BC CARPENTER APPRENTICESHIP PROGRAM

LEVEL 1

2017 (Harmonized)

Line H: Wood Frame Construction

Competency H-5: Build Stair Systems

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Symbol Legend



Electric shock: This icon is a reminder for potential electric shock.



Explosive: This icon is a reminder for a possibly explosive situation.



Flammable: This icon is a reminder for a potentially flammable situation.



Important: This icon highlights important information.



Poisonous: This icon is a reminder for a potentially toxic/poisonous situation.



Resources: The resource icon highlights any required or optional resources.



Safety gear: The safety gear icon is an important reminder to use protective equipment.



Self Test: This icon reminds you to complete a self test.

We want your feedback! Please go to the BC Trades Modules website (www.bctradesmodules.gov.bc.ca) to enter comments about specific sections that require correction or modification. All submissions will be reviewed and considered for inclusion in the next revision.

Program Outline

Line A – Safe Work Practices
A-1 Apply Shop and Site Safety Practices
A-2 Apply Personal Safety Practices

Line B – Documentation and Organizational Skills
B-1 Use Construction Drawings and Specifications
B-2 Interpret Building Codes and Bylaws
B-3 Plan and Organize Work
B-4 Perform Trade Math

Line C – Tools and Equipment
C-1 Use Hand Tools
C-2 Use Portable Power Tools
C-3 Use Stationary Power Tools

Line D – Survey Instruments and Equipment
D-1 Use Levelling Instruments and Equipment

Line E – Access, Rigging, and Hoisting Equipment
E-1 Use Ladders, Scaffolds and Access Equipment
E-2 Use Rigging and Hoisting Equipment

Line F – Site Layout
F-1 Lay Out Building Locations

Line G – Concrete Formwork
G-1 Use Concrete Types, Materials, Additives and Treatments
G-2 Select Concrete Forming Systems
G-3 Build Footing and Vertical Formwork
G-4 Build Slab-On-Grade Forms and Suspended Slab Forms
G-5 Install Reinforcement and Embedded Items
G-7 Place and Finish Concrete

Line H – Wood Frame Construction
H-1 Describe Wood Frame Construction
H-2 Select Framing Materials
H-3 Build Floor Systems
H-5 Build Stair Systems
H-10 Build Decks and Exterior Structures

Line J – Building Science
J-1 Control the Forces Acting on a Building

Competency H-5: Build Stair Systems

Stair construction is one of the fundamental skills in carpentry. Stairs are used in all types of construction. They're built from wood, steel, and concrete. The principles included in this Competency apply to all types of stairs.

Learning Objectives

When you have completed the Learning Tasks in this Competency, you will be able to:

- describe stair systems
- plan straight stairs
- name the parts of stairs and balustrades
- calculate, lay out, cut, and assemble a straight stair
- construct stairs

Competencies

Written: "Build Straight Stairs"

You will be tested on your knowledge of the terminology for stairs; methods of calculation for rise, run, and methods of layout.

Practical: You will be required to calculate, lay out, cut, and assemble a straight stair.

LEARNING TASK 1

Describe Stair Systems

Stair Terms

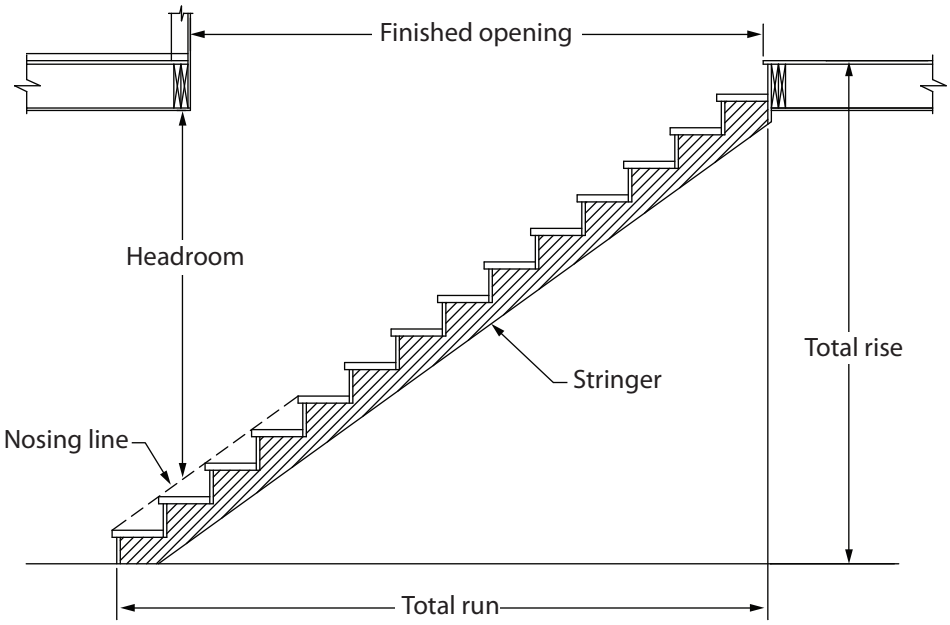


Figure 1 — Stair terms

The ***total rise*** is the vertical distance from finish floor to finish floor.

The ***total run*** is the horizontal distance from the face of the bottom riser to the face of the top riser.

The ***rise*** is the vertical distance from one tread to the next.

The ***run*** is the horizontal distance from one riser to the next.

The ***tread*** is the horizontal board that forms the step.

The ***riser*** is the vertical board placed between treads.

The ***nosing*** is the projection of the tread or floor beyond the face of the riser. ("Nosing" also refers to moulding that can be applied to the edge of the floor at a balcony.)

A ***nosing line*** is an imaginary line drawn along the top edge of the nosings.

The ***tread depth*** is the sum of the run plus the nosing.

Headroom is the vertical distance from the nosing line to the underside of the floor above.

The opening in the floor for the stairs is called the ***stairwell***.

The ***finished stairwell opening*** is the horizontal distance from the edge of the nosing at the upper landing to the finished surface at the other end of the stairwell opening.

The ***rough stairwell opening*** is framed before finishes or stairs are installed. The rough opening is typically 3" or 75 mm larger than the finished opening.

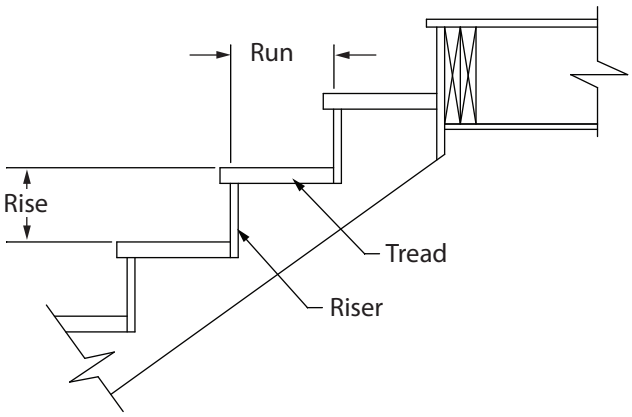


Figure 2 — Stair terms

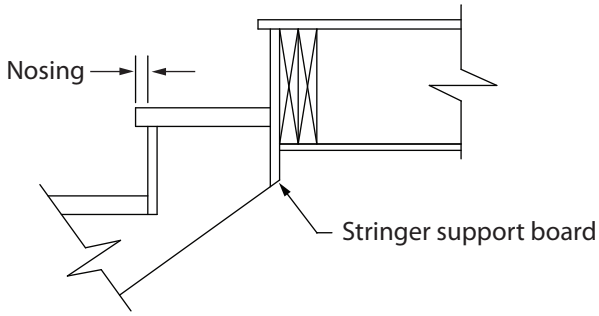


Figure 3 — Stair terms

Stringer support board, also known as a "hanger board," is used to attach the stair at the top (Figure 3). It's common to use 19 mm thick plywood nailed or screwed to the stringers and to the header of the stairwell opening.

The hypotenuse of the rise and run triangle is referred to as the ***unit of bridge***. It's used to calculate stringer length. It can also be used to lay out stringers.

The ***stringer*** is the structural support for the treads and risers.

The material from the inside of the cut to the bottom of the stringer is the ***effective depth***. This is sometimes referred to as the "throat."

Stringers

The stringer is also called the "stair horse" or "carriage." Stringers are usually cut in pairs or threes and should be good-quality lumber, straight, and clear. The *BC Building Code* requires the stringer to have a minimum effective depth of 90 mm (3½") and an overall depth of not less than 235 mm (9¼"). Stringers can be cut out (notched), dadoed, cleated, housed, solid, made of two pieces (a cut out and solid piece, referred to as "semi-housed"), mitred, or laminated into a curved stringer.

It's becoming common for builders to use LVL stock for stringers. LVL is more dimensionally consistent (stable and straight) and stronger than lumber.

Wooden Stringers

The minimum size of wooden stringers is 2×10 if not supported along its length. 2×12s are commonly used due to the strength of the additional 2" of effective depth. If the stringer has a support wall below it, the thickness can be reduced to an actual thickness of 1".

Cut-out Stringer

A cut-out stringer is the most common type of stringer. It's commonly referred to as a "notched" stringer. The rise and run are laid out on the face of the board and cut out to support the treads and risers (Figure 4).

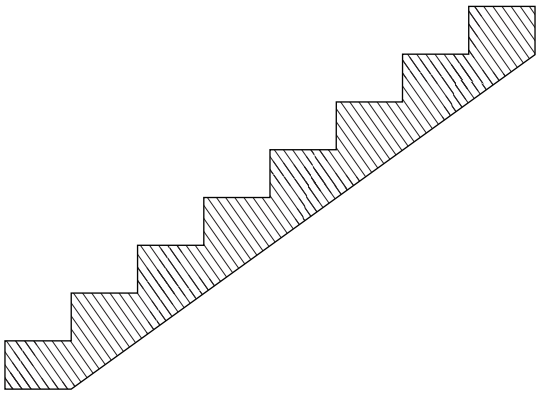


Figure 4 — Cut-out stringer

Cleated Stringer

Cleated stringers are commonly used in outdoor construction or as temporary stairs. The plain stringers have wooden supports called "cleats" nailed to them. The treads rest on and are fastened to the cleats (Figure 5). Steel angle iron brackets are also used.

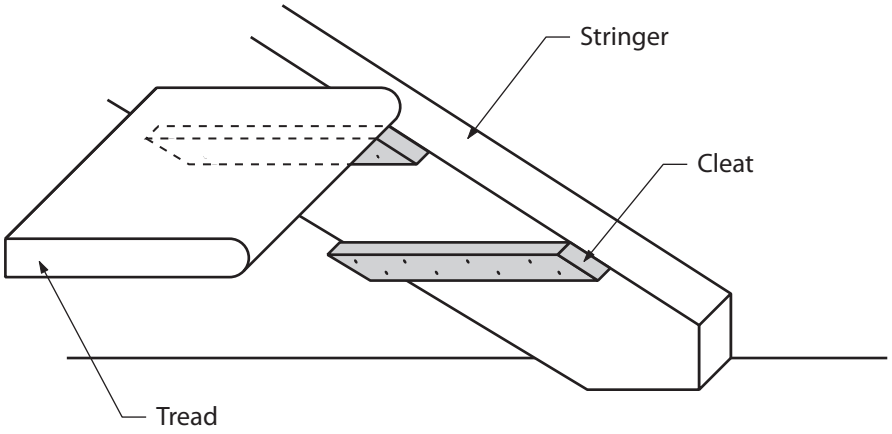


Figure 5 — Cleated stringer

Dadoed Stringer

Dadoes are cut or routed into the inside surface of the plain stringers to receive the ends of the treads (Figure 6). Dadoed stringers are usually made in mated pairs.

