**8** Read the passage below and answer the questions that follow.

Skiing is a popular recreational activity involving using skis to move across snow. Ski resorts in snowy mountain regions have ski lifts to transport skiers uphill. The chairs in ski lifts move on a continuously circulating wire rope. Fig. 8.1 shows a two-person chair that is commonly used in ski lifts.


**Fig. 8.1**

A particular ski lift uses 48 two-person chairs, evenly spaced along the wire rope, to transport skiers up a height of 300 m from the lower station to the upper station. Each chair has a mass of 80 kg and moves at a constant speed of 2.5 m s$^{-1}$. The distance between the two stations is 900 m as shown in Fig. 8.2.

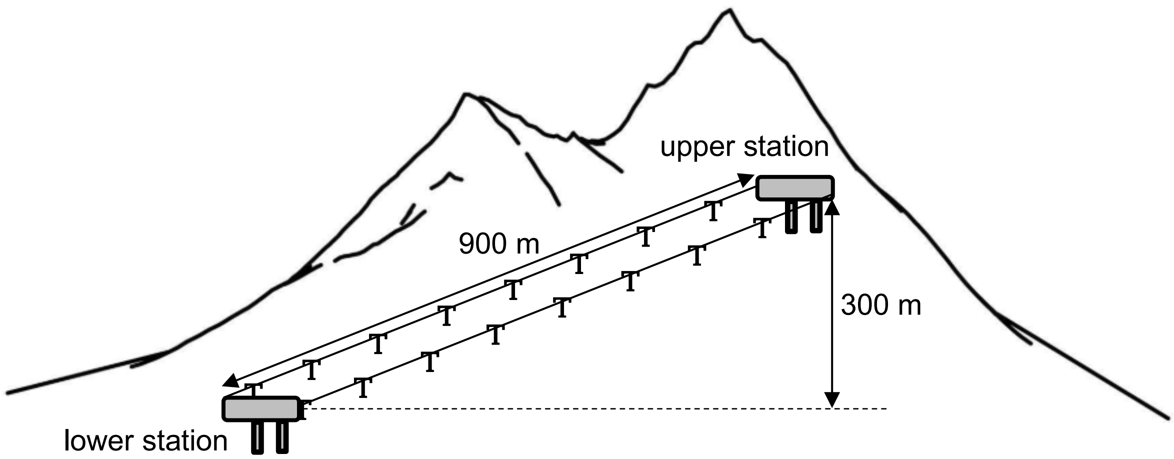


**Fig. 8.2** (not to scale)

Ski resorts offer ski lessons where skiers new to skiing can learn the two basic techniques: sliding and carving.

Sliding occurs when a skier moves down a slope in a straight path. This movement results from the interaction between two forces: the skier's weight and the friction between the skier and snow surface.

When skis press against snow, the increased pressure beneath the skis causes localised melting, creating a microscopic layer of water. This water layer significantly reduces friction, facilitating smoother ski movements. The type of snow plays a crucial role in this process, directly affecting both the skier's control and velocity.

The friction $f$ between the skis and the snow is related to the normal contact force $N$ acting on the skier due to the snow by the equation:

$$f = \mu N$$

where $\mu$ is the coefficient of friction.

**(a)** **(i)** On a crowded day, each chair carries two skiers uphill and no skiers downhill. The average mass of a skier is 75 kg.

Calculate the mechanical power required to drive the ski lift.

power = .................................... W [3]

**(ii)** Suggest a reason why your answer in **(a)(i)** is an underestimation.

..............................................................................................................................

.............................................................................................................................. [1]

**(b)** Table 8.1 shows the values of $\mu$ for various types of snow.

**Table 8.1**

| type of snow | $\mu$ |
|---|---|
| hard snow | 0.050 |
| medium snow | 0.080 |
| soft snow | 0.12 |
| wet / icy snow | 0.030 |

To maintain control and regulate speed while sliding, skiers will adjust their direction of motion relative to the downhill direction. The angle between the direction of motion and the downhill direction, known as the ski angle $\alpha$, is shown on Fig. 8.3.

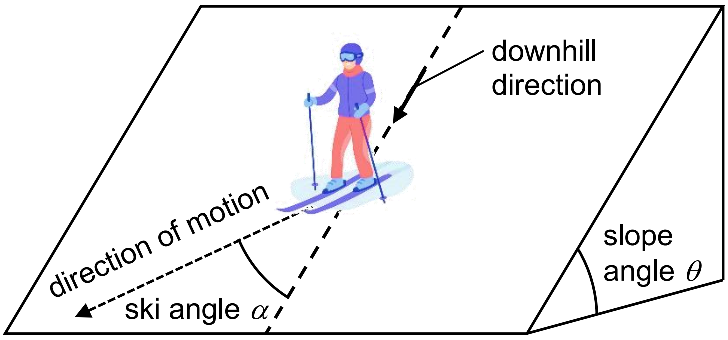


**Fig. 8.3**

Skiers typically ski across the face of the slope in a zig-zag pattern for optimal control. The acceleration $a_g$ in the direction of motion due to gravity varies depending on the slope angle $\theta$ and ski angle $\alpha$.

