.*

(c) *Award [4 max].*
Accept answers on protecting data as it moves from network to network (or, for example, from a local storage device to a cloud storage device) and answers on protecting data stored on any device.

Use of encryption keys;
so that only devices with the correct key can communicate with access points (Wired Equivalent Privacy (WEP));

Use the most up-to-date wireless encryption protocol (accept Wi-Fi Protected Access/WPA2/WPA3);
to protect internet traffic on wireless networks;

Media Access Control (MAC) addresses attached to each device can be filtered;
to limit connection to access points/ use of trusted/authorised devices;

Service Set Identifiers (SSIDs);
to prevent connection to access points (unless a device uses a given identifier correctly);

Multi-factor verification;
the login process by requiring the user to verify their identity with a text message/email/an authenticator app;

Authentication (user ID + password/ biometric) should be used on all devices/ data files;
to verify the identity of the user;

Strong password (that includes special characters, numbers, and uppercase and lowercase characters/ that is changed regularly/ never shared);
To prevent data breaches / to prevent brute-force attacks (systematically guessing passwords until the correct one is found);

Encryption/ encoding data in such a way that it cannot be read by anyone;
except for the intended recipient with decryption key;

Activate firewall protection (software or hardware) to protect the system/network from unauthorized access;
by controlling the incoming and outgoing traffic/data;

(Buy and) use a high-quality data intercept security software;
that protects the sensitive data from being intercepted by hackers/ helps to protect against viruses, malware, spam;

Keep software and firmware up to date;
to patch any security vulnerabilities;

Use a VPN;
to encrypt communication between devices and network;

Segment network;
to limit access to sensitive data;

Intranet and extranet could be implemented;
extranet is accessible to all users / extranet provides limited access from outside the WLAN for all users/ the intranet (private/secure network) is restricted to group of users /employees;

Authorization;
To specify actions an authenticated user is permitted to perform/ to specify role access rights (to resources and operations);

Install antivirus software;
to identify, block and protect against malicious software/ infected links/suspicious activity;

(d) *Award [4 max].*

VPN ensures that only authorized users can connect using authentication;
Tunnel established between the employee's device and the organization's network;
All data passing through this tunnel is encrypted, even if someone intercepts it, they cannot understand it;
Employees can access the WLAN from home / remote access to the WLAN (to files, databases, printers, or applications);
Masks the employee's IP address making the data origin untraceable;
Uses multiple exit nodes making it hard to trace the data path;

12. (a) (i) *Award [2 max].*
Award [1] mark for identifying an advantage of using direct observation to the system analyst, ***x2****.*

The system analyst can gather data at the time they occur/ where activity is occurring/ can obtain direct/ first-hand information about the system / can observe how processes are really carried out;

The analyst does not rely on users' willingness to provide information/ does not have to ask users about their behaviour (can observe users' actions/expressions/reactions);

The analyst can reveal system issues that the users are unable to identify/ are not aware of;

The analyst can conduct his/her study over a longer period/ analysis can be detailed;

the analyst can gain information that is more reliable/less biased/more accurate (than data collected by other methods);

Note*: Reward other reasonable answers.*

(ii) *Award [1 max].*

interview;
surveys/questionnaires;
focus groups/ brainstorming;

(iii)*Award [2 max].*
Award [1] mark for identifying an advantage to the system analyst, ***x2****.*
Note: The response should match the method identified in (ii).

Example (*advantages of interviews to the system analyst*):

Allows the system analyst
to obtain original/unique data directly from the end users/ key stakeholders;
to quickly obtain direct/ in-depth information about a subject or situation by asking accurate questions;
to detect non-response/ spontaneity/ biased responses / non-verbal clues/ body language of the interviewee;
to modify/change questions in personal face-to-face interviews to obtain the required information;

Example (*advantages of surveys to the system analyst*):

Allows collecting data from a large number of respondents;
Numerous questions can be asked about processes in a short period of time/ a broad range of data can be collected quickly;
Allows different question types that helps to collect both quantitative and qualitative data;
Relatively easy to administer/ can be administered remotely via mobile devices, mail or telephone;
Can be conducted remotely (can reduce geographical dependence);
Can use survey software to analyse survey data to determine validity/reliability/ statistical significance;
A broad range of data can be collected (e.g., attitudes, opinions, behaviour, factual);
cost/time effective to create/distribute/analyse;

