

The Institution of Structural Engineers

Membership Examination

Part 3



4 APRIL 1997

Structural Engineering Design and Practice

9.30 a.m. – 1 p.m. and 1.30 – 5 p.m. (Discussion between individuals is not permitted during the luncheon period).

A period of fifteen minutes is provided for reading the question paper, immediately before the commencement of the examination. Candidates are not permitted to write in answer books, or on drawing paper or to use a calculator during this time.

Candidates must satisfy the Examiners in ONE question.

Important

The written answer to the question selected and any drawings must bear the candidate's index number and the question number in the bottom right-hand corner. Only the answer book(s) supplied by the Institution may be used. The candidate's name should not appear anywhere in the script.

Notes to Candidates

1. TO PASS THE EXAMINATION, CANDIDATES MUST SATISFY THE EXAMINERS IN BOTH PARTS OF THE QUESTION ATTEMPTED.
2. A fair proportion of marks will be awarded for the demonstration of an understanding of fundamental engineering concepts, as distinct from calculation of member forces and sizes.
NOTE: In the calculation part of all questions, establishing "form and size" is taken to mean compliance with all relevant design criteria, ie bending, shear, deflection, etc.
3. In all questions 40 marks are allocated to Part 1 and 60 marks to Part 2.
4. The Examiners are looking for sound structural designs.
It should also be remembered that aesthetics, economy and function are important in any competent engineering scheme.
Candidates should read carefully the examiners' reminder on Page 3.
5. Any assumptions made and the design data and criteria adopted must be stated.
6. Portable battery calculators may be used but sufficient calculations must be submitted to substantiate the design, and these should be set out as in practice.
7. Good clear drawings and sketches are required; they should show all salient and structural features to suitable scales and should incorporate adequate details.
8. This paper is set in SI Units, together with an alternative set of numerical data in British Imperial Units in parentheses. Candidates may use either set of data and may work in either system of units but should note that the two sets of data do not necessarily correspond. This is in order to avoid complicated arithmetic in one set of units.

A Reminder from your Examiners

The work you are about to start has many features in common with other examinations which you have tackled successfully but it also has some which are unusual.

As in every examination you must follow carefully the NOTES FOR CANDIDATES set out for your guidance on the front cover of this paper; allocate the available time sensibly and set out your work in a clear and logical way.

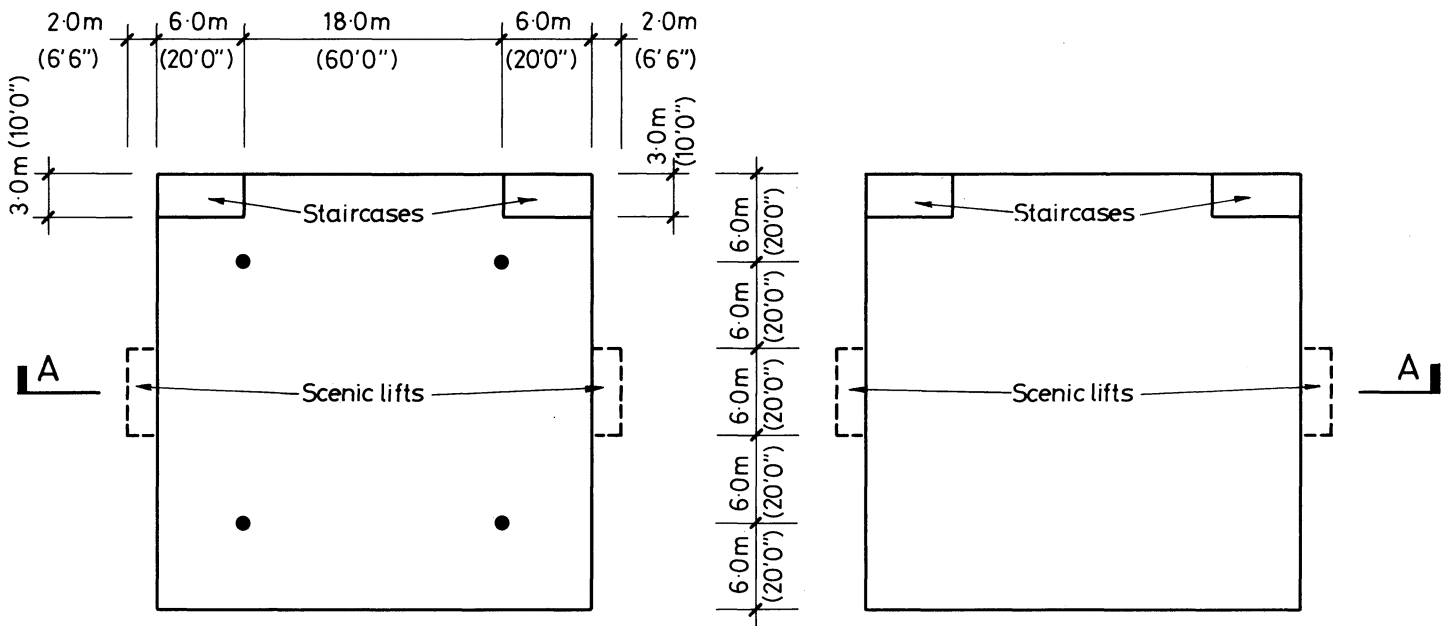
The unusual requirement of the examination is that you must demonstrate the validity of the training and experience that you have acquired in recent years. The Institution must be satisfied that you are able to bring all the various skills you are expected to possess to the effective solution of a structural design problem – whether or not the problem is presented in terms that are within your actual experience.

A Chartered Structural Engineer must have an ability to design and a facility to communicate his design intentions. Where you are required to list and discuss possible structural solutions you must show by brief, clear, logical and systematic presentation that you understand the general structural engineering design principles involved.

In selecting and developing your design you should also remember the guidance given in the Institution's report, 'Aims of Structural Design', and in particular:

- (1) 'the structure must be safe',
- (2) 'a good design has certain typical features – simplicity, unity and necessity',
- (3) 'the structure must fulfil its intended function'.

If you have difficulty in deciding the correct interpretation of a question, pay particular attention to point 5, Notes to Candidates, on the front cover. The examiners will take into account your interpretation – and the design you base on this – if this is clearly stated at the beginning of your answer.

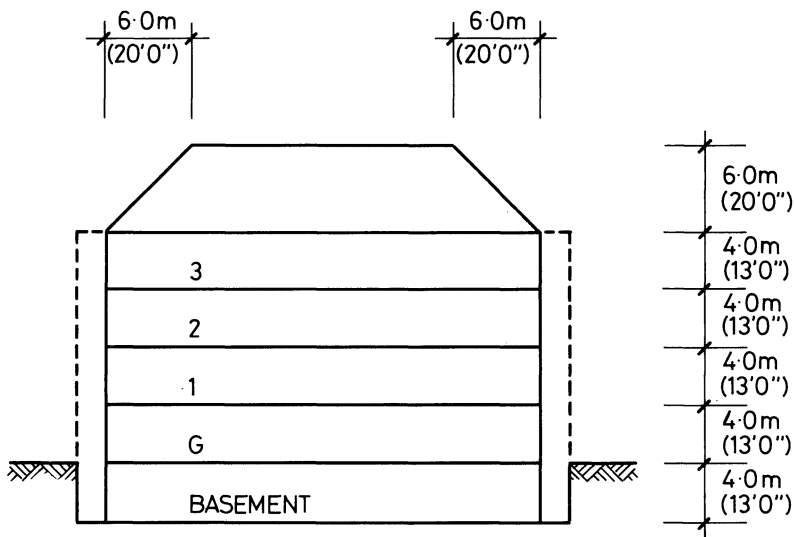


GROUND FLOOR PLAN

(4 INTERNAL COLUMNS ARE PERMITTED ONLY AT THE POSITIONS SHOWN)