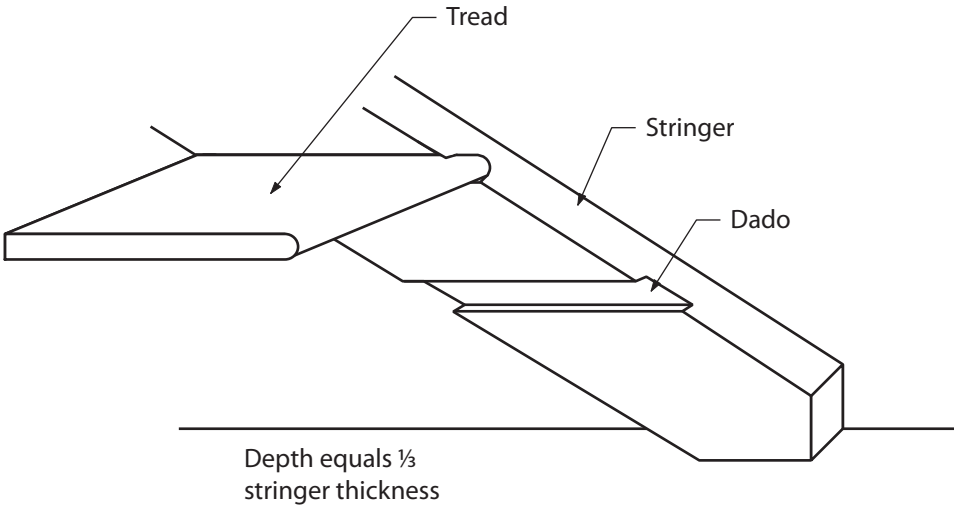


Figure 6 — Dadoed stringer

Housed Stringer

Housed stringers are typically used in finished stairs. Special, adjustable templates are commercially available or a template can be made for the rise and run of the stair, which includes an allowance for wedges to tighten the treads and the risers in place. A router is used with the template to cut a gain (recess) into the side of the stringers. The treads and risers fit into the gains and are glued and wedged tightly in place.

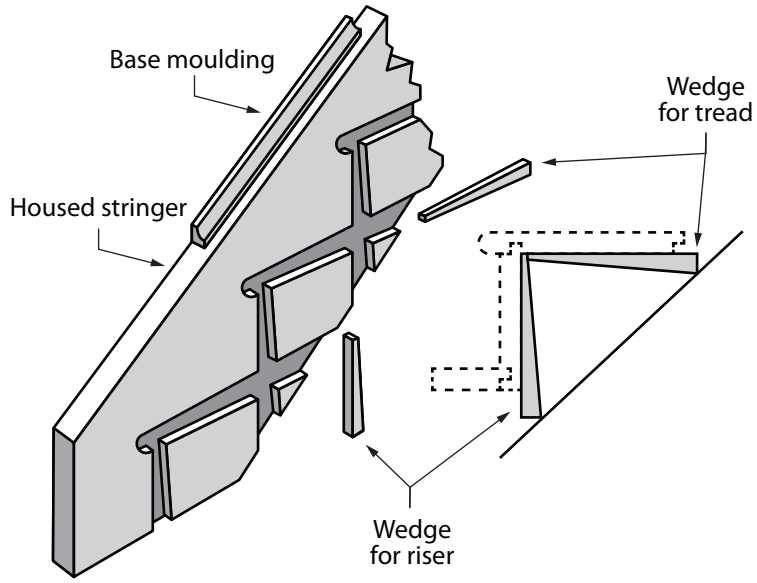


Figure 7 — Housed stringer

Semi-housed Stringer

A semi-housed or "planted" stringer has two parts: a cut-out stringer and a plain stringer. The plain stringer is a finished piece of wood attached to the wall. The cut-out stringer is laminated to the plain stringer. The treads and the risers butt into the finished plain stringer.

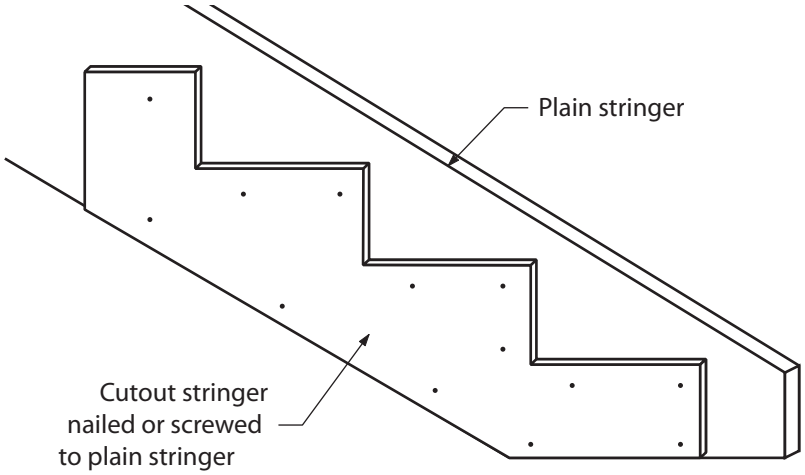


Figure 8 — Semi-housed or planted stringer

Mitred Stringer

Mitred stringers are used in finished stairs when one or both sides are open. They can be used in combination with a housed stringer on the wall side. Where the riser and stringer meet on the open side, the end of the riser is bevelled and the plumb cut on the stringer is mitred. The mitred join has no visible end grain.

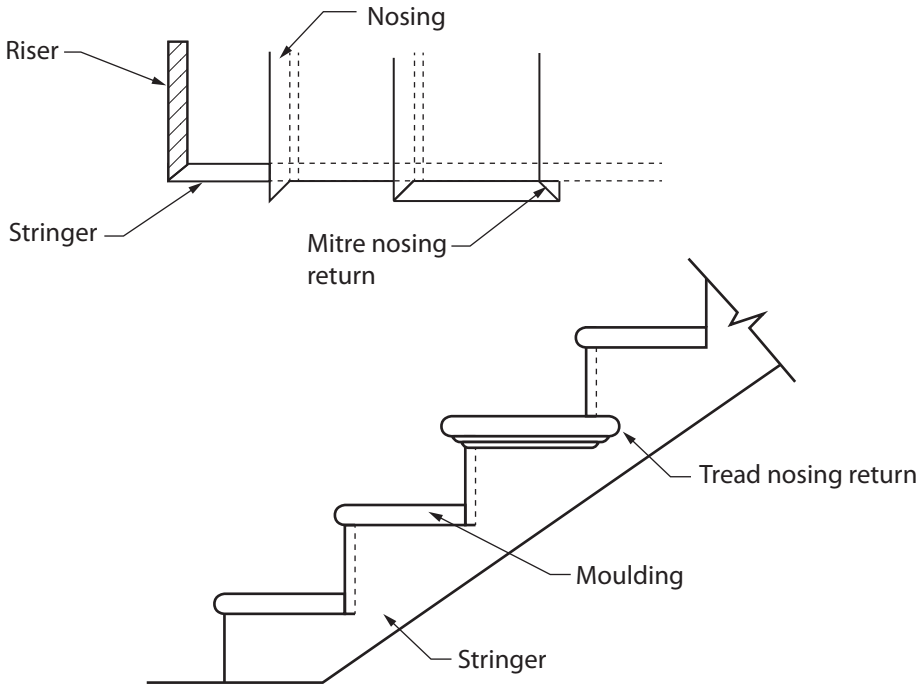


Figure 9 — Mitred stringer

The nosing of the tread returns on the outside edge of the facing stringer so that joints of balustrade and tread are covered.

Curved Stringer

Circular stairs can be built from wood, concrete, or steel.

Wooden stringers used in circular stairs are made of laminated layers of thin plywood.

The stairs are often manufactured in a stair building plant using curved walls to form a jig and shipped to the job site.

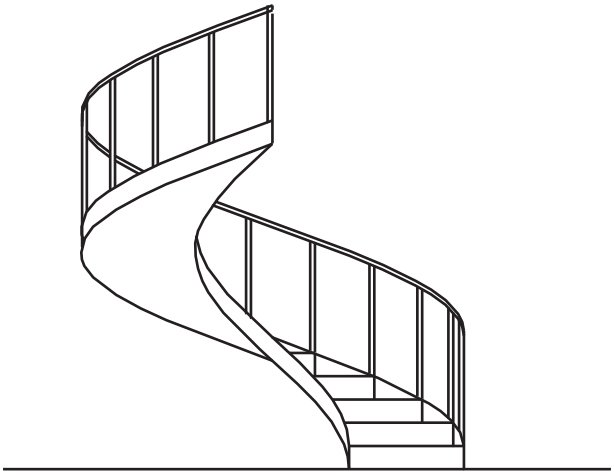


Figure 10 — Curved stringer

Treads

Treads are the horizontal boards that are stepped on in a set of stairs. The *BC Building Code* has several requirements for treads, which will be discussed in Learning Task 2.

The treads should fit closely to the level surfaces of the stringer. Any variation should be planed smooth before installing the treads. Treads should be glued in place using construction adhesive. Finishing nails, casing nails, or wood screws should be used to attach treads to stringers.

Risers

Risers are the vertical board between each tread.

They should be cut to run past the back of the tread as shown in Figure 11. This allows the riser to be nailed to the back of the tread. Nailing the riser to the tread adds considerable strength to the tread.

The joins between the risers and treads should be glued as well as nailed. Construction adhesive is the best type of glue for this procedure. It's common to used glue blocks at this joint. A glue block is a strip of wood glued to the underside of the tread and the back of the riser.

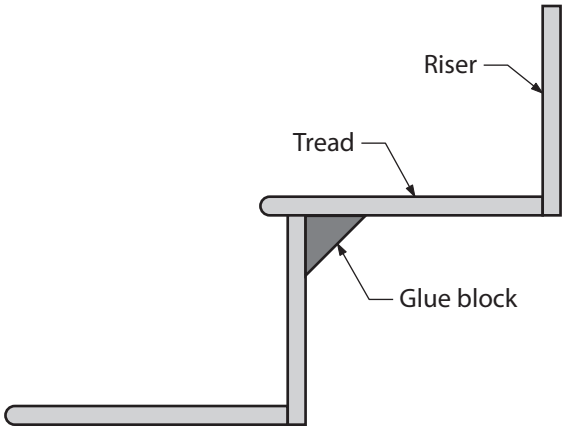


Figure 11 — Glue block

Parts of a Finished Stairway

Balustrade or Banister

The system of newel posts, handrails, and balusters that guard the open side of a stairway or landing and provide a handhold for using the stairs is called the "balustrade."

Newel Posts

Newel posts are the posts supporting the balustrade. The three main types of posts are:

- the starting newel, used at the bottom of the stair
- the angle newel, used at the turn of a stair
- the landing newel, used at the top end of a stair

Newels can be any shape, from plain, square to fancy, turned posts. It's important to anchor the posts securely in place. They're subjected to strain when people pull on them to ascend the stairs or use them to swing around at the bottom of the stairs. The starting newel should extend into the floor frame system and be securely blocked to floor joists to prevent any movement. It's important to ensure dryness in balustrade material. Tightly fastened posts will loosen considerably as they air dry.

Handrail

A handrail is a rail designed to be grasped by the hand to provide stability or support. They're formed in several standard shapes. Depending on the design, the handrail will run between the newel posts with a recess on their bottom surface to take balusters. On a closed stair, the handrail is attached to one or both walls with brackets.

Materials used as handrails must be graspable. Graspable means that most people are able to grip it securely without having to stretch or strain their hand.