Example (*advantages of focus groups to the system analyst*):

The system analyst can interact with the end-users, which allows for follow-up questions;
information is provided more quickly than if end-users were interviewed separately;
Discussion among participants would bring out insights/ better understanding of the system;
Can explore the degree of consensus on system/ get feedback;

(b) (i) *Award [2 max].*
Award [1] for an advantage and award [1] for a reasonable expansion.

the final computer system is more successful/better meets the user's requirements;
as feedback is provided by the users during the development process/ as different prototypes can be tried out/ due to the users' active participation in the development process;

costs savings;
best design decided upon early so total cost (and duration) is decreased / prototype (model) can be reused for more complicated (or similar) computer systems in the future;

time savings;
feedback avoids spending time (and money) on later changes/ missing functionality or errors can be found/detected/resolved early.

better communication among stakeholders;
visual models bridge gaps between technical teams and non-technical clients;

reduced risk of failure;
by testing early, the company can avoid investing heavily in flawed designs;

(ii) *Award [2 max].*
Award [1] for a disadvantage and award [1] for a suitable expansion.

Prototyping expense / model is costly;
in terms of hardware/software/development time;

Final computer system can be of less than highest quality/ users may not be satisfied;
because of demand the actual product to be delivered soon after seeing an early prototype;

Increased development time;
users might start to ask for features to be included which were never in the original user requirements or specifications/ producing more than one prototype takes time;

Difficulty in scaling;
a prototype that works well in a small test environment may not scale effectively to full production;

(c) *Award [6 max].*

***Note**: Award marks for an account of similarities and differences between local and cloud storage referring to both of them throughout.*
Award up to 2 marks for cost, up to 2 marks for security/privacy and up to 2 marks for accessibility/availability.

***Cost: (**example differences/similarities)*

Local storage	**Cloud storage**
- hardware/ infrastructure costs are high (pay for cooling systems to ensure that servers are running efficiently, for electricity to run the servers 24/7, or for hardware maintenance, etc.); - Adding more storage space creates extra costs; - a dedicated employee/ an IT team that can maintain software/ backups for the company's data, etc.;	-cloud storage is usually cheaper than local storage/ low cost of maintenance; -the company doesn't have to purchase/ maintain any hardware; -a subscription fee should be paid to use cloud storage/ a subscription fee depends on the space needed; - is automatically backed up at specific intervals (no need for human intervention);

Privacy/security: (*example differences/similarities)*

Local storage	**Cloud storage**
-the company has full control over the data (how data is stored, who has access, and information security protocols); - access levels are set up in the company/ can be added or removed easily within the company; - employees directly concerned can be able to read data/ less people should be able to edit it; - devices can be removed from the company's network at any time (for protection); -encryption or firewall can be implemented; - physical access to servers should be controlled; -security requires trained IT staff or outsourcing; - backup needs to be planned/ implemented;	-a third-party provider controls the company's data; -cloud relies on encryption to secure data; - cloud service providers protect their own servers; - cloud service providers implement stronger backup mechanisms; -possibility of data getting breached (even providers could access sensitive data without authorization)/ data can be intercepted during transmission over public network;

Accessibility/Availability: (*example differences/similarities)*

Local storage	**Cloud storage**
-a device (removable disks or similar) for moving the data between machines is needed; - data is harder to share with other colleagues when needed; - no need for an internet connection to access data; - access to data stored on local storage can be faster than cloud storage;	-access to data from anywhere (only an internet connection and credentials needed)/ any device that has an internet connection; -cloud storage is exclusively online/ if internet goes down, employees cannot access data; - access is slower as it is over the public network/ limited with internet connection's speed; - in cases of hardware failure/ infrastructure breakdown/natural disasters, data recovery in the cloud is a lot easier;

13. (a) *Award [3 max].*

creating/designing illustrations/ digital art;
creating website layouts/ edit website designs;
drawing maps/ other diagrams;
editing images/videos/adding visual effects;
3D drawings/ models;
creating presentation slides;
image restoration/retouching;
***Note**: Reward other reasonable answers.*

(b) *Award [1 max].*

stores data permanently/ non-volatile;
high storage capacity;
scalable storage capacity (can be changed to meet a user need);
can be removable or fixed;
cheap/ (cheaper than other types of memory for example, primary memory);
slow access speed (slower than, for example, primary memory);
indirect access by CPU;