PLAN (BASEMENT AND FLOOR LEVELS 1, 2 AND 3)

MINIMUM COLUMN SPACING INTERNALLY OF 6.0m (20'0")



SECTION A-A

NOTE All dimensions are in metres (feet and inches)

FIGURE Q1

Question 1

Science Park Office Building

Client's requirements

1. A four storey building with a basement and partly pitched roof; see Figure Q1. The entire roof is to be metal clad.
2. The headroom to the underside of the suspended ceiling at each level is 3.0m (10'0"). A clear zone of 0.3m (1'0") is required at all levels for services. The floor to floor height, including the basement, is 4.0m (13'0").
3. The client does not require to use the roof space except for a small water tank and access for maintenance.
4. Elevations are to be a glazed curtain wall system. If bracing is required in the external elevations then consideration must be given to its appearance. Lift support structures cannot be used for stability.
5. There is no restriction on column location in the external elevations but consideration must be given to their appearance behind the curtain walling. The internal columns at the upper floor levels must be on a square grid of not less than 6.0m (20'0").
6. The client requires a large column free zone at the ground floor level; see the ground floor plan, Figure Q1.

Imposed loadings

7. Roof:	Imposed	0.6kN/m ²	(12.5lbf/ft ²)
	Services	1.0kN/m ²	(20lbf/ft ²)
Office floors:	Imposed	5.0kN/m ²	(100lbf/ft ²)
	Services	0.5kN/m ²	(10lbf/ft ²)

Site conditions

8. The site is situated on the outskirts of a large town. Basic wind speed is 40m/s (90 mile/h).

Ground conditions

9. Ground level - 3.0m (10'0")	Topsoil and loose fill
3.0m (10'0") - 5.0m (16'6")	Dense sand. Safe bearing pressure 200kN/m ² (4000lbf/ft ²)
5.0m (16'6") to depth	Stiff clay, Safe bearing pressure 100kN/m ² (2000lbf/ft ²)
Groundwater is not present	

Omit from consideration

10. Detailed design of cladding, stairs, curtain walling and lift structure.

Part 1

(40 marks)

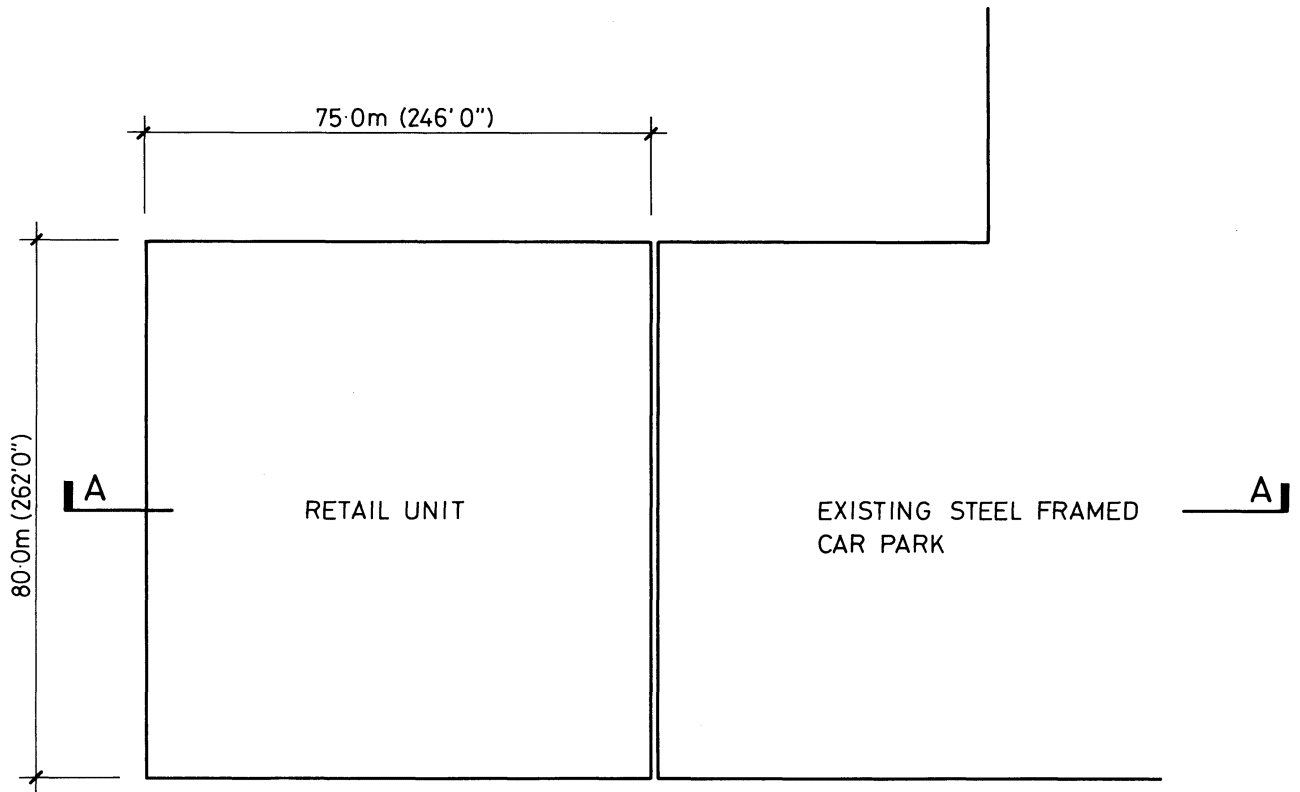
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the building, foundations and floors. Indicate clearly the functional framing, the load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice.
- b. After your recommended solution has been approved in principle, the client asks whether the first floor can be made column free to the same extent as the ground floor. Write a letter to the client explaining the effect of this request on the design.

Part 2

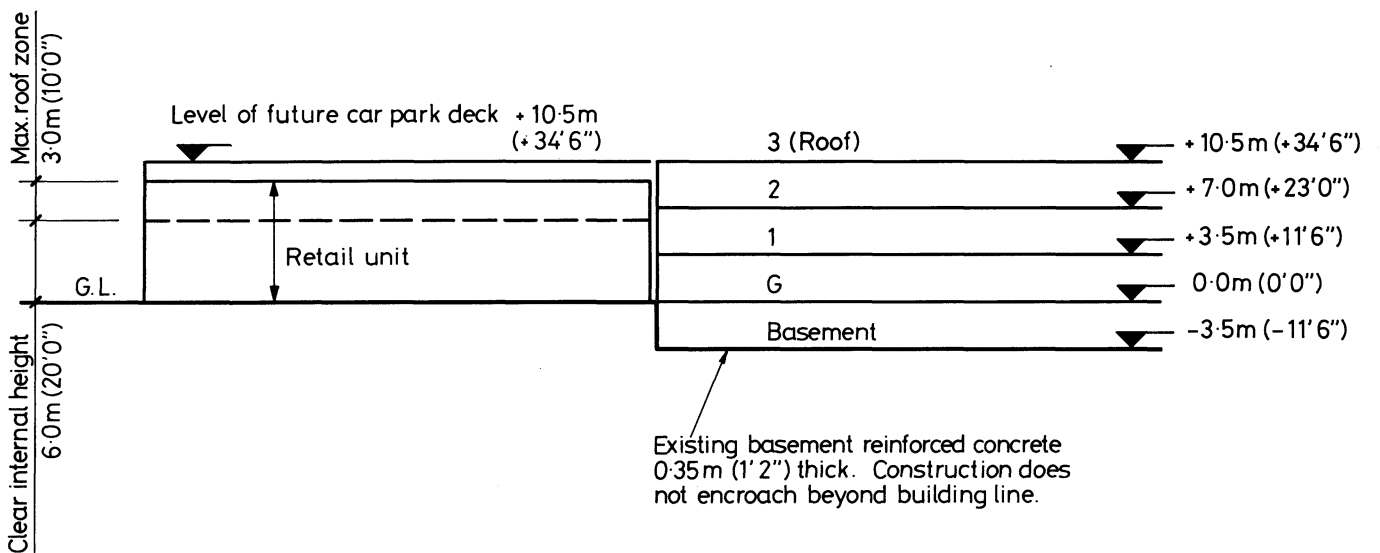
(60 marks)