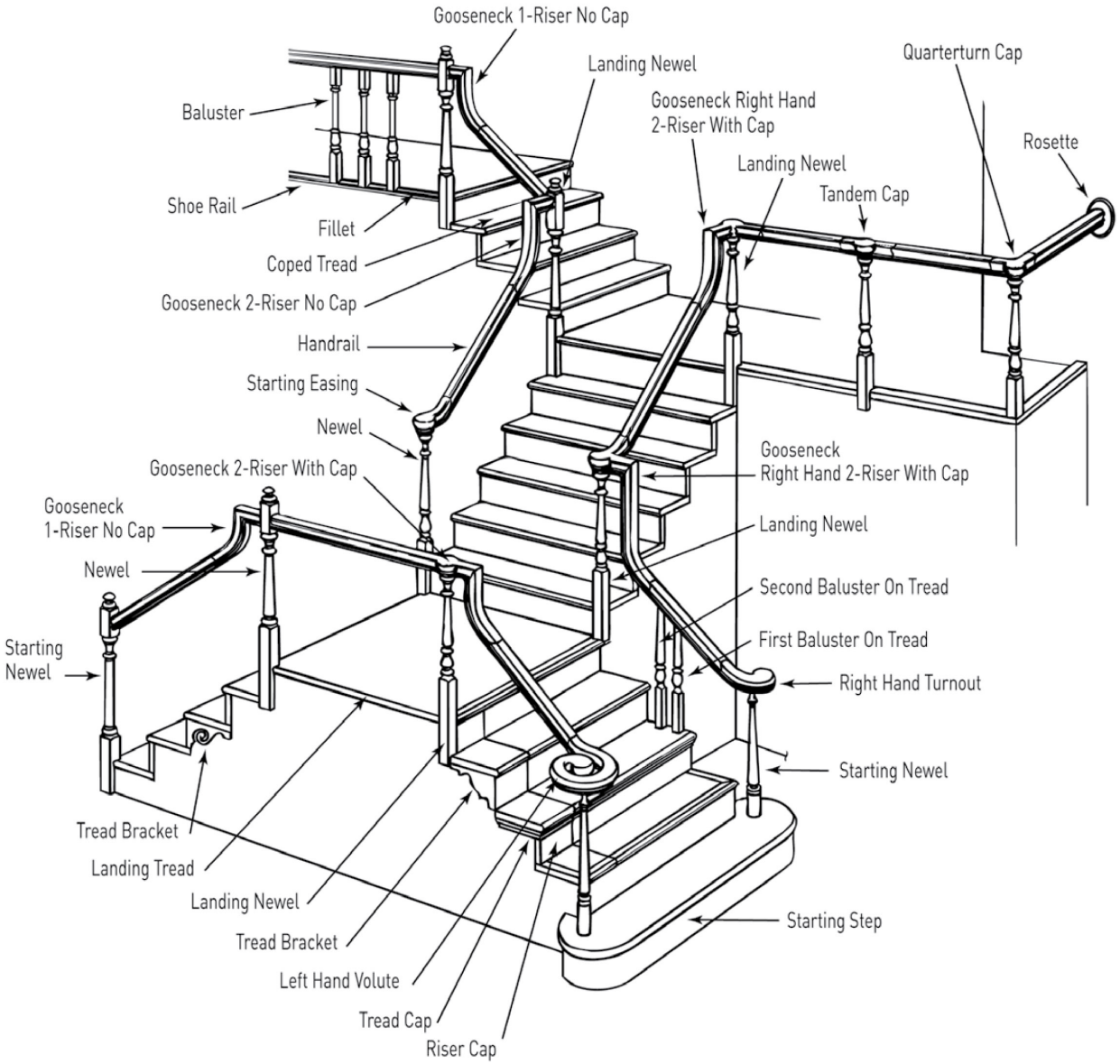


Figure 12 — Parts of a finished stairway

Balusters

Balusters are narrow wood or metal uprights under the handrail that close in the open side of the stairs for safety. There are many styles and shapes, from plain square balusters to fancy turned spindles. The *BC Building Code* requires balusters to be spaced such that a 100 mm diameter object cannot pass between them. One of the dangers of improperly spaced balusters is the chance that small infants may get their heads stuck between the balusters.

Buttress Cap or Stringer Cap

Buttress caps can be used under the balusters. It's shaped to take the end of the baluster and can be directly on the floor of a landing or raised off the floor to form a bottom rail. More traditional handrail designs used a buttress cap as sloped bottom rail.

Fillets

Fillets are shaped to fit between the balusters under the handrail and on top of the buttress cap as shown in Figure 13.

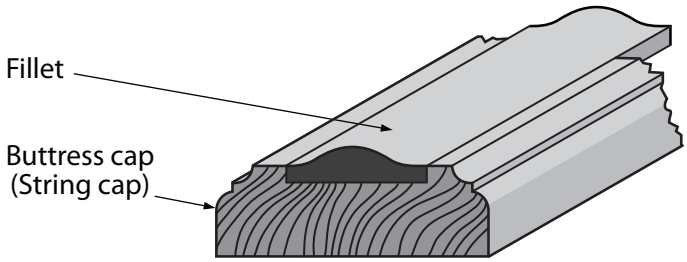


Figure 13 — Buttress cap

Types of Stairwells

Open Stairwells

Open stairwells have one or both sides open to a room or hallway. Open stairwells have a balustrade, which acts as a guard and gives a handhold to people using the stairwell.

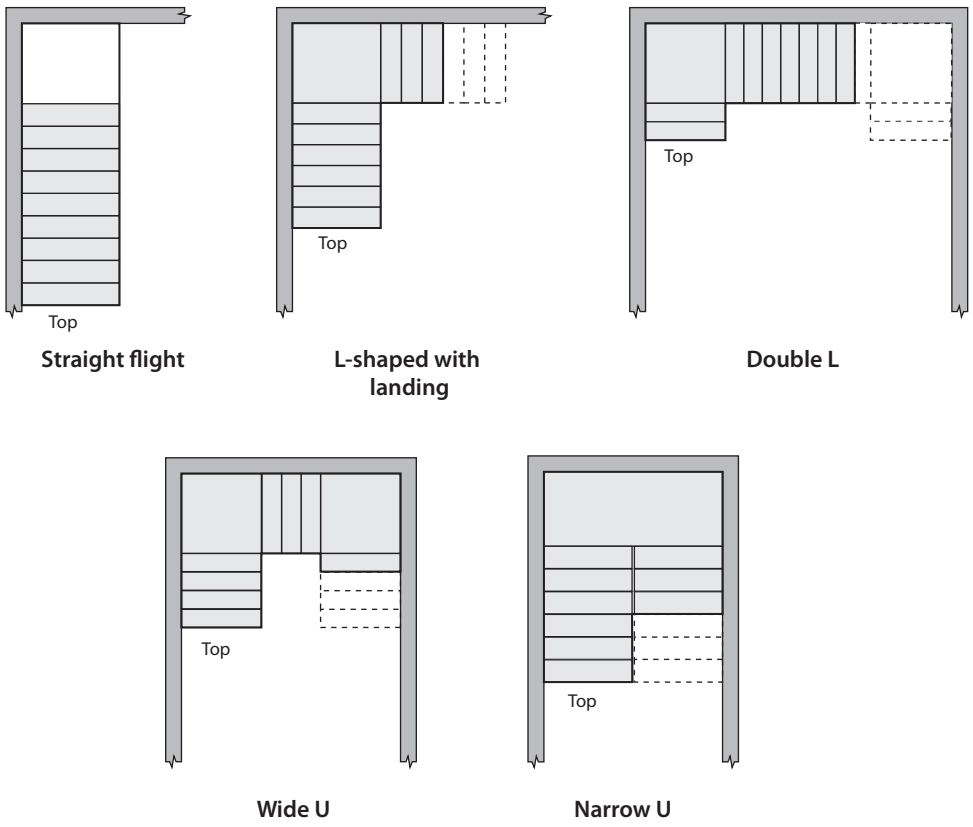


Figure 14 — Open stairwells (stairwell opening shaded)

Closed Stairwells

Closed stairwells are enclosed on both sides of the stairway. A handrail is attached to the wall on one or both sides.

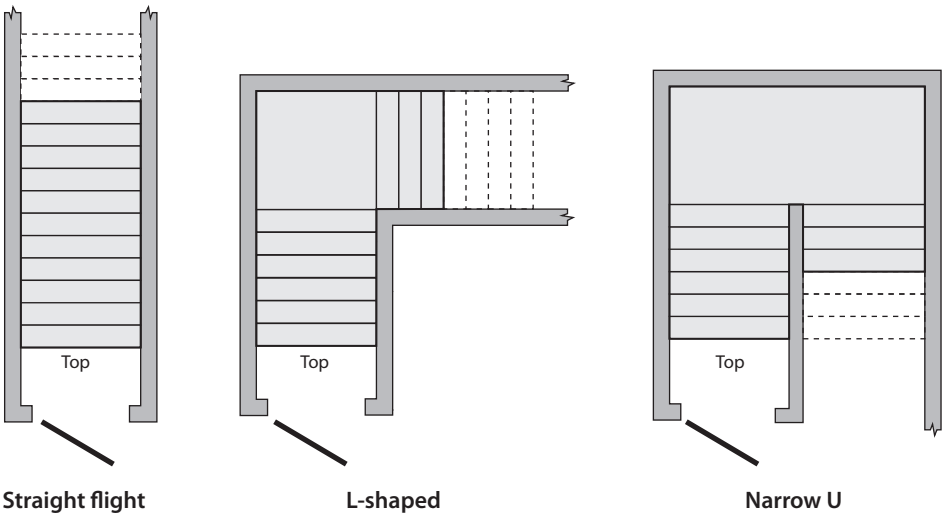


Figure 15 — Closed stairwells (stairwell opening shaded)

Combination stairwells are open at the bottom and closed at the top.

"U" Stairs

Narrow "U" stairs have two flights of stairs running in opposite directions with a landing at the midway point. These stairs are popular due to their compact size, and a distinct feature in split-level homes or split-entry apartments.

Wide "U" stairs have three flights separated by two landings. This type of stairway has an open centre that allows light to penetrate to flights below. It's common for skylights to be placed above wide "U" stairs.

"L" Stairs

Long "L" stairs consist of a long straight flight, with a short flight of 2 or 3 treads at the top or bottom at a right angle to the long stairs. A landing or winders are used at the change of direction.

Wide "L" stairs consist of two straight flights at right angles to each other, with a landing or winders at the change of direction.

Double "L" stairs consist of a straight flight, with 2 or 3 treads at right angles to the main stairs at both the top and bottom. A landing or winders are used at the change of direction.

Quarter Turn Stairs with Winders

Stairs such as the wide "L" and the long "L" are also known as quarter turn stairs. Quarter turn stairs may use a landing or have winders where the stairs change direction.

Winders are stairs with tapered treads at either exactly 30 or 45 degrees. The *BC Building Code* only allows winders within dwelling units.

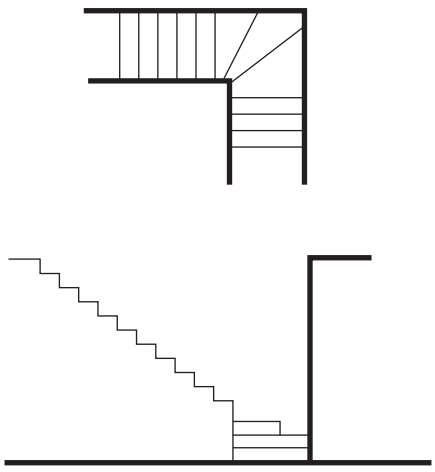


Figure 16 — Quarter turn stairs with winders

Only one set of winders is allowed between each floor level and the turn created by the winders cannot exceed 90 degrees.