Fig. 8.4 shows the variation with $\alpha$ of $a_g$ at various values of $\theta$.

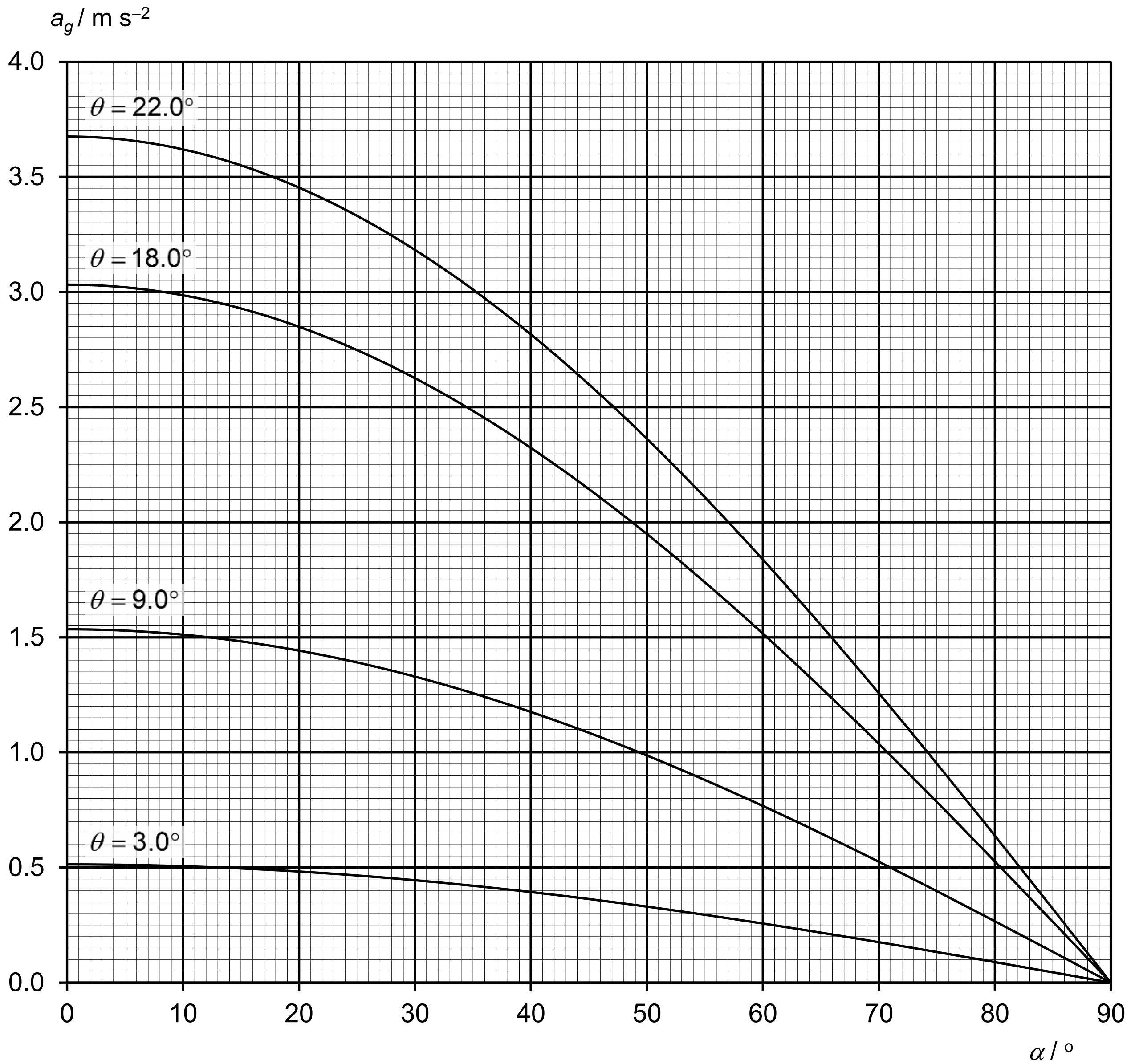


**Fig. 8.4**

A skier of mass 75 kg moves down the slope with slope angle $\theta = 9.0°$ and ski angle $\alpha = 0°$. The slope is covered with medium snow. Assume that air resistance is negligible.

**(i)** Show that the normal contact force $N$ acting on the skier is 730 N.

[1]

**(ii)** Determine the friction acting on the skier.

friction = .................................... N [2]

**(iii)** Determine the acceleration of the skier.

acceleration = .................................... m s$^{-2}$ [2]

**(c)** The skier moves down a new slope of slope angle $\theta = 22.0°$. The new slope is covered with soft snow. To maintain a constant speed, the skier adjusts his direction of motion to a ski angle $\alpha$.

**(i)** Determine the friction acting on the skier on the new slope.

friction = .................................... N [1]

**(ii)** Use Fig. 8.4 to determine the ski angle $\alpha$.

$\alpha$ = .................................... ° [3]

**(iii)** State how the skier can increase his speed.

.................................................................................................................................