For the solution recommended in Part 1(a):

- c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including the foundations and basement walls.
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes.
- e. Prepare clearly annotated sketches to illustrate details of:
 - (i) The connection of an internal column to the foundation and basement slab.
 - (ii) The connection of an internal column with the first floor.
 - (iii) The connection of the curtain walling with the roof structure.
- f. Provide a detailed method statement for the safe erection of the building and provide a programme showing the main construction activities.



PLAN AT GROUND FLOOR



SECTION A-A

NOTE All dimensions are in metres (feet and inches)

FIGURE Q2

Question 2

Retail Unit With Future Roof Car Park

Client's requirements

1. A large retail unit with provision for a future roof car park; see Figure Q2.
2. At the present time, planning and client constraints will only permit the construction of a conventional lightweight roof with maximum slope of 1 vertically to 10 horizontally. A maximum of 4 internal columns is permitted inside the building. There is no restriction on the size, number and spacing of the external columns.
3. The clear internal height within the retail unit is 6.0m (20'0"). The maximum roof height is 9.0m (30'0").
4. In 6 years time the adjoining car park will be extended at its 3rd floor (roof) level over the entire roof of the retail unit. The level of the new car park deck is to be 10.5m (34'6") above ground level.
5. At this stage, and to assist in supporting the car park deck, an additional 8 internal columns will be permitted within the retail unit if required.
6. When the car park deck is constructed, disruption inside the retail unit must be kept to an absolute minimum. Work inside the retail unit will only be allowed outside normal trading hours of 9.00am to 5.00pm, Mondays to Saturdays.
7. It is a requirement that the future car park deck and any alterations to the building are designed as part of this project. As much of the preparatory works to the future car park deck as possible are to be constructed at this stage to minimise work when the car park is extended over the retail unit.
8. The existing car park has a basement.

Imposed loadings

9. Roof of retail unit	Imposed	0.6kN/m ²	(12.5lbf/ft ²)
	Services	0.3kN/m ²	(6lbf/ft ²)
Car park (All Levels)	Imposed	2.5kN/m ²	(50lbf/ft ²)
Ground Floor of retail unit	Imposed	40kN/m ²	(850lbf/ft ²)

Site conditions

10. The site is situated on the outskirts of a large town. Basic wind speed is 38m/s (85 mile/h).
11. Ground conditions
 - Ground level – 1.0m (3'3")
 - 1.0m (3'3") – 3.0m (10'0")
 - 3.0m (10'0") to depth
 - Groundwater was encountered at 6.0m (20'0") below ground level.

Omit from consideration

12. Work to adjoining car park.
13. Design of car park deck surfacing and entrance and exit ramps and barriers.
14. Side and roof cladding to retail unit.

Part 1

(40 marks)

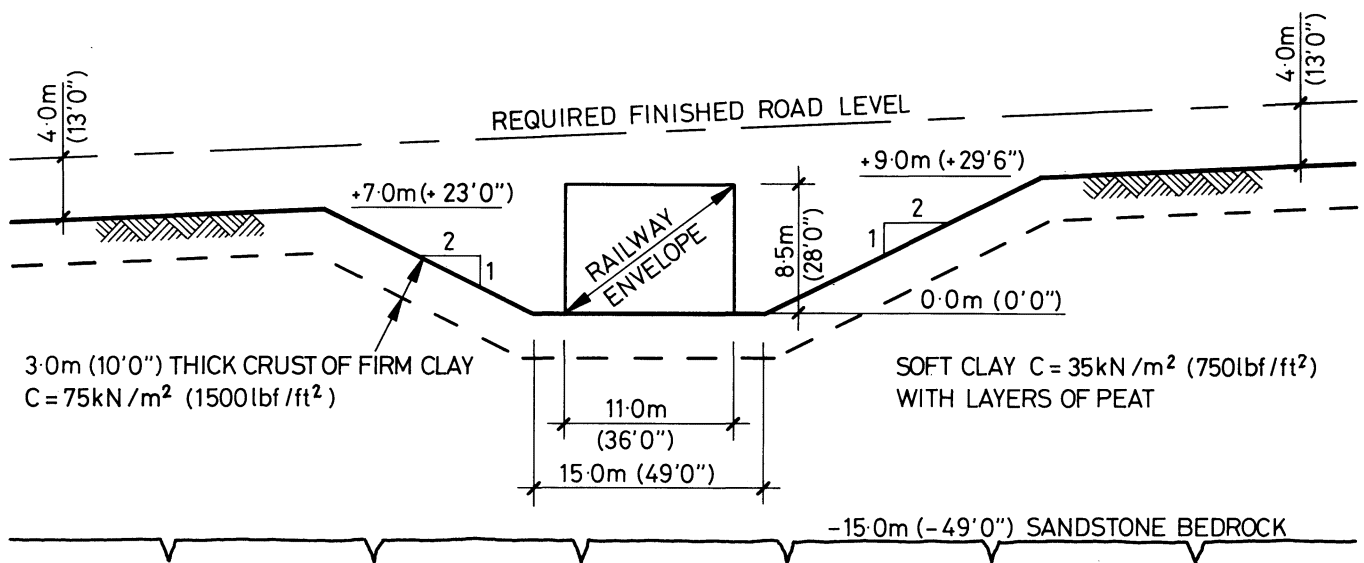
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the building, foundations and floors and the future car park deck. Indicate clearly the functional framing, the load transfer and stability aspects of each scheme and how the car park supporting structure and deck will be incorporated at a future date. Identify the solution you recommend, giving reasons for your choice.
- b. Following completion of your design the client asks whether an additional level of car parking (ie level 4) can be incorporated on top of the retail unit. Write a letter to the client describing how this might be achieved. You need not consider how the additional level will be added to the existing car park.