Landings

Landings are used either to change the direction of the stairs or to break the total rise to create shorter flights of stairs. As per the *BC Building Code*, the maximum total rise for a flight of stairs is 3.7 metres.

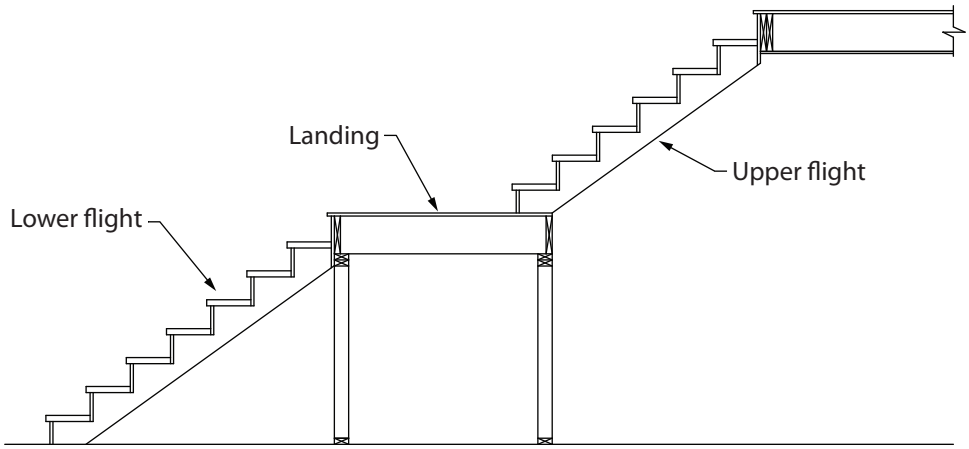


Figure 17 — Two flights of stairs with a landing

A "flight" of stairs is from one landing to another. A stairway may have several flights of stairs.

Landings must be as wide as the stair treads and have a minimum length ranging from 860 mm to 1100 mm depending on the stair configuration and location.

The *BC Building Code* requires a landing at the top and bottom of most stairs. It does not require the total rise or run of a single flight to be the same as the next flight, but it's good building practice to do so.

Now, complete Self Test 1 and check your answers.

Self Test 1

1. Describe the following terms:
   a. total rise

   b. total run

   c. rise

   d. run

   e. nosing line

   f. finished opening

2. What is the difference between a long "L" stair and a wide "L" stair?

3. When is a landing required in a stairway?

4. What is the difference between an "open stairwell" and a "closed stairwell?"

5. What are the main parts of a balustrade?

6. What is a semi-housed stringer?

LEARNING TASK 2

Plan Straight Stairs

The *BC Building Code* divides stairs into three categories: service stairs, private stairs, and public stairs. This Learning Task deals with stairs designed using *Part 9, Section 8* of the *BC Building Code*.

Service Stairs

Service stairs are used to access service rooms or spaces only (e.g., stairs to an attic or utility room). These stairs cannot access any living space. Service stairs are used by a small number of people (such as building maintenance workers) who are familiar with the stair.

Private Stairs

Private stairs are interior stairs within a dwelling unit, or exterior stairs serving a single dwelling unit. In a multi-family housing development, stairs within the units are private stairs. Stairs shared by several units are considered public stairs.

Public Stairs

Public stairs are all stairs not described as service stairs or private stairs. Public stairs include stairs in schools, parkades, and other public buildings. These stairs need to be easier to use (less steep) because the people using them are less familiar with the stair.

Private and public stairs are often considered as part of the "means of egress," or the way to get out of the building in case of an emergency. Public exit stairs in particular are subject to constraints found in *Part 3* of the *BC Building Code*.

Stair Dimensions

Safety is the main concern of the *BC Building Code* when designing and building stairs. If the rise is high and the run short, the stairs will be quite steep. Conversely, if the rise is too low and the run too long, the stairs will be very flat. Both situations are dangerous. Improperly designed or built stairs are a tripping hazard.

The rise and run are the primary stair specifications restricted by the *Building Code*, but there are also *Code* requirements for tread width, nosings, stair width, construction, and headroom.

Rise

The maximum rise for private stairs is 200 mm and the minimum rise is 125 mm. The most comfortable rise is about 180 mm or 7 inches. Refer to the *BC Building Code* for service and public stairs.

Within a single flight, all rises and runs must be identical. As per the *BC Building Code*, there can be a maximum difference of 10 mm in the rise or run of any two steps in a stairway. There can be a difference of only 5 mm in the rise or run between adjacent steps in a stairway.

Run

The maximum run for private stairs is 355 mm and the minimum run is 210 mm. The most comfortable run is about 250 mm or 10 inches. Refer to the *BC Building Code* for service and public stairs.

Treads

Lumber or plywood treads for stairs must be at least 25 mm in actual thickness. If open risers are used and the distance between stringers exceeds 750 mm, the treads must be at least 38 mm actual thickness.

Special 1" thick OSB or plywood, complete with a full round over bullnose, is often used for carpeted stairs.

"Tread depth" refers to the width of the tread, not the length of the tread. The minimum depth of the tread must be at least 235 mm or 9¼" for private stairs. The minimum tread depth is 25 mm wider than the minimum run of 210 mm. Presumably, this is so that even large feet will fit on the tread.

The maximum depth of tread is the same as the maximum run: 355 mm or 14". No nosing is required for runs over 235 mm, and it is not allowed at the maximum run of 355.

Stair Proportioning Rules

Proportioning rules are used to design stairs that are both comfortable and safe to use. Three different rules were developed over 50 years ago that still apply today. These rules are based on the imperial system of measurement:

- the rise plus the run = 17" (440–450 mm)
- twice the rise plus the run = 24" (610–635 mm)
- the rise times the run = 72" (45 000–48 000)

The first rule is the most common. Notice that the most comfortable rise of 7" plus the most comfortable run of 10" meets this rule perfectly.'

The equal sign in each rule is better thought of as "approximately equal." The rules are not perfect and are not requirements of the *BC Building Code*. Often the dimensions of lumber will be used to determine run. For example, a set of exterior stairs with treads made from two 2×6s conveniently have a tread depth of 11¼" (2 × 5½" + ¼" space for drainage) and a run of 10 to 10½".

The Preferred Angle of Stairs

The slope of a stair also describes its comfort. The preferred angle of a stair is between 30° and 35°. A 7 in 10 stair has a slope of approximately 35°.

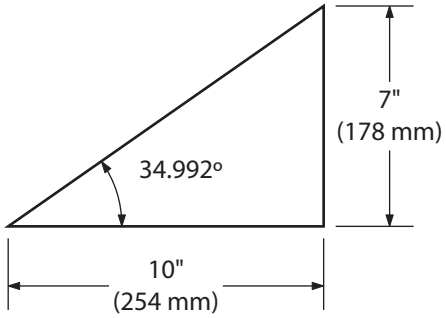


Figure 1 — Angle of stairs

The preferred angle of stairs is quite flat compared to the maximum slope allowed by the *BC Building Code*—a slope of rise 200 and run 210, which is 43 ½°.

Headroom Requirements

The minimum headroom, measured vertically from the nosing line (Figure 2), must be at least 1950 mm for stairs located within dwelling units and 2050 mm for all other stairs. These requirements are minimums and are rarely used in primary staircases.

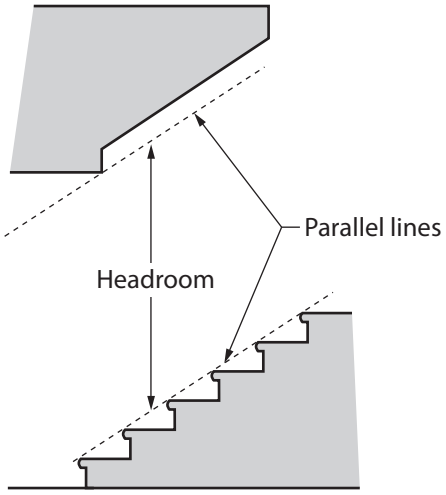


Figure 2 — Headroom requirements

Stair Construction

The stair stringer must be strong enough to support the live load imposed on the treads and spaced close enough together to keep the treads from flexing under load. The *BC Building Code* regulates this construction by specifying the size and spacing of components.

Stringer Size

Wooden stair stringers must have a minimum effective depth of 90 mm and an overall width of at least 235 mm. Stringers must be at least 25 mm actual thickness if supported along their length, and 38 mm actual thickness if unsupported along their length.

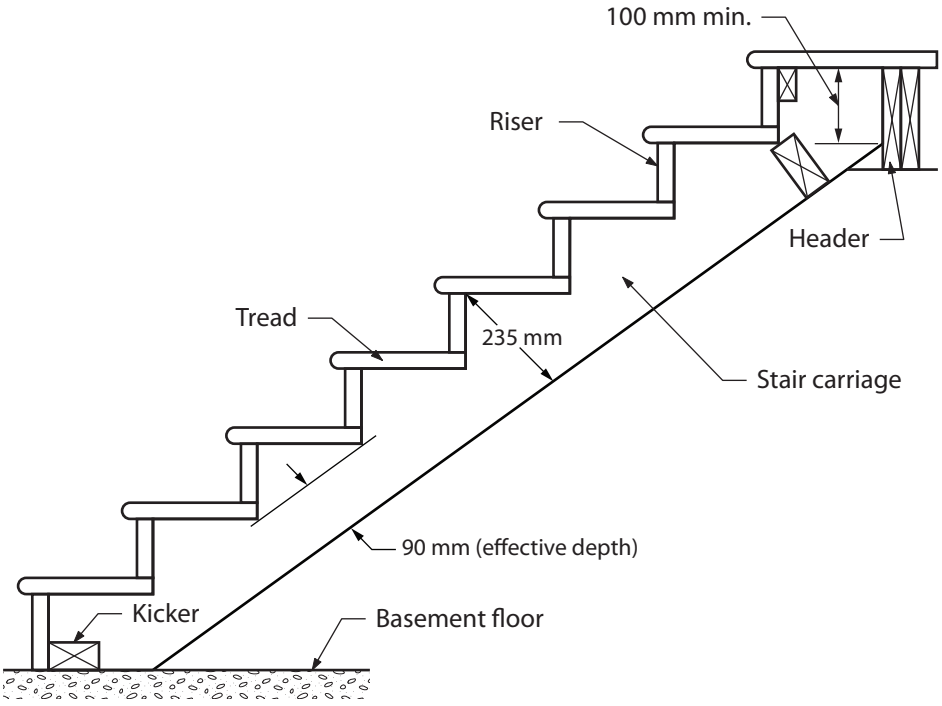


Figure 3 — Stair stringer requirements

Stringer Spacing

The maximum distance between the stringers is set by the flexibility of the tread material. If the riser boards support the leading edge of the tread, the spacing can be increased to 1200 mm o.c. For stairs serving not more than one dwelling unit, the maximum spacing is 900 mm o.c. Remember, the *Code* is the minimum—it's good practice to include a third, centred stringer.

For stairs serving other than single-family residential units, the maximum spacing of stringers is 600 mm o.c. This is regardless of whether the riser supports the tread or not.

