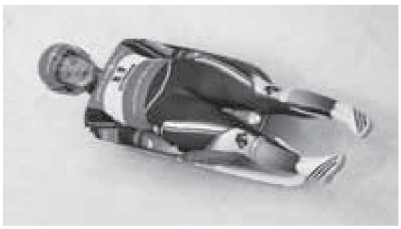
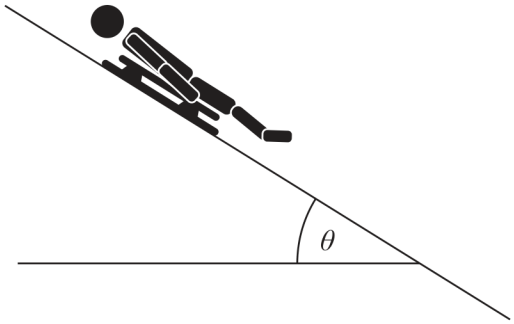
18 The luge is an event at the Winter Olympics. An athlete lies on a small sledge and races down an icy track, feet first.



Source: www.wtop.com

(a) An athlete accelerates down a straight section of the track as shown. The track is at an angle θ to the horizontal.



Draw a free-body force diagram for the sledge and athlete.
You should consider the relative sizes of the forces when drawing your diagram.

(4)

(b) The mass of the athlete is one of the factors that affects her time to complete the race.

(i) Explain why the mass of the athlete has little effect on the initial acceleration.

(3)

(ii) Explain, in terms of forces, why the athlete reaches a maximum velocity.

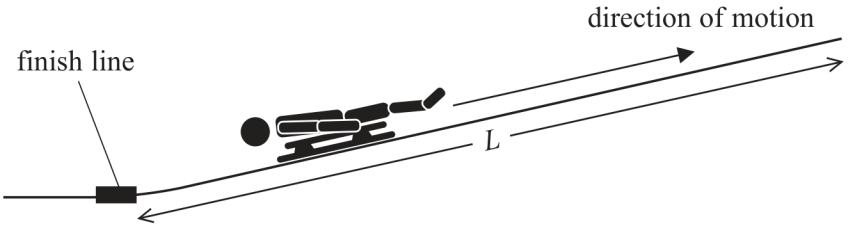
(3)

(iii) It is stated that the maximum speed is greater for athletes of greater mass.

Suggest why this is only correct up to a certain mass.

(2)

(c) After the finish line there is a straight, uphill section of track for the sledge to decelerate in. The maximum permitted gradient of this section is 20%.



(i) Show that a track with a gradient of 20% is at an angle to the horizontal of about 11°.

(1)

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(ii) An athlete reaches the finish line at a velocity of 33 m s^{-1}. She then applies a minimum braking force of 240 N as she moves along the uphill section of track to help her come to a stop.

Calculate the minimum uphill length of track *L* that should be available for braking. You should ignore all frictional forces other than those applied by the athlete.

mass of sledge and athlete = 95 kg

(5)

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L = ...

(Total for Question 18 = 18 marks)