Part 2

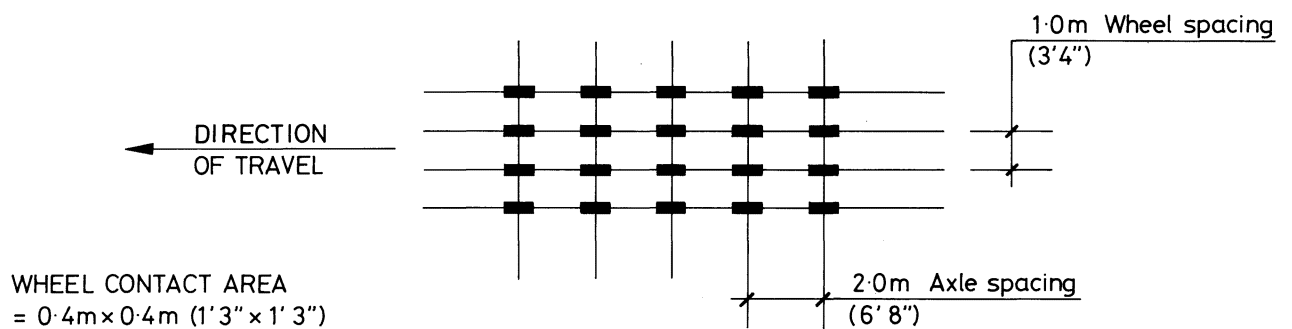
(60 marks)

For the solution recommended in Part 1(a):

- c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including the foundations and future car park deck.
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes.
- e. Prepare clearly annotated sketches to illustrate details of the structure at the following locations:
 - (i) The junction of the foundation and a future internal column.
 - (ii) The junction of the car park deck and a perimeter column of the retail unit.
 - (iii) A section showing the car park deck and waterproofing.
- f. Prepare a detailed method statement for the safe erection of the car park deck taking into account that the retail unit will still be trading.



SECTION



PLAN ON TRANSPORTER WHEEL LAYOUT

NOTE All dimensions and levels are in metres (feet and inches)

FIGURE Q3

Question 3

Heavy Load Bridge

Client's requirements

1. A bridge is required to carry specialist heavy industrial transporters across a railway cutting; see Figure Q3.
2. The railway must remain in operation at all times, except that up to five railway possessions, each of up to 18 hours duration, can be provided to allow construction of the bridge deck above the railway envelope. Deck or parapet construction work may only be carried out above the railway envelope within the railway possession periods.
3. No sub-structure work may be carried out within 5m (16'6") of the edge of the railway envelope.
4. Guard rails 1m (3'3") high shall be provided at the edge of the deck with a clear width of 7.5m (24'6"). No footpaths are required.

Imposed loading

5. A transporter has an overall weight of 6000 kN (600 tonf) spread uniformly on 20 wheels, with wheel and axle spacings as shown in Figure Q3. No other vehicles will be permitted to use the bridge whilst the transporter is crossing.

Site conditions

6. The ground conditions are as indicated in Figure Q3.

Omissions

7. Design of the embankment and detailed design of the guard rail.

Part 1

(40 marks)

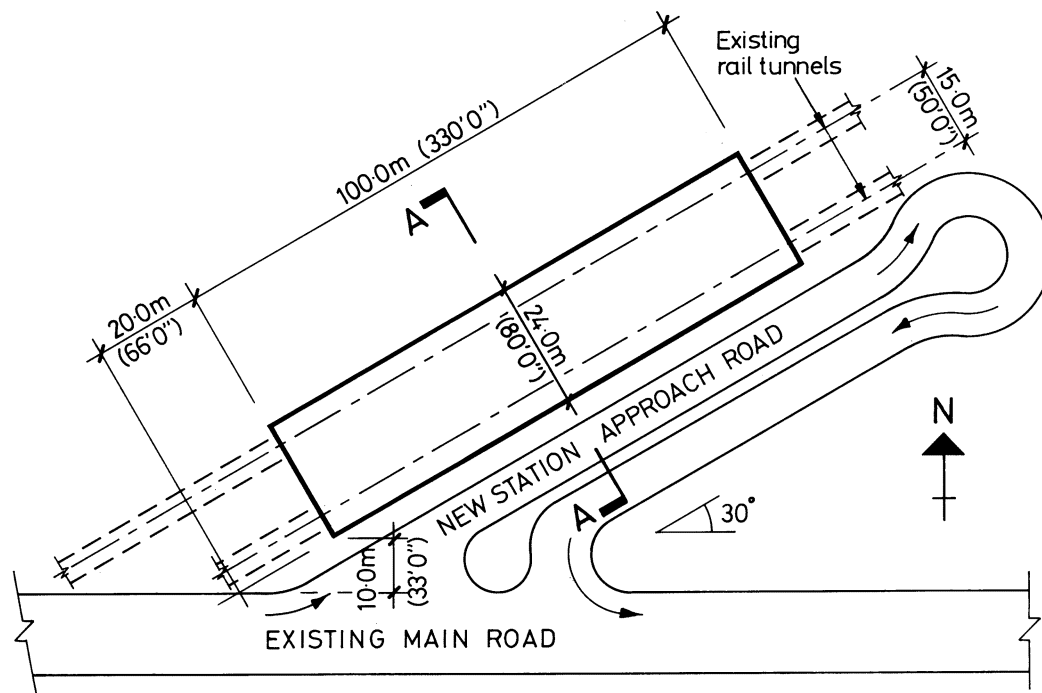
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable structural solutions for the bridge construction. Identify clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice.
- b. After your recommended solution has been approved in principle, the client asks if it is possible to raise the proposed road level by 2m (6'6").
Write a letter to the client explaining the effect of this request on the design.

Part 2

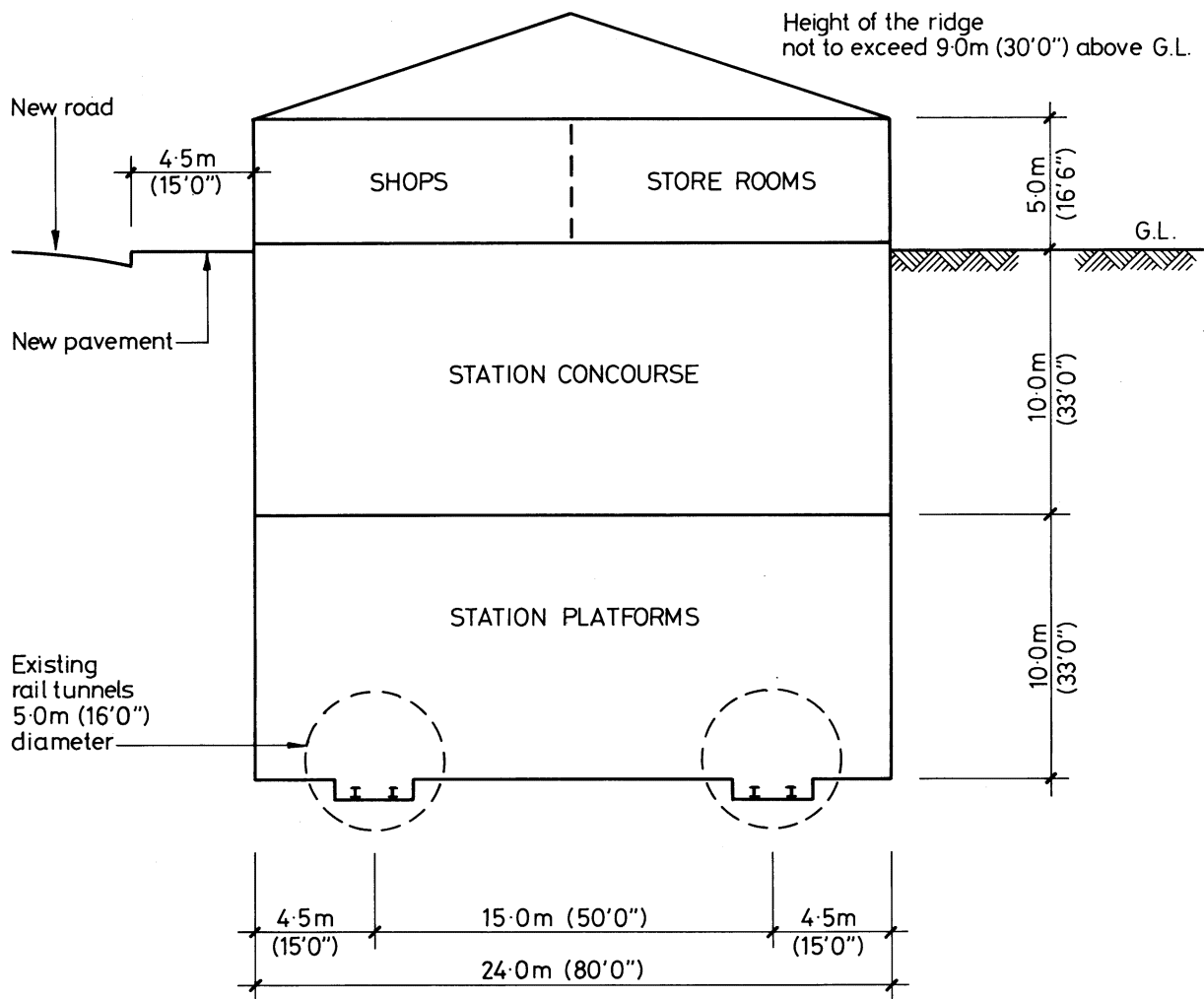
(60 marks)