Handrail Requirements

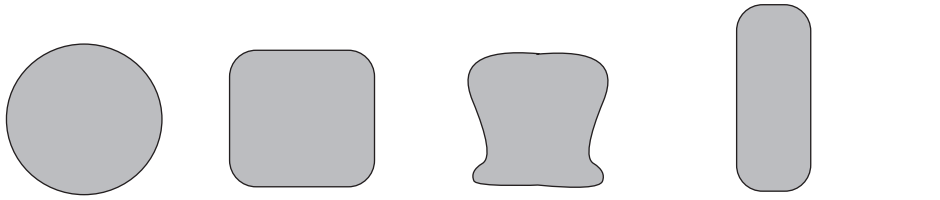
A handrail must be provided on at least one side of stairs less than 1100 mm wide and on two sides for wider stairs. The handrail must be continuous along the length of the stairway, including landings, except where interrupted by doorways, newels, or at changes in direction. Handrails are not required for stairs having two risers within dwelling units. This is a condition encountered in attached garages. If the difference in elevation between the garage floor and the house is greater than two risers, a handrail is required.

The height of handrails on stairs and ramps must be between 865 mm and 965 mm, measured vertically from the nosing line or from the surface of the ramp.

Handrails are usually attached to a wall with metal handrail brackets. The brackets must provide a clearance of at least 50 mm between the inside of the rail and the wall.

Handrails need to be attached solidly to the framing members in the wall. Good framing techniques include solid blocking (at the correct height) between the studs of the wall beside a staircase.

Handrails must be graspable, meaning that the user is able to grip the rail without having to stretch their hand. A 2×4 on flat is not graspable, as it is too wide for most people.



Acceptable round section of 30 mm to 50 mm diameter

Acceptable regular non-round section of 100 mm to 155 mm perimeter

Acceptable non-regular section of 100 mm to 155 mm perimeter

Acceptable section with 55 mm cross-section dimension and 155 mm perimeter

Figure 4 — Handrail dimensions

Width of Stairway

The primary stairway between each floor in a dwelling unit must have a minimum width between wall faces of 860 mm.

Attachment

Staircases must be supported and secured at the top and bottom. The technique used to attach the stair will be determined by the framing of the stairwell opening. A common technique is a stringer support at the top and a kicker at the bottom.

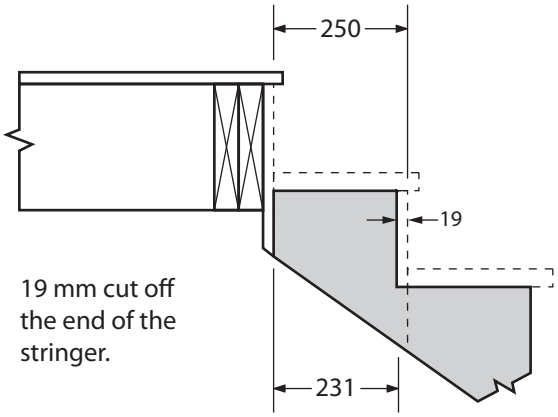


Figure 5 — Stringer support board

Some carpenters frame the header with a wider board to fully support the plumb cut at the top of the stringer.

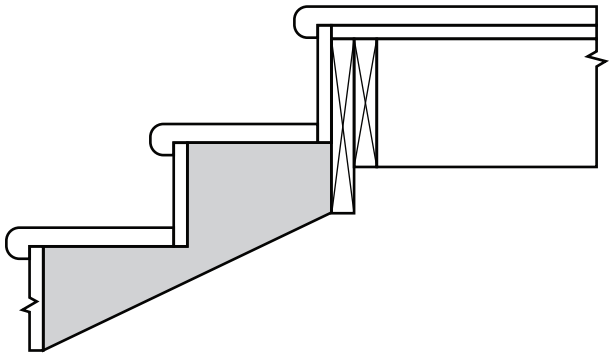


Figure 6 — Deep header used to fully support stringer

If there are no constraints on total run, the stair can be built with the same number of treads and risers and the top tread will be flush with the finished floor, and the stringers fully supported by the header.

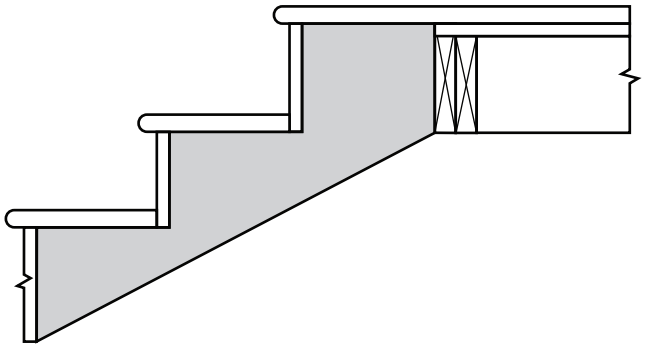


Figure 7 — Top tread of stringer flush with finished floor

A full scale sketch is always useful prior to cutting stringers.

Now complete Self Test 2 and check your answers.

Self Test 2

1. List the three stair proportioning formulas.

2. What is the preferred angle of a stair?

3. Where are "service stairs" used?

4. What are the most comfortable units of rise and run?

LEARNING TASK 3

Calculate Straight Stairs

The construction industry uses both metric and imperial units of measurement. Stair calculations are easily done in either system, although there is less converting when using the metric system and millimetres are more accurate than 16ths of an inch.

Total Rise

The starting point for all stair calculations, whether they're stairs with landings or curved stairs or winders, is determining total rise.

Total rise is measured from the finished floor level at the bottom of the stairs to the finished floor level at the top of the stairs. Generally, the finished flooring material (such as carpet, wood flooring, or ceramic tile) has not been installed when the stairs are installed. Therefore allowances for the flooring thickness must be included in the total rise calculation.

If the floor at the bottom of the stairs is sloping, as it may for exterior stairs, determine where the stairs will land and measure the vertical distance from this point to the landing at the top. For a long set of stairs this may require the use of a builder's level.

The total rise cannot be changed or adjusted. The landings, or floor levels, are usually set and cannot be moved.

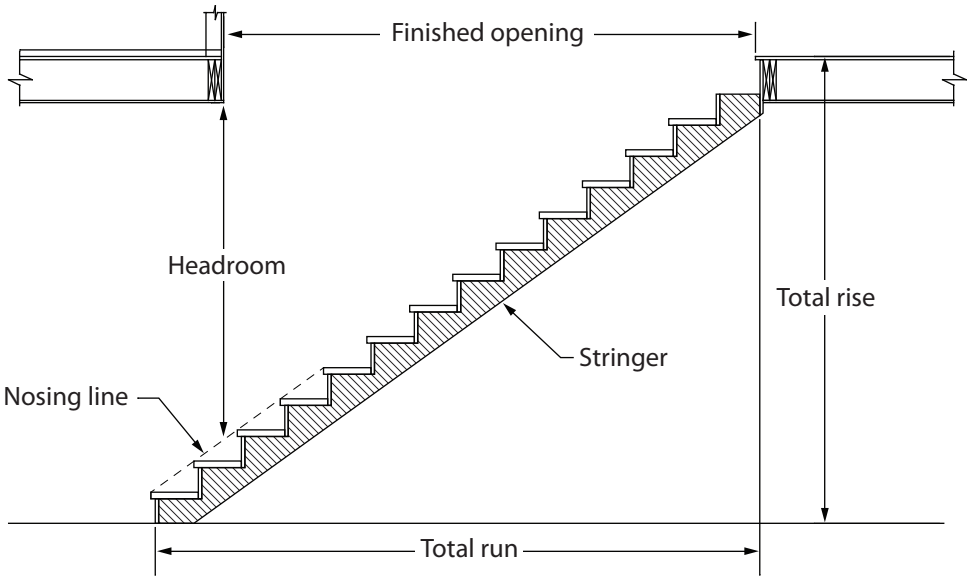


Figure 1 — Total rise

Desired Rise

In residential construction, the designer may specify the number of rises, but not the dimension. The stair calculations are left to the carpenter. This is because the actual total rise may differ slightly from the dimensions shown on the drawings.

The next step when calculating stair dimensions is to decide on a "desired rise." The desired rise can be as small as the minimum rise or as large as the maximum allowed by the *BC Building Code*.

Often, the building designer allows the minimum space for the stairs in order to save floor space. This requires that the desired rise be close to the maximum allowed by the *Code* to reduce the number of risers and treads. The fewer the number of treads, the shorter the stair, and the less square footage of floor area it takes up.

If space is the main criteria, choose the maximum rise allowed by the *BC Building Code* as the desired rise. However, best practice is for a safe and comfortable stair—use 7" or 180 mm as the desired rise.

Number of Risers

To find the number of risers for the stair, divide the total rise by the desired rise. The result is usually a decimal fraction. It must be rounded off to a whole number because there cannot be a partial step. All rises must be equal.

The fraction is rounded up if the decimal fraction is 0.5 or over, and down if the decimal fraction is less than 0.5. If the *Code* maximum rise is used as the desired rise, the decimal fraction must always be rounded up (rounding down would produce a rise greater than the maximum allowed by the *Code*).

Example

Total rise	=	2650 mm
Desired rise	=	180 mm
2650 ÷ 180	=	14.722 risers
Rounded off	=	15 risers

Rise Per Step

The whole number of risers is then divided into the total rise to give the rise per step. This rise is an exact measurement and should be rounded to the nearest millimetre.

Example

2650 mm ÷ 15 = 176.667 mm (round to 177 mm)

Although this rounding might seem insignificant, its effects are cumulative over the entire flight. By rounding to 177 mm, each step is greater by 0.333 mm. Since there are 15 risers, this adds up to 15 × 0.333 mm = 4.995 mm, which is the maximum variation between rises.

Typically this small of rounding works itself out in the layout and cutting. On longer stairs, the rounding error needs to be considered and included in the layout. This is why carpenters will refer to a number such as "177 light," so that the layout is on the small side of 177 and the entire rounding doesn't occur at one place.

Number of Treads and Run

The number of treads in a stair is usually one less than the number of risers. Remember the phrase "one less tread than riser."

The run can be found using one of the stair proportioning rules or can be set to meet a fixed total run.

In residential construction, the total run is often unconstrained and the run is found using one of the following proportioning rules:

- the rise plus the run = 17" (440 – 450 mm)
- twice the rise plus the run = 24" (610 – 635 mm)
- the rise times the run = 72" (45 000 – 48 000 mm)

The first rule is the simplest and most commonly used.

Which formula to use and whether to use the low end of the range or the high end is the choice of the carpenter.

Using the first proportion rule (rise plus run equals 450 mm), the run is calculated as follows:

Rise = 177 mm
450 mm – 177 mm = 273 mm
Run = 273 mm

The second proportion rule (twice the rise plus the run = 635 mm) gives the following result:

Rise = 177 mm
635 mm – (2 × 177 mm) = 281 mm
Run = 281 mm

Finally, the third proportion rule (the rise times the run = 48 000 mm) results in the following run:

Rise = 177 mm
48 000 ÷ 177 mm = 271 mm
Run = 271 mm

The resulting run from each of these calculations meets the *BC Building Code* requirements and will produce a safe stair.

Trapped Run

A trapped run is a condition where the total run of the stair is fixed (e.g., the stair and landing might have to fit between a beam and a wall). This is common in multi-storey stairwells in commercial construction. In these cases, no proportion rule is used.

For example, if the distance between a beam at the top and a wall at the bottom is fixed at 4600 mm and the required landing at the bottom is 900 mm, the total run of the stair is 3700 mm. In this case, divide the total run by 14 treads and get a run per step of 264 mm:

3700 mm ÷ 14 treads = 264.286 mm (round to 264 mm)

Stairwell Openings

The length of the stairwell opening must be calculated before building the opening in the floor framing. The length of the rough opening is dependent on the headroom required, the thickness of the floor system, the rise, and the run.

Finished Opening

The finished opening is the horizontal distance from the edge of the nosing at the landing to the face of the finished wall at the header at other end of the opening (Figure 1). This is calculated first. The rough opening must be greater than the finished opening. An allowance of 3" or 75 mm is used to make room for the nosing, the riser thickness and the wall finishes.