(c) *Award [4 max].*
Award [1] for stating a drawback/limitation and [1] for a reasonable expansion, ***x2**.*

Some compression methods (lossy) discard data;
And decompression will not return the complete file/some detail will have been removed which may not be acceptable/ loss of quality;

The compressing/uncompressing process slows down the performance/ time consuming when the large number of files should be compressed (decompressed)/ use significant memory and processor time;
which is a disadvantage when a file should be accessed quickly;

High cost of compression software with advanced tools/with all features required;
that may not produce intended results in some situations (file size cannot be significantly reduced for example, compressing audio/video files);

Compression may not produce significant/intended results (file size cannot be significantly reduced);
because there are no repetitions of data patterns / the original file is very small /lossless compression was used;

The anti-virus program may not be able to scan a compressed file (for viruses and other malware);
resulting in the student's computer being exposed to files that may contain viruses/ spyware/ other harmful programs;

If the student sends a compressed file to someone else via the Internet, email or on a computer network;
that person may not be able to open the file (if they don't have a program to decompress it);

(d) *Award **max** [3].*

not enough colours provided by the graphic card/ the number of colours is limited/ only 2^{16} available colours;
leads to inferior quality of colourful images / fewer shades of colour / less smooth colour transitions;
because original images typically contain millions of colours (a lot more than 2^{16} colours) monitor may not accurately represent the original image;

(e) *Award **max** [4].*
*Award [1] for a hardware upgrade and [1] for a justification, **x2**.*

Upgrade RAM/ add more memory modules along existing ones or replace the old ones with a set of new with higher capacity;
To allow faster access to data/ to improve application(gaming) performance/to improve the multitasking capabilities;

Upgrade secondary storage/ hard disk/ SSD;
To get a faster storage device/ more storage space/ more reliable storage device;

Upgrade processor;
To have a faster processor that increases the speed of execution/ improves the efficiency of the computer/ upgrade processor to increase cache;

Upgrade peripherals;
to have full support for the electronic devices/ to increase efficiency/ to increase satisfaction/ to enjoy all the latest features and enhancements;

Accept examples of peripherals such as:
Replace a standard mouse/keyboard with a gaming mouse/keyboard;
To enhance play;

Replace the old monitor with a new one;
to improve the graphic display of games;

14. (a) *Award [3 max]*
Award [1] for each feature of dynamic data structures, ***x3****.*

The size of a dynamic data structure does not have to be predetermined/ determined at compile-time/ the size is not fixed/ can change during runtime;
Memory allocation using techniques such as heap memory allocation or pointer-based data structures prevents memory waste;
Dynamic data structures are suited for applications that have varying sizes or a changing number of elements (*Accept examples.*);
Insertion and deletion operations are fast (since elements can be inserted or deleted without the need to shift other elements);
Elements in a dynamic data structure cannot be directly accessed/ pointer traversal (sequential search) is needed to access elements in the dynamic data structure;
Accessing elements in a dynamic data structure may be slow since memory may be spread out in different locations;

(b) (i) *Award [3 max]*

Each node in a circular linked list consists of data fields and a pointer field;
Each pointer points to the next node and the pointer in the last node points to the head node/ to the beginning of the circular list (there are no NULL pointers in the circular list);
An external pointer points to the first/ head node (the first node can be any node in the list);

(ii) *Award [2 max]*

Circular linked lists can be used
to implement a queue/ deque;
to create a playlist (for a music or media player);
in image galleries;
in multiplayer games to swap between players in a loop;
in navigation systems / can be used to model the movements of vehicles on a circular route; ***Note***: *Accept any real-time application or simulation where data needs to be processed in a continuous loop.*
in memory allocation;
in task scheduling (Round Robin scheduling);
can be used by the operating system to share time for different users (Round Robin time-sharing mechanism);
in cache management;
in file system management to track the allocation of disk space;

(c) (i) *Award [2 max]*

Stack follows the LIFO (Last In First Out) order to store the elements (the element that is inserted last will come out first) whilst queue follows the FIFO (First In First Out) order to store the elements (the element that is inserted first will come out first);

Stack has only one end (top) at which both insertion and deletion take place whilst queue has two ends (rear and front), the rear end is used to insert the elements whereas the front end is used to delete the elements from the queue.