For the solution recommended in Part 1(a):

- c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including all foundations.
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes.
- e. Prepare clearly annotated sketches to illustrate details of:
 - (i) The bearing details at the abutments.
 - (ii) An abutment foundation.
- f. Prepare a brief method statement for the safe construction of the structure, including any temporary works required.



PLAN



SECTION A-A

NOTE All dimensions are in metres (feet and inches)

FIGURE Q4

Question 4

Underground Railway Station

Client's requirements

1. A new underground railway station is to be constructed incorporating two existing underground operational rail tunnels; see Figure Q4.
2. The station entrance, shops and store rooms are to be constructed at existing ground level above the station concourse. The front of the shops is to be fully glazed, whilst the external walls of the store rooms are to be of full height masonry.
3. The existing underground rail system is to remain operational at all times apart from occasional weekends when full closure of the track will be permitted between 2300 hrs on Friday and 0600 hrs on Monday.
4. Internal columns are permitted but at not less than 10.0m (33'0") centres.
5. A minimum clear floor to ceiling height of 8.0m (26'6") must be provided throughout the underground structure with a minimum 0.3m (1'0") deep ceiling void for services.
6. The existing main road cannot be diverted and must remain open to traffic at all times.

Imposed loading

7. Shops:	Roof	0.75kN/m ² (15lbf/ft ²)
	Floor	5.0kN/m ² (100lbf/ft ²)
Concourse:	Floor	5.0kN/m ² (100lbf/ft ²)
Platform:		7.5kN/m ² (150lbf/ft ²)

Site conditions

8. The site is level in a city suburb.
9. Basic wind speed is 35m/sec (78 mile/h)
10. Ground conditions:

Ground level - 0.3m (1'0")	Top soil
0.3m (1'0") - 2.0m (6'6")	Soft silty clay
Below 2.0m (6'6")	Stiff clay, Average C = 200 kN/m ² (4000 lbf/ft ²).

Ground water is not present.

Omit from consideration

11. Stairs and lift and their location.
12. New tunnel headwalls.
13. New Station Approach Road.

Part 1

(40 marks)

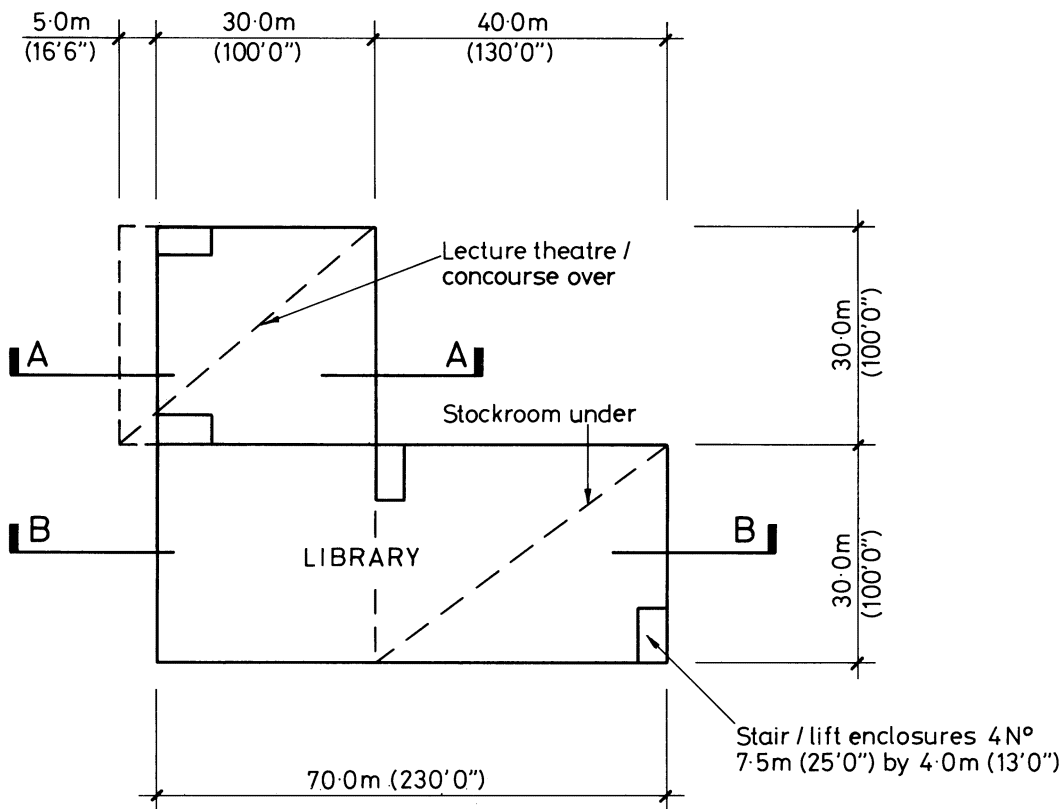
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable structural solutions for the proposed structure. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice.
- b. After your recommended solution has been approved in principle, the highway authority considers allowing the traffic on the existing main road to be diverted for the duration of the construction period.
Write a letter to the client outlining the implications this proposed change may have on the design, construction and cost of the scheme.

Part 2

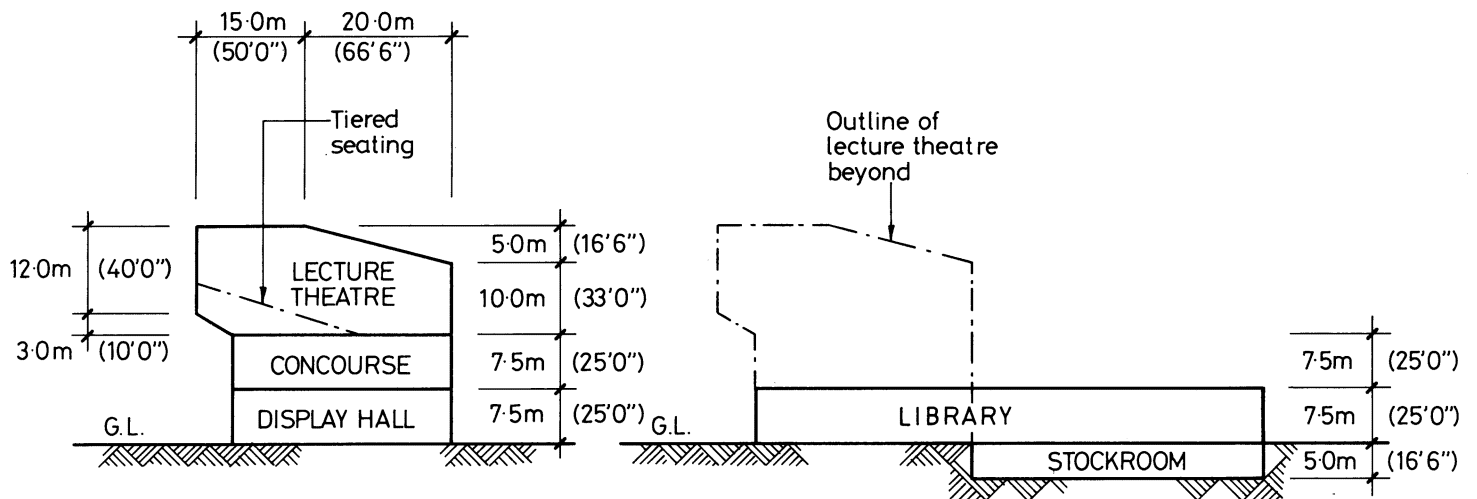
(60 marks)