Rough Opening

To calculate the length of the rough opening for the stairwell, start with the finished opening.

The similar triangle equation is:

$$\frac{\text{Finished Opening}}{\text{Floor thickness} + \text{Headroom}} = \frac{\text{run}}{\text{rise}}$$

The finished stairwell opening (FSO) is the unknown and will be in the same proportion to the floor thickness + headroom as the run is to the rise.

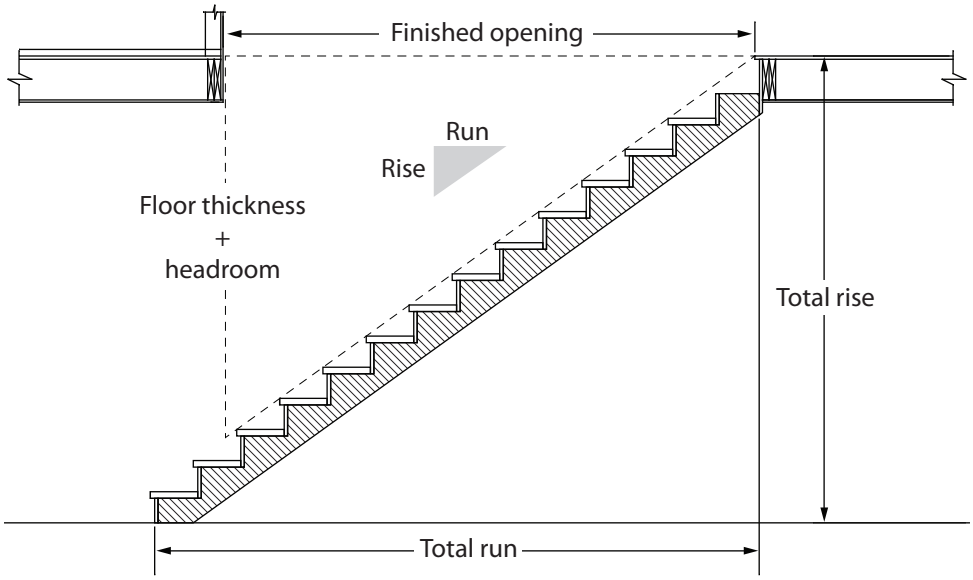


Figure 2 — Stairwell opening triangles

The "floor thickness" is the sum of the ceiling finish, the joist depth, the subfloor thickness, and the finished floor thickness.

Metric Example

No. of risers = 15
No. of treads = 14
Unit rise = 177 mm
Unit run = 273 mm
Headroom = 1950 mm
Floor thickness = 227 mm

$$\frac{\text{FSO}}{1950+227}=\frac{273}{177}$$

Finished Opening = 3358 mm
Rough Opening = 3358 + 75 mm = 3433 mm

A common mistake when calculating the length of the rough opening is to forget to add the 75 mm allowance for nosing and finishes.

The resulting rough opening allowance is used to position the headers in the floor frame.

The following formula is a shortened version of the similar triangle equation above with the 75 mm allowance added:

$$\text{Rough opening} = \frac{\text{Unit run}}{\text{Unit rise}} \times (\text{Headroom} + \text{Floor thickness}) + 75 \text{ mm}$$

Imperial Example

Total Rise = 107 ¼"
Desired rise = 7"

107.25" ÷ 7" = 15.32 rises (round down to 15 rises)
107.25" ÷ 15 = 7.15" = 7 ⅛"

Trying all three proportion rules, we find that all runs are *Code*-compliant:

- rise + run = 17"
  17" – 7.15" = 9.85"

- (2 × rise) + run = 24"
  24" – 14.3" = 9.7"

- rise × run = 72"
  72" ÷ 7.15" = 10.07"

Given a floor thickness of 11¼" and desired headroom of 6' 6":

$$\frac{\text{FSO}}{89.25"} = \frac{9.85"}{7.15"}$$

Finished stairwell opening = 122.953"
Rough stairwell opening = 122.953" + 3" = 125 15⁄16" (frame it at 126")

Unit of Bridge

The hypotenuse of the rise and run triangle is referred to as the "unit of bridge." The unit of bridge is useful when laying out long stair stringers and calculating the stringer length and will be discussed in greater detail in Learning Tasks 4 and 5 of this Competency.

The unit of bridge for the metric example given above (rise = 177 mm, rise = 273 mm) is calculated as follows:

$$\text{Unit of bridge} = \sqrt{177^2 + 273^2}$$

$$= \sqrt{31329 + 74529}$$

$$= \sqrt{105858}$$

$$= 325.358 \text{ mm}$$

$$= 325.4 \text{ mm (round to the nearest 10th of a mm)}$$

Now complete Self Test 3 and check your answers.

Self Test 3

Show all the steps in your calculations, not just the answer.

1. Calculate the rise if the total rise is 3150 mm and the desired rise is 178 mm.

2. Calculate the run if the rise is 183 mm. Use the stair proportioning formula "rise plus run = 430 mm."

3. Calculate the unit of bridge for a stair with a rise of 178 mm and a run of 255 mm.

4. Calculate the run if total rise is 10' 4". Use a desired rise of 7" and the stair proportioning formula "twice the rise plus run = 24"."

5. Calculate the rough stairwell opening if the rise is 175 mm and the run is 245 mm. Use the minimum headroom requirement for residential stairs and a floor thickness of 295 mm.

6. Calculate the rough stairwell opening if the rise is 7¼" and the run is 10". Use the minimum headroom requirement for residential stairs and a floor thickness of 12⅛".

7. How is the total rise measured?

8. How is the floor thickness calculated?

LEARNING TASK 4

Build Straight Stairs

Care must be taken when building stairs. Poorly designed and constructed stairs are a safety hazard and the building inspector will check them closely. The inspection can only be done after the stairs are completely finished. Even minor discrepancies in the rise or run may require that the stairs be reconstructed, an expensive setback.

Staircases are often important architectural features and the highest standards of precision and finishing are required.

Stringer Layout

The first step in stair construction is to lay out the stringers. The rise, run, unit of bridge, and stringer length are used in stringer layout.

Visualize

Hold the piece of lumber being used for the stair stringer in front of you. In your mind, decide which end of the board will be the top of the stairs. If the board has a crown, it should be up when the stringer is fastened in place.

If you can visualize the shape and location of the stringer in your mind's eye, the layout will be much easier.

A sketch of the stair will help with the layout.

Plumb Cut

The stringer layout begins with a plumb line at the base of the stringer. The plumb line is made using the rise and run on a framing square (Figure 1). Ensure the same side (outside edge or inside edge) of the framing square is used for both numbers. This is the layout line for the bottom riser cut.

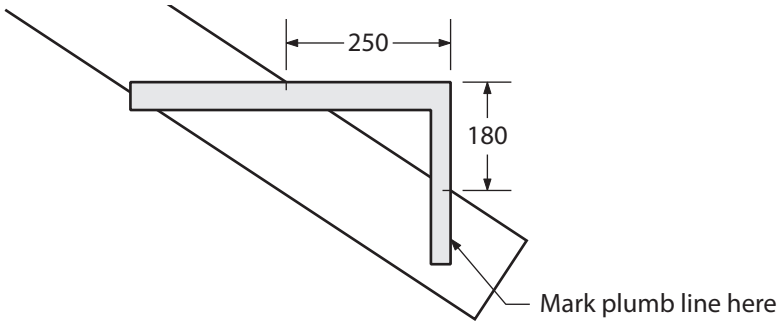


Figure 1 — Lay out the plumb line

Lay Out the Steps

Where the top of the plumb cut meets the edge of the stringer is a working point. Measure the length of the stringer from this point towards the top of the stringer to establish the working point at the top.

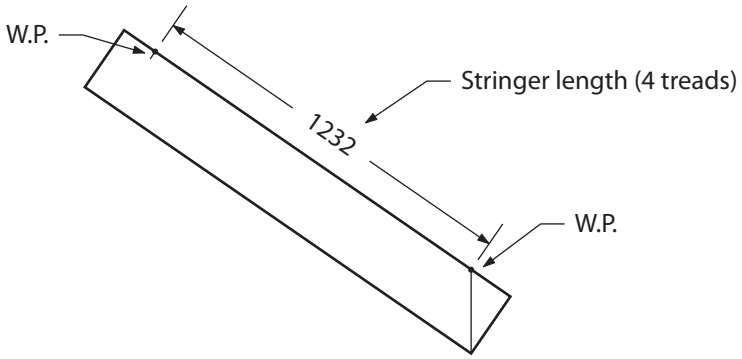


Figure 2 — Measure the stringer length

Step off the units of bridge from the first working point towards the working point at the top of the stringer. (This is easily done with a set of callipers.)

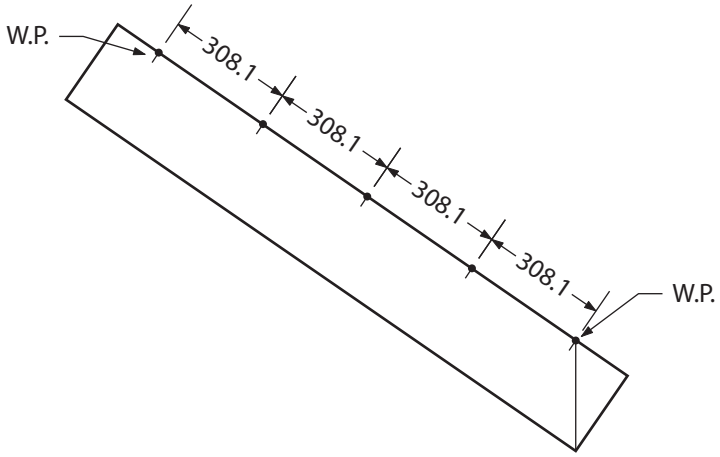


Figure 3 — Step off the units of bridge

It's unrealistic to lay out a unit of bridge such as 308.1 mm, but for longer stringers, the fractional millimetres will add up. The stringer length is accurate to the nearest millimetre and takes into account the fractional amount. If the last unit of bridge doesn't meet the upper working point, adjust the units of bridge slightly to average the difference.

Use a framing square to draw the cut lines between the units of bridge using the rise and run of the stairs.

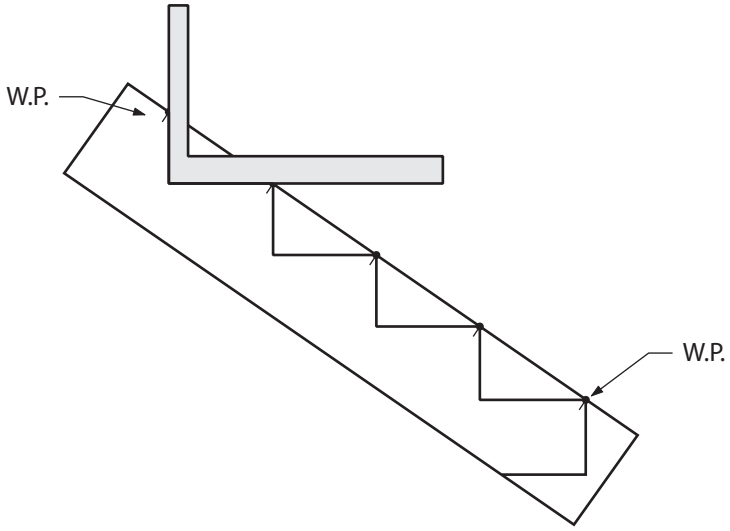


Figure 4 — "Stepping off" the cut lines with a framing square

A less accurate, but faster, method is to step off the rise/run steps without using the unit of bridge.