Stack is/ can be used to solve recursive problems, queue is used to solve problems based on sequential processing;

Stack uses push() to add an element, queue uses enqueue() / Stacks use pop() to remove an element, queues use dequeue();
Note: *Accept other reasonable answers.*

(ii) *Award [5 max]*

Award [1] for using access methods isEmpty(), pop() and enqueue()
Award [1] for the loop
Award [1] for popping an element from the stack
Award [1] for correct call to subprogram firstletter()
Award [1] for correct condition(s) in if statement(s)
Award [1] for enqueuing the element popped from the stack to the correct queue

Example 1:

```
while not CUSTOMERS.isEmpty()
    X=CUSTOMERS.pop()
    if firstletter(X) >= 'A' and firstletter(X)<= 'M'
        then ONE.enqueue(X)
        else TWO.enqueue(x)
    end if
end loop
```

Example 2:

```
while CUSTOMERS.isEmpty()= False
     NAME = CUSTOMERS.peek()
     F = firstletter(NAME)
     if F > 'M'
        then
            TWO.enqueue(NAME)
     end if
    if F < 'N'
        then
            ONE.enqueue(NAME)
    end if
    X = CUSTOMERS.pop()
end loop
```

15. (a) *Award **max** [1].*

1, 6, 7, 0 ;

(b) *Award **max** [2].*
compare the row and column indexes of the matrix element;
if row index is equal to column index, it is diagonal element;
if not, it is not a diagonal element;

(c) *Award **max** [7].*

Example 1:

[1] for correctly initializing and changing (if needed) the value of flag (`F`)
[1] for nested loops
[1] for correct outer loop (correct initial and final value of control variable- `ROW`)
[1] for correct inner loop (correct initial and final value of control variable- `COL`)
[1] for correct use of row index and column index in the `MAT` array
[1] for checking if `MAT[ROW][COL]` is a non-zero element
[1] for correct return

```
isUpper(MAT,N)  //sub-program heading may not appear
    F = 1
    loop ROW from 1 to N-1
        loop COL from 0 to ROW-1
            if MAT[ROW][COL] != 0
                then F = 0  // or return False
            end if
        end loop
    end loop
    if F == 0
        then return False
        else return True
    end if
end isUpper
```

Example 2:

[1] for nested loops
[1] for correct outer loop (correct initial and final value of control variable- `ROW`)
[1] for correct inner loop (correct initial and final value of control variable- `COL`)
[1] for correct use of row index and column index in the MAT array
[1] for checking if `MAT[ROW][COL]` is a non-zero element
[1] for early return (return False if `MAT[ROW][COL]` is a non-zero element)
[1] for returning True after nested loops

```
isUpper(MAT,N)  //sub-program heading may not appear
    loop ROW from 1 to N-1
       loop COL from 0 to ROW-1
          if MAT[ROW][COL] != 0
                then return False
          end if
        end loop
     end loop
     return True
   end isUpper
```

Example 3:

[1] for correctly initializing and changing (if needed) the value of flag
1] for correct row loop (correct initial and final value of control variable - `I`)
[1] for correct column loop (correct initial and final value of control variable - `J`)
[1] for checking if `MAT[I][J]` is below the main diagonal (`I > J`)
[1] for correct use of row index and column index in the MAT array
[1] for checking if `MAT[I][J]` is a non-zero element
[1] for correct return

```
A = TRUE
loop I from 0 to N-1
    loop J from 0 to N-1
        if (I > J) AND (MAT[I][J] != 0)
                    //I-row index, J-column index
            then A = FALSE //or return False
        end if
    end loop
end loop
return A
```

(d) *Award **max** [5].*
[1] for correct use/call of subprograms `isLower(MAT,N)` *and* `isUpper(MAT,N)`
*[1] for correct condition and output, **x4**.*

Example 1:

```
if isUpper(MAT,N)
    then
        if isLower(MAT,N)
            then output(' BOTH ')
            else output(' UPPER ')
        endif
    else
        if isLower(MAT,N)
            then output(' LOWER ')
            else output(' NONE ')
        endif
end if
```

Example 2:

```
identify (MAT, N) //sub-program heading may not appear

    A = isUpper(MAT,N)
    B = isLower(MAT,N)

    if A and B
        then output(' BOTH ')
    endif
    if A and not B
        then output(' UPPER ')
    endif
    if not A and B
        then output(' LOWER ')
    endif
    if not A and not B
        then output(' NONE ')
    endif
end identify
```