For the solution recommended in Part 1(a):

- c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including the station, station concourse and shops.
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes.
- e. Prepare clearly annotated sketches to illustrate details of:
 - (i) The connection between the station concourse floor and wall.
 - (ii) The roof eaves detail to the shops.
- f. Prepare an outline sequence of construction for the station identifying which operations are to be carried out during rail closure periods and what temporary measures are required to construct the works safely.



GROUND FLOOR PLAN



SECTION A-A

SECTION B-B

NOTE All dimensions are in metres (feet and inches)

FIGURE Q5

Question 5

Library and Lecture Theatre

Client's requirements

1. A library building with a lecture theatre and other facilities; see Figure Q5.
2. The elevations are to be full height glazing at ground floor level and brickwork/blockwork walls to the concourse and lecture theatre levels. Structural column elements are to be left exposed.
3. The minimum floor to ceiling height is to be as stated below with an additional allowance of 0.4m (1'4") to be made throughout for services in the ceiling void.

Stockroom	3.5m (11'6")
Library, Concourse, Display Hall	6.25m (20'6")
Lecture Theatre	8.0m (26'3")
4. No internal columns are permitted within the lecture theatre. However, internal columns are permitted at all other levels at centres not less than 10.0m (33'0").
5. The fire resistance of the structure is to be 2 hours.

Imposed loading

- | | | |
|---------------------|-------|--|
| 6. Lecture Theatre: | Roof | 0.75kN/m ² (15lb/ft ²). |
| | Floor | 5.0kN/m ² (100lb/ft ²) |
| | | (including proprietary tiered seating) |
| Concourse | Floor | 5.0kN/m ² (100lb/ft ²) |
| Library | Roof | 0.75kN/m ² (15lb/ft ²) |
| | Floor | 10.0kN/m ² (200lb/ft ²) |
| Stockroom: | | 10.0kN/m ² (200lb/ft ²) |

Site conditions

7. A level site in a city centre. Basic wind speed is 40m/s (90 mile/h)
8. Ground conditions:

0 - 0.3m (1'0")	Made ground
0.3m (1'0") - 2.4m (8'0")	Sand and gravel (N = 8)
2.4m (8'0") - 3.0m (10'0")	Highly compressible organic material
Below 3.0m (10'0")	Sand and gravel (N = 30)

 Ground water was encountered at 3.5m (11'6") below ground level.

Omit from consideration

9. Detailed design of the stair/lift enclosures and the proprietary tiered seating (in the lecture theatre).

Part 1

(40 marks)