Adjustment at the Bottom

The rise must be the same for each step. This means that the first rise must be reduced by the thickness of the tread (i.e., "dropping the stringer"). This will make the rise of the first step equal to the others (Figure 5). Although this is easy to calculate, it's usually done as part of the layout, much the same as layout adjustments are made for rafters.

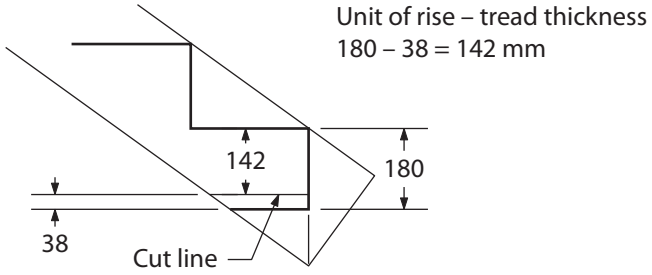


Figure 5 — Adjustment at the bottom of the stringer

Finished Floor Allowance

If the finished floor at the bottom of the stairs is installed after the stringer is installed, its thickness must be considered along with the tread thickness. The thickness of the floor finish is added at the bottom (Figure 6).

If the finish floor is continuous from the lower floor level up the stairs and onto the upper floor level, the thickness is not considered.

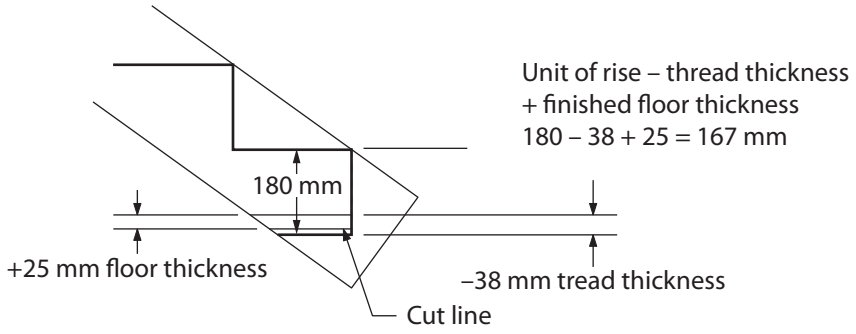


Figure 6 — Finished floor allowance

Adjustments at the Top

The adjustment at the top of the stair will vary depending upon how the stringer is attached to the floor framing. Several methods are common.

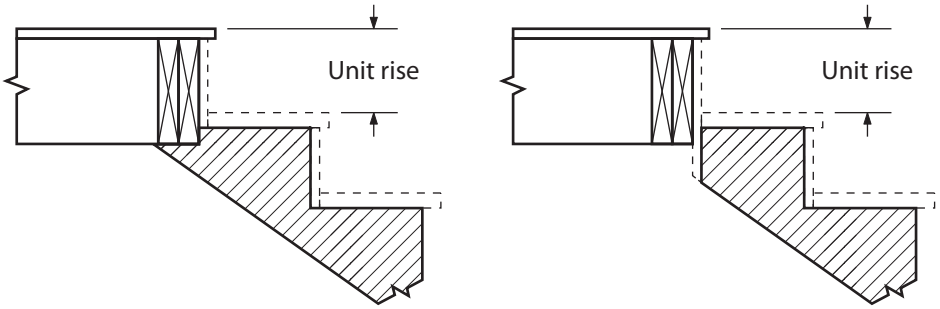


Figure 7 — Attachment to the floor framing at the top of the stair

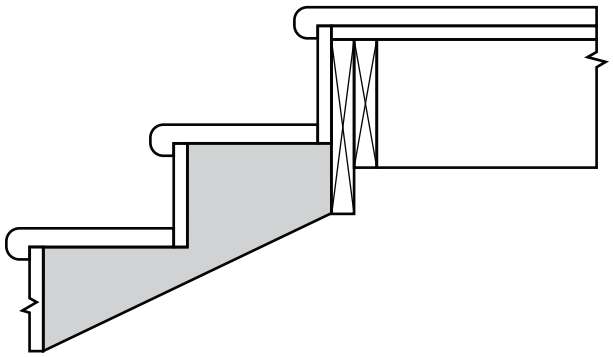


Figure 8 — Stringer attached to deep header

When determining the attachment point at the top of the stair, the thickness of the subfloor, finished floor, and tread must be considered along with the joist depth and the unit of rise.

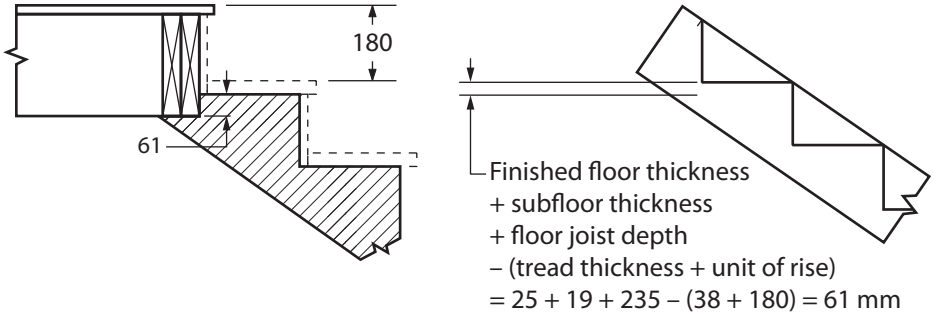


Figure 9 — Locating the attachment point at the top of the stringer

If a stringer support board is the finished riser, the cut line is adjusted by the thickness of the riser so that when the riser is installed, the run is the same as the rest of the treads.

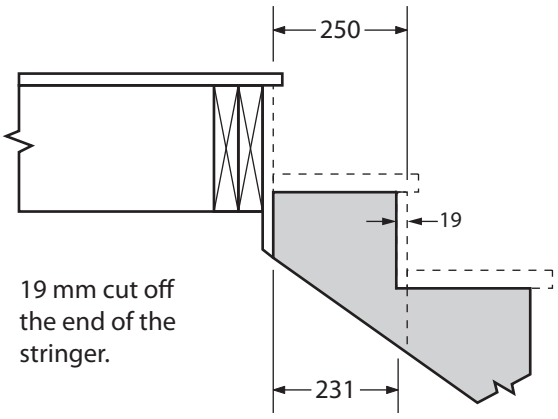


Figure 10 — Stringer supported with a support board

There are other variations to the stringer to joist connection. When laying out the stringer, consider all pieces carefully.

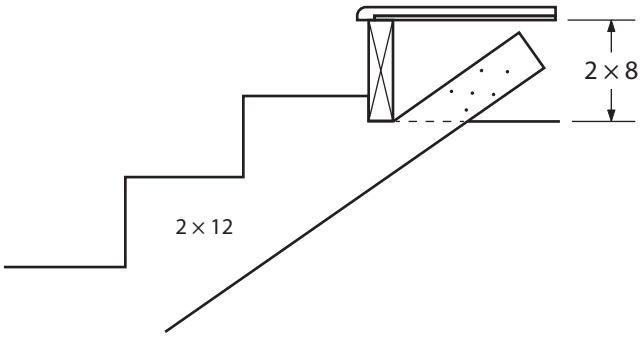


Figure 11 — Attaching the stringer to the floor frame

Full-size Drawing

For complicated connections, make a full-size drawing of the connection. Draw all of the details, including the finish floor thicknesses, full size. This will allow measurements to be taken for the various cuts directly from the drawing without having to calculate them.

Semi-housed Stringers

Semi-housed stringers are made up of two parts, the cut-out stringer and a plain stringer. The plain stringer is a finished piece of lumber with plumb and level cuts at both ends to fit behind the cut-out stringer. The thickness of the plain stringer should match the thickness of the baseboard.

The top of the plumb cut should be level with the top of the baseboard at the bottom of the stringer. At the top of the stringer, the level cut should be flush with the top of the baseboard.

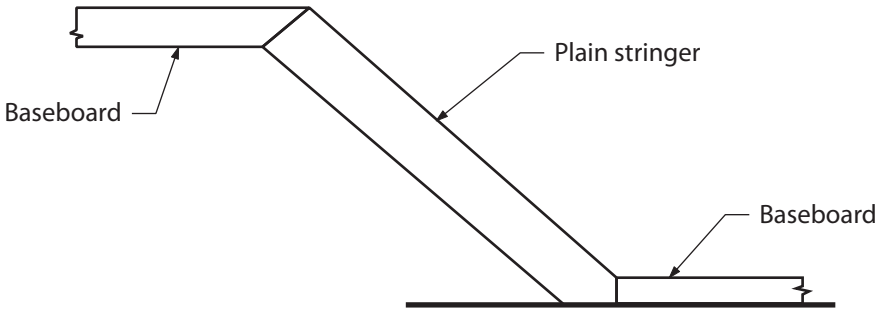


Figure 12 — Plain stringer

Once the plain stringer is in place, install the cut-out stringer as shown in Figure 13. Install the risers and treads between the two plain stringers.

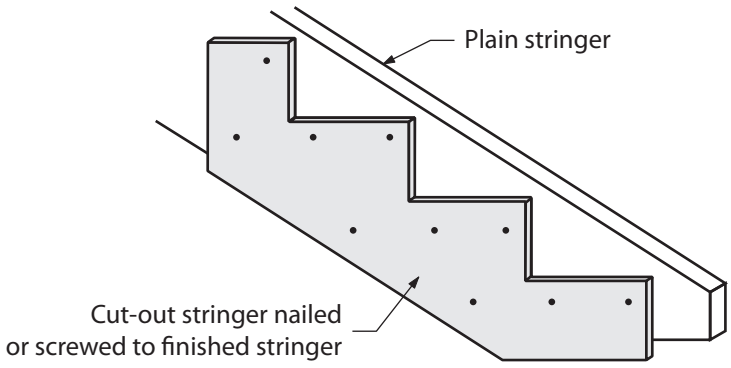


Figure 13 — Installing a semi-housed stringer

If the risers and treads are stain-grade, the join between them and the plain stringer must be tight. If the stringers are twisted or cupped, it's useful to make a pattern for each join. (Door skin or thin MDF work well for making a pattern.)

Mitred Stringer

Mitred stringers are similar to cut-out stringers. The layout is the same. Cut the riser portion of the stringer at a 45° angle. The end of the riser is cut at 45° to fit to the stringer.

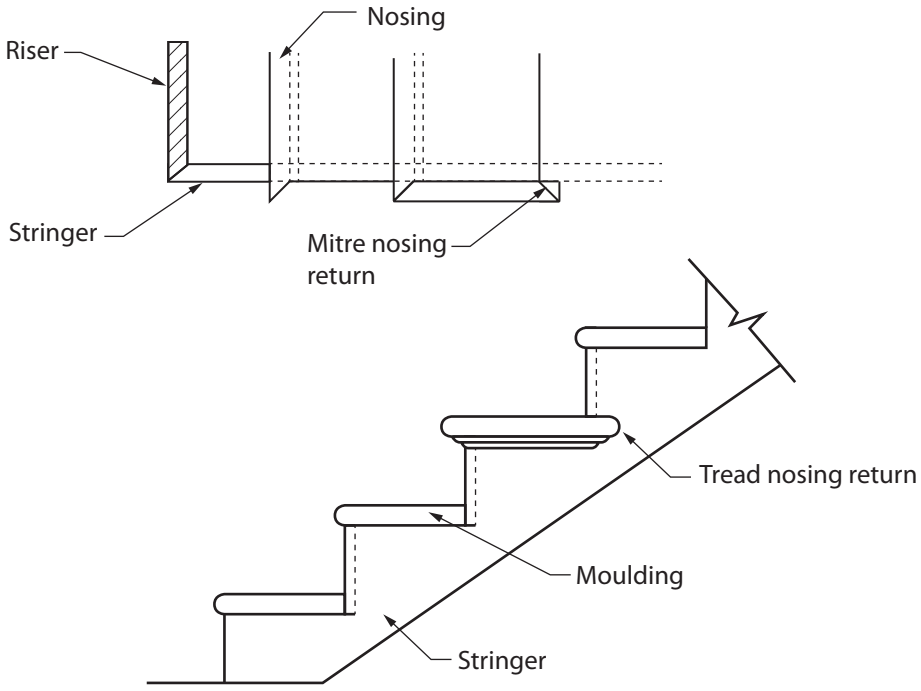


Figure 14 — Mitred stringer

If one side of the stair is open, a housed or semi-housed stringer is used on the closed side. If both sides of a stair are open, mitred stringers are used on both sides.

