3-39 A ski lift is operating steadily at 10 km/h. The power required to operate and also to accelerate this ski lift from rest to the operating speed are to be determined.

Assumptions **1** Air drag and friction are negligible. **2** The average mass of each loaded chair is 250 kg. **3** The mass of chairs is small relative to the mass of people, and thus the contribution of returning empty chairs to the motion is disregarded (this provides a safety factor).

Analysis The lift is 1000 m long and the chairs are spaced 20 m apart. Thus at any given time there are 1000/20 = 50 chairs being lifted. Considering that the mass of each chair is 250 kg, the load of the lift at any given time is

Load = (50 chairs)(250 kg/chair) = 12,500 kg

Neglecting the work done on the system by the returning empty chairs, the work needed to raise this mass by 200 m is

$$W_g = mg(z_2 - z_1) = (12{,}500\ \text{kg})(9.81\ \text{m/s}^2)(200\ \text{m})\left(\frac{1\ \text{kJ}}{1000\ \text{kg}\cdot\text{m}^2/\text{s}^2}\right) = 24{,}525\ \text{kJ}$$

At 10 km/h, it will take

$$\Delta t = \frac{\text{distance}}{\text{velocity}} = \frac{1\ \text{km}}{10\ \text{km/h}} = 0.1\ \text{h} = 360\ \text{s}$$

to do this work. Thus the power needed is

$$\dot{W}_g = \frac{W_g}{\Delta t} = \frac{24{,}525\ \text{kJ}}{360\ \text{s}} = \mathbf{68.1\ kW}$$

The velocity of the lift during steady operation, and the acceleration during start up are

$$V = (10\ \text{km/h})\left(\frac{1\ \text{m/s}}{3.6\ \text{km/h}}\right) = 2.778\ \text{m/s}$$

$$a = \frac{\Delta V}{\Delta t} = \frac{2.778\ \text{m/s - 0}}{5\ \text{s}} = 0.556\ \text{m/s}^2$$

During acceleration, the power needed is

$$\dot{W}_a = \frac{1}{2}m(V_2^2 - V_1^2)/\Delta t = \frac{1}{2}(12{,}500\ \text{kg})\left((2.778\ \text{m/s})^2 - 0\right)\left(\frac{1\ \text{kJ/kg}}{1000\ \text{m}^2/\text{s}^2}\right)/(5\ \text{s}) = 9.6\ \text{kW}$$

Assuming the power applied is constant, the acceleration will also be constant and the vertical distance traveled during acceleration will be

$$h = \frac{1}{2}at^2\sin\alpha = \frac{1}{2}at^2\frac{200\ \text{m}}{1000\ \text{m}} = \frac{1}{2}(0.556\ \text{m/s}^2)(5\ \text{s})^2(0.2) = 1.39\ \text{m}$$

and

$$\dot{W}_g = mg(z_2 - z_1)/\Delta t = (12{,}500\ \text{kg})(9.81\ \text{m/s}^2)(1.39\ \text{m})\left(\frac{1\ \text{kJ/kg}}{1000\ \text{kg}\cdot\text{m}^2/\text{s}^2}\right)/(5\ \text{s}) = 34.1\ \text{kW}$$

Thus,

$$\dot{W}_{\text{total}} = \dot{W}_a + \dot{W}_g = 9.6 + 34.1 = \mathbf{43.7\ kW}$$

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