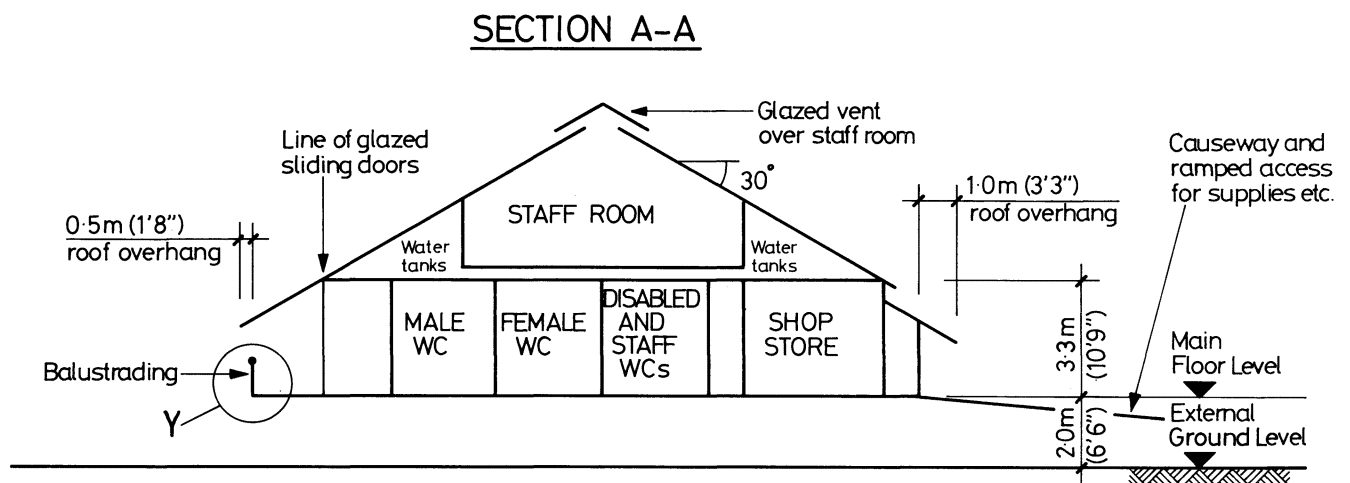
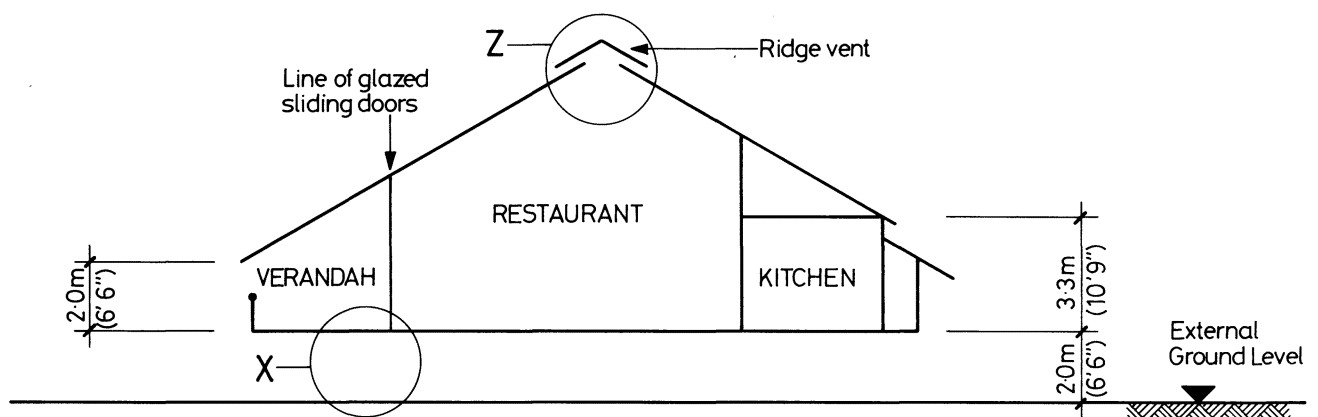
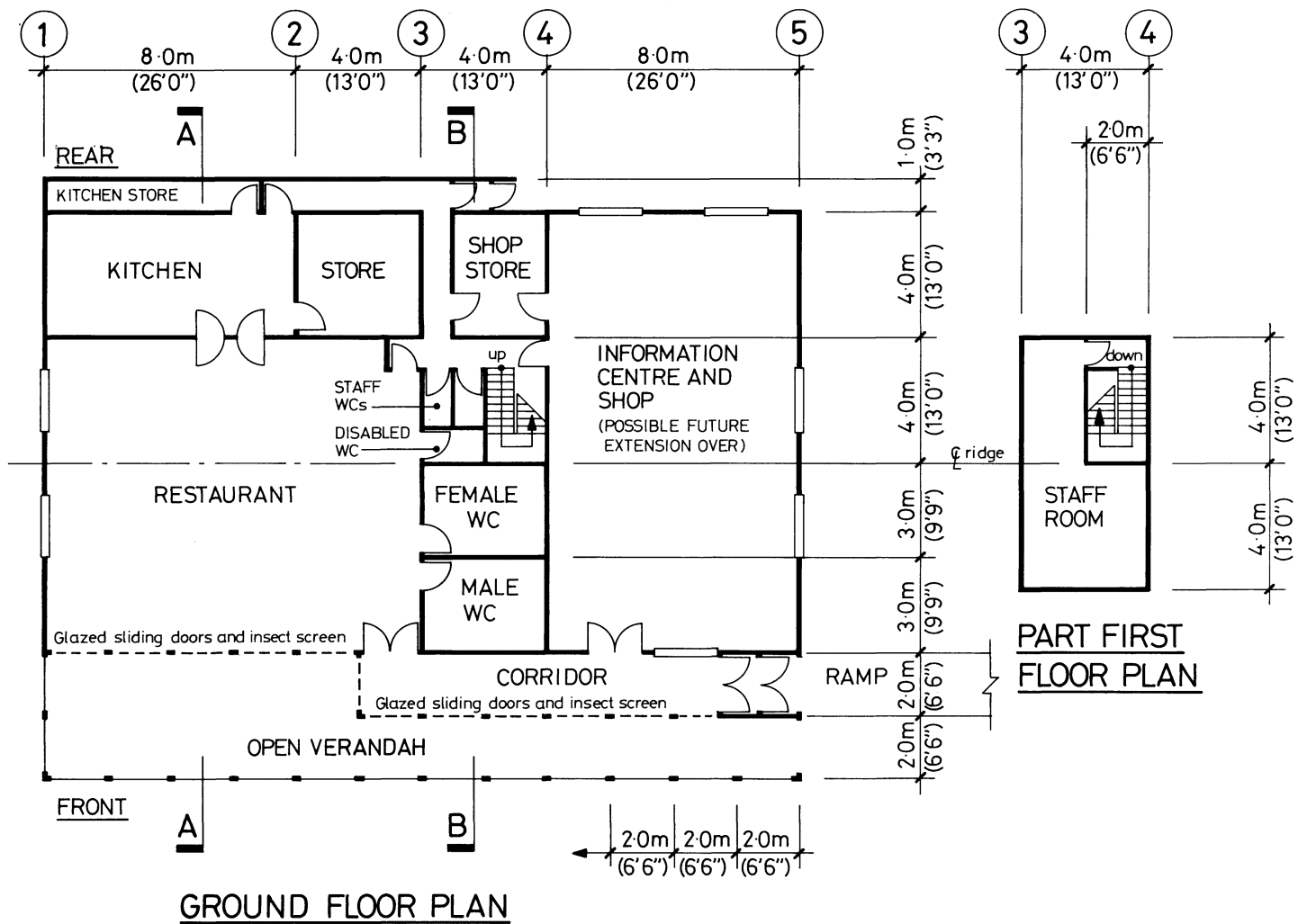
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable structural solutions for the proposed structure. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice.
- b. After your recommended solution has been approved in principle, the client considers making provision for a second lecture theatre to be built in the future, above the library and immediately adjacent to the existing theatre.
Write a letter to the client outlining the effects this consideration will have on your chosen solution.

Part 2

(60 marks)

For the solution recommended in Part 1(a):

- c. Prepare sufficient design calculations to establish the form and size of all principal structural elements including the foundations and stockroom walls.
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements for estimating purposes.
- e. Prepare clearly annotated sketches to illustrate details of:
 - (i) The junction between an external column and the floor of the lecture theatre adjacent to the cantilever section.
 - (ii) The junction of the stockroom floor and walls.
 - (iii) A cross section through the roof of the lecture theatre showing structural details and external finishes.
- f. Prepare a detailed method statement for the safe construction of the cantilever section of the lecture theatre.



NOTE All dimensions are in metres (feet and inches)

FIGURE Q6

Question 6

Visitors' Centre

Client's requirements

1. A visitors' centre is to be built in a National Park in a remote area; see Figure Q6.
2. Local natural materials are to be used as far as possible; steel, cement and other materials may be imported if required. The area around the National Park is forested and there are clay, sand and gravel strata in the vicinity. Vehicular access for construction and supplies is via a twisty mountain road approaching the rear of the centre. The maximum length that can be transported to the site by road is 8.0m (25'0").
3. The site is a wetland area with reed beds, prone to flooding. The visitors' centre is to have its main floor 2.0m (6'6") above the level of the land.
4. There is to be a verandah along the entire front elevation, with sliding glass doors covered with sliding insect netting to separate the verandah and the corridor/restaurant areas. For natural ventilation, there is to be a central vent along the ridge and a longitudinal gap between the main roof and the lean-to at the rear.
5. A 30° pitched roof is required; the roof is to have a 1.0m (3'3") overhang at the rear and sides, reduced to 0.5m (1'8") over the verandah. The full height of the roof and the main structural members are to be visible internally over the restaurant, the information centre and shop and the verandah. No more than two internal support points are permitted in each of these two areas (four in total for the whole building).
6. A half hour minimum fire resistance is required for all structural elements.

Site conditions

7. The site is located in open country. Basic wind speed is 40m/s (90mile/h).
8. Ground conditions established from trial pits are:

0 - 2.0m (6'6")	Silts and clays: $C = 25\text{kN/m}^2$ (500lbf/ft ²), $N = 5$
2.0m (6'6") - 3.0m (10'0")	Partially decomposed vegetable matter
Below 3.0m (10'0")	Sands and gravels: $N = 25$

The water level is typically at about external ground level, but varies seasonally between 1.0m (3'3") below and 1.0m (3'3") above external ground level.