Housed Stringer

Housed stringers have a tapered recess (gain) routed out to receive the ends of the treads and risers (Figure 15). Wedges are tapped in to tighten the treads and risers against the visible side of the recess and glued in place.

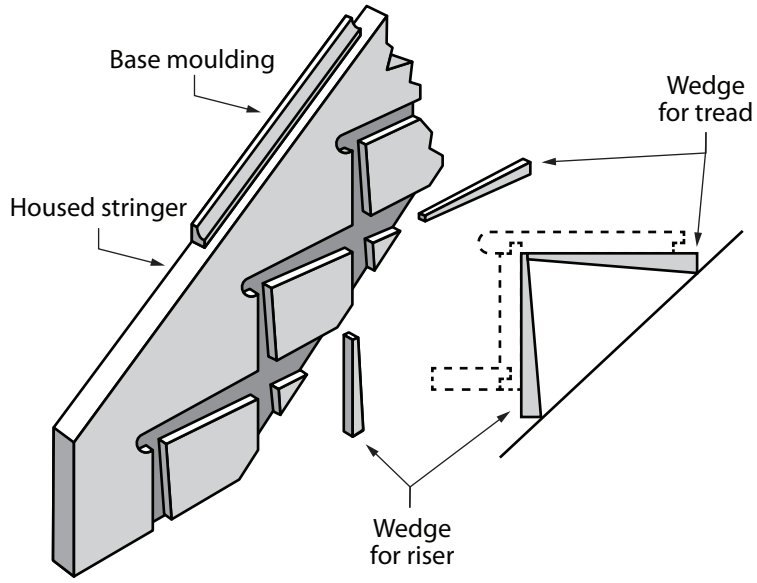


Figure 15 — Housed stringer

The depth of the gain should be about ½". This gives adequate bearing for a well-fastened tread and does not substantially weaken the stringer.

The cuts at the bottom and top of the stringer should mitre with the baseboard. If there is no baseboard, the stringer should be cut level at the finish floor line.

Templates

Templates are used to rout the gains for the riser and tread. The templates can be job-built or manufactured. Manufactured templates can be adjusted to fit different runs and rises.

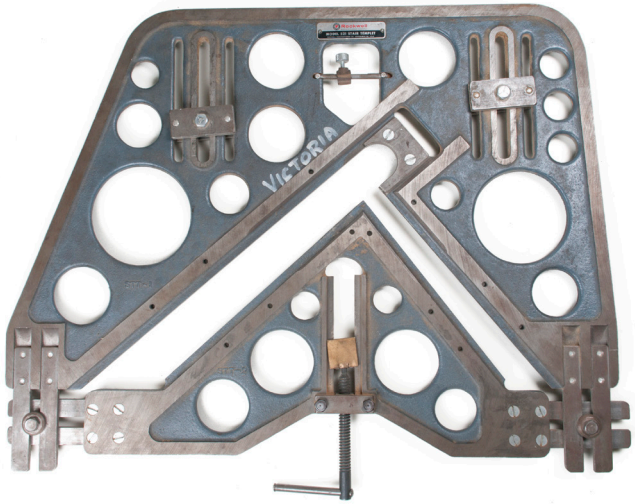


Figure 16 — Manufactured templates

Building the Stairs

Putting it all together, especially a stain-grade staircase, is one of the most advanced carpentry practices. By using good material, careful planning, and precise technique, the assembly of the pieces will go well.

It's common to install the stringers and then assemble the treads and risers from the bottom up. Especially with larger stairs, it's difficult to assemble them in a shop and get them into tight places or around corners.

Start by installing the stringers in the correct position. Often, the stairs are installed before other finishes. As mentioned previously, when laying out the stringer, make an allowance for the finished floor at the bottom.

At the landing at the top, hold the tape above the subfloor by the thickness of the finished floor (or better yet, use a piece of the flooring) and measure down the rise plus thickness of the tread. This puts the top of the stringer in the correct position so that when the treads and finish floor are installed, the last rise is the same as the rest. This layout can be made on the stringer support board. A full-scale drawing will help. This is the layout method of locating the stringer similar to the calculation method described in Figure 9.

If the interior wall finish is not installed, the stringers must be kept away from the wall so that the drywallers can slide the drywall between the stringer and the studs. A gap of ⅝" works well for ½" drywall. A ⅝" strip of plywood fastened to the bottom edge of the stringer before it's installed gives the correct gap and the drywallers something to measure to.

A common cause of squeaks in stairs is the stringers or treads rubbing against the wall. The stringers and treads must be either spaced so they are not in contact with the wall or fastened hard with adhesive and strong fasteners.

Once the stringers are set at the top, ensure they're level from side to side and along the length of several tread cuts. Fasten at the top and bottom. The bottom is best fastened with a "kicker" either notched into the stringer or in between the stringers.

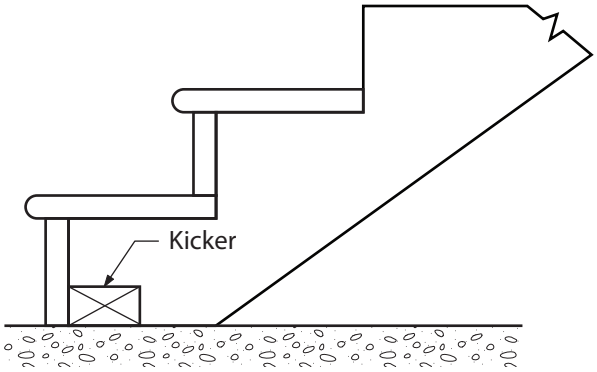


Figure 17 — Kicker at bottom of stringer

Starting at the bottom, install riser, tread, riser, tread, and so on. Glue blocks are installed at this time.

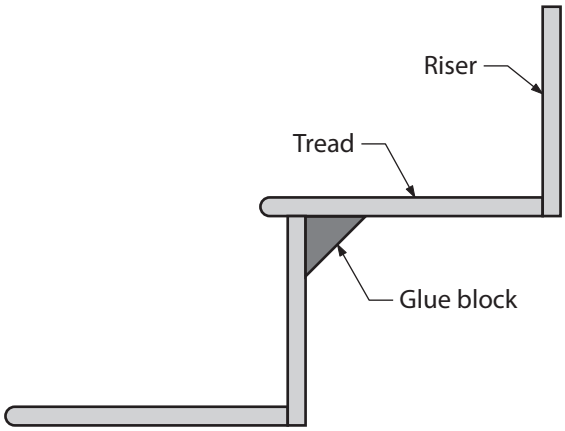


Figure 18 — Glue blocks

Points to consider during stair construction:

- spread construction adhesive thin and evenly
- hide fasteners in stain-grade work
- pre-drilling for nails or screws will prevent splitting, especially when using lumber stringers

Handrails and Guards

When designing and installing handrails and guards, safety is the primary concern. The handrails and guards must be very strong. They have to support a heavy person who is using the handrail or guard to keep them from falling. Guards protect the occupants from falling over an edge, and they must be able to resist heavy lateral forces.

Handrails must be attached directly to framing members. It's best to install solid blocking between the studs along the stairs at the height where the handrail brackets are attached. Brackets cannot be greater than 1.2 m apart.

Height

The height of handrails must be between 865 mm and 965 mm above the nosing line. Guards are set at 1070 mm above the landing surface. (Within a dwelling unit, guards can be 900 mm above the landing surface.) Refer to the *BC Building Code* for further information.

Graspable

The handrail must be continually graspable. The user must be able to grip the rail without having to stretch their hand. This means that 2×4s or 2×6s on flat are not allowed.



Now complete Self Test 4 and check your answers.

Self Test 4

1. Sketch the layout of the top end and the bottom end of a stair stringer with the following specifications:

   Unit rise = 172 mm
   Unit run = 258 mm
   Stringer size = 2×10
   Subfloor = ¾" plywood
   Finish floor = 25 mm ceramic tile at the bottom and ⅝" hardwood at the top
   Riser board = ¾" plywood
   Tread = 1½" lumber

Show all parts with their dimensions.

2. Define the term "graspable."

3. What two parts make up a semi-housed stringer?

4. How deep are the gains on a housed stringer?

5. Sketch the connection between the riser board and the stringer for a mitred stringer stair.

Answer Key

Self Test 1

1. a. the vertical distance from finish floor to finish floor
   b. the horizontal distance from the face of the bottom riser to the face of the top riser
   c. the vertical distance from one step to the next
   d. the horizontal distance from one step to the next
   e. an imaginary line drawn along the top edge of the nosings
   f. the horizontal distance from the edge of the nosing at the upper landing to the opening edge of the finish at the other end of the stairwell opening
2. A long "L" has a long flight and a short flight connected by a landing or winders. A wide "L" has two similar length flights at right angles to each other.
3. A landing is required when the total rise for the stairway is greater than 3.7 m.
4. Open stairwells have one or both sides open to a room or hallway. Closed stairwells are enclosed on both sides.
5. newel posts, handrail, balusters
6. a plain stringer laminated with a cut-out stringer

Self Test 2

1. i. the rise plus the run = 17" (440–450 mm)
   ii. twice the rise plus the run = 24" (610–635 mm)
   iii. the rise times the run = 72" (45 000–48 000)"
2. between 30 and 35°
3. utility rooms or rooms used by service workers familiar with the stairs
4. 7" and 10" (180 mm and 250 mm)

Self Test 3

1. 3150 mm ÷ 178 mm = 17.69 rises (round up to 18)
   3150 mm ÷ 18 = 175 mm
2. 430 mm – 183 mm = 247 mm
3. $\sqrt{1782 + 2552} = 310.981$ mm
4. 124" ÷ 7" = 17.71 (round up to 18)
   124" ÷ 18 = 6.888" = 6 7⁄16"
   24" – (2 × 6.888") = 10.224" = 10¼"

5. $$\frac{\text{FSO}}{1950+295}=\frac{245}{175}$$

   finished stairwell opening = 3143 mm
   rough stairwell opening = 3143 mm + 75 mm = 3218 mm

6. Headroom: 1950 mm ÷ 25.4 = 76.772"

   $$\frac{\text{FSO}}{76.772+10.125}=\frac{10}{7.25}$$

   finished stairwell opening = 119.858"
   rough stairwell opening = 119.858" + 3" = 122⅞"

7. from the finished floor level at the bottom of the stairs to the finished floor level at the top of the stairs

8. the sum of the ceiling finish, the joist depth, the subfloor thickness, and the finished floor thickness

Self Test 4

1. Your drawings may vary.

2. able to grip without having to stretch their hand

3. a plain stringer and a cut-out stringer

4. about ½"

5. Your drawings may vary.



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