................................................................................................................................. [1]

**(d)** Carving occurs when skiers tilt their skis to execute controlled turns as shown in Fig. 8.5.

**Fig. 8.5**

The angle between the skis and the snow surface known as the edge angle $\beta$ is shown in Fig. 8.6.

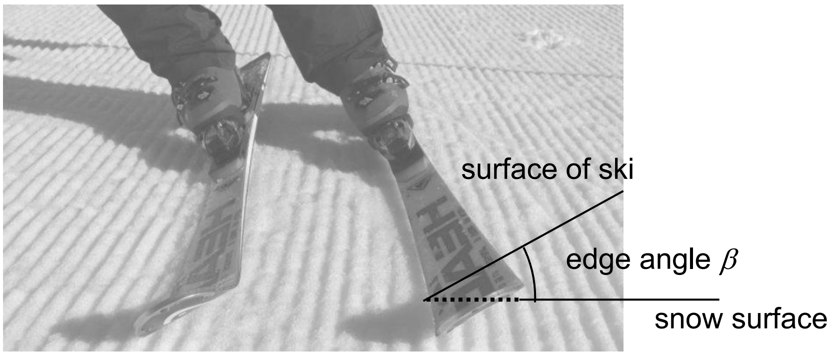


**Fig. 8.6**

 

Unlike sliding, carving involves following a circular arc in the plane of the slope. The edge angle $\beta$ determines the turn radius $r$.

Fig. 8.7 shows the variation with $\beta$ of $r$ for different types of snow when the skier moves at a speed of 5.0 m s$^{-1}$ and a ski angle $\alpha = 0°$.

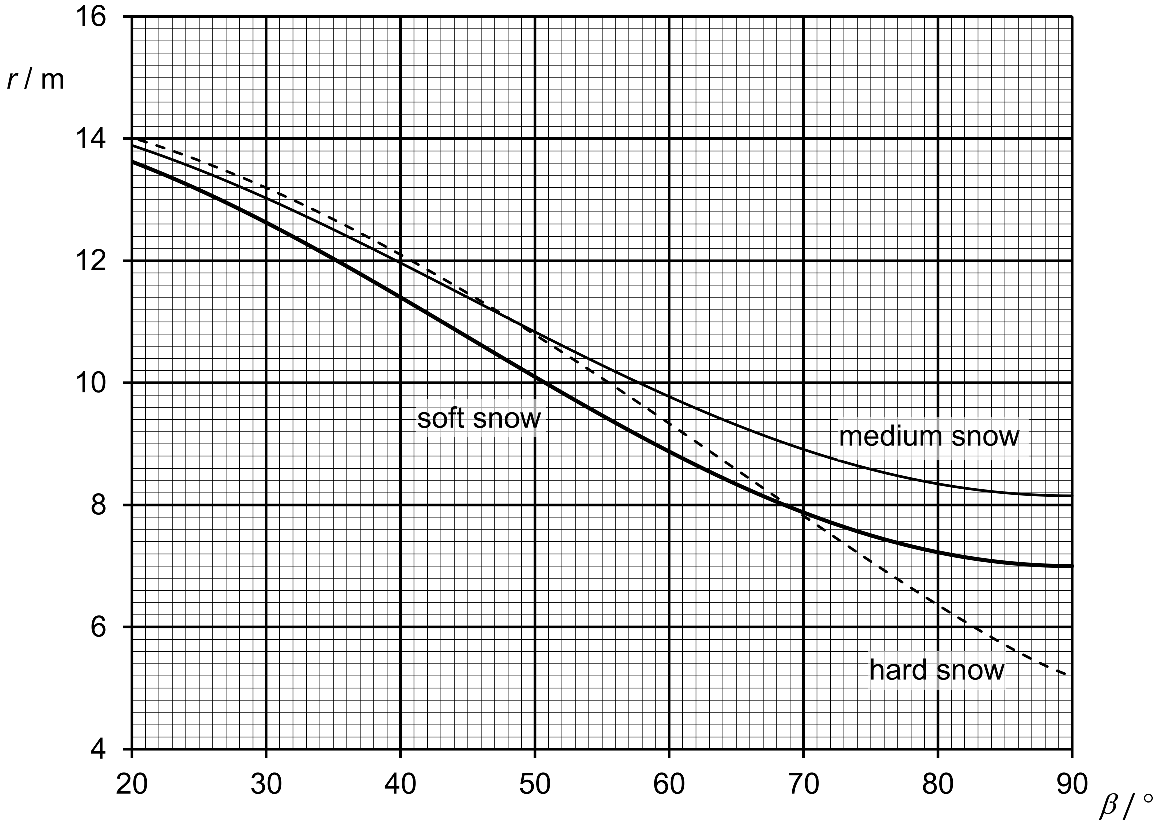


**Fig. 8.7**

**(i)** Determine the centripetal force acting on the skier for edge angle of 61° on hard snow.

centripetal force = .................................... N [3]

**(ii)** With reference to the forces acting on the skier and the stability of the skier, explain why a larger edge angle is required to generate a higher centripetal force.

[3]

[Total: 20]