Omit from consideration

9. Detailed design of the stairs.

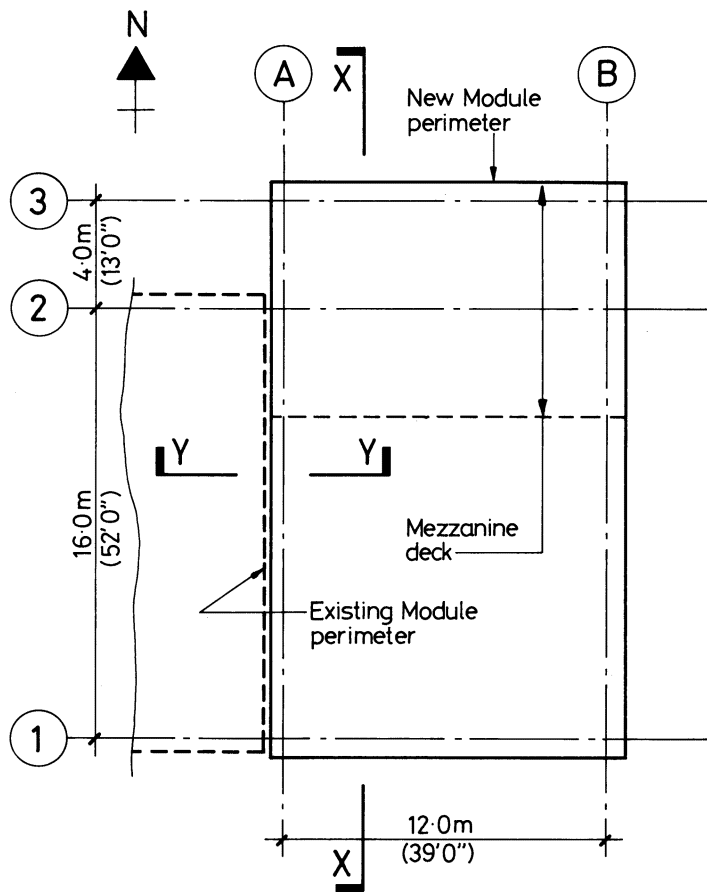
Part 1 (40 marks)

- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable structural solutions. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice.
- b. After your recommended solution has been approved, the client considers extending the first floor area into the roof space over the central area of the information centre and shop. Write a letter to the client outlining the effects this consideration will have on your chosen solution.

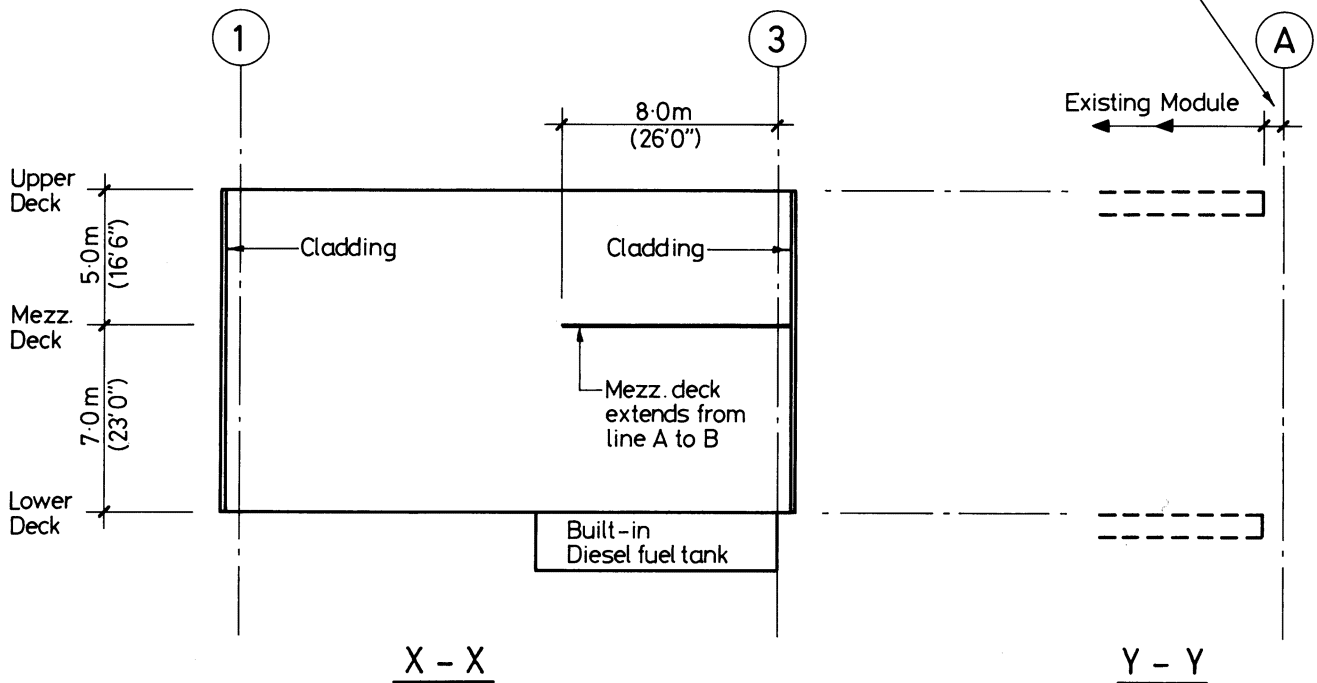
Part 2 (60 marks)

For the solution recommended in Part 1(a):

- c. Prepare sufficient design calculations to establish the form and size of all principal structural elements, including the foundations.
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of all the structural elements for estimating purposes.
- e. Prepare clearly annotated sketches to show details of the structure at the following locations:
 - (i) The foundation and ground floor at X;
 - (ii) The connection of the balustrading to the verandah at Y;
 - (iii) The connection at the ridge and support to the roof vent at Z.
- f. Prepare a detailed method statement for the safe preparation of the site and construction of the building, identifying any temporary works that you consider necessary. This should include a description of how materials will be obtained, delivered and erected.



PLAN



NOTE All dimensions are in metres (feet and inches)

FIGURE Q7

Question 7

An additional facilities module for an existing offshore oil platform

Client's requirements

1. A new module is to be added to an existing production platform; see Figure Q7.
2. The module will be attached to the east side of one of the existing modules.
3. The existing module has structural members of the necessary strength on lines 1 and 2, and at upper and lower deck levels only.
4. The module is to be lifted into position offshore and the lift vessel's crane hook disengaged as quickly as possible.
5. The module is expected to have a minimum service life of 20 years.
6. Pipe and electrical connections at pre-prepared interface points will be made in an offshore hook-up phase.
7. The module will be clad on south, east and north external faces.
8. Internal framing should be minimised to provide open floor areas for equipment.
9. The diesel fuel tank has a nominal capacity of 80m^3 (2825ft³), and is not to extend below the main lower deck structure. Plan dimensions are to be determined in the design.

Loading Requirements

10. Basic wind speed is 45m/s (100 mile/hr).
11. Deck superimposed loading:

lower deck	8.0kN/m^2 (160lbf/ft ²)
mezzanine deck	2.0kN/m^2 (40lbf/ft ²)
upper deck	5.0kN/m^2 (100lbf/ft ²)
12. Blast loading:

external blast load from south of 0.25 bar	(4.0lbf/in ²)
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Omit from consideration

13. Modifications to existing module to receive new module other than connecting joint detail.

Part 1

(40 marks)

- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable structural solutions for the proposed new module. In each case the method of loadout and installation should be discussed. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice.
- b. Having received your recommended design, your client then proposes to add an equipment package onto the upper deck of the module. The package will not be delivered to the construction yard until just prior to sailaway. The package is 10.0m x 8.0m x 6.0m high (32'0" x 26'0" x 20'0" high); it is to be located to the north end of the deck and weighs 850kN (85 tonf) dry and 1500kN (150 tonf) in the operating condition.
Write a letter to the client outlining the effects this consideration will have on your chosen solution.

Part 2

(60 marks)

For the solution recommended in Part 1(a):

- c. Prepare sufficient design calculations to establish the form and size of all principal structural elements for both the temporary and the permanent conditions.
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements including attachment points and lift points, as required for estimating purposes.
- e. Prepare clearly annotated sketches to illustrate the details of:
 - (i) The attachment to the existing module on line 2.
 - (ii) A typical lift point.
 - (iii) The built-in tank construction.
- f. Discuss the implications of the different deflection cases for the varying temporary and permanent support conditions and the impact these may have on the piped services which include relatively large bore, heavy walled oil lines.

