

## The Science of cable-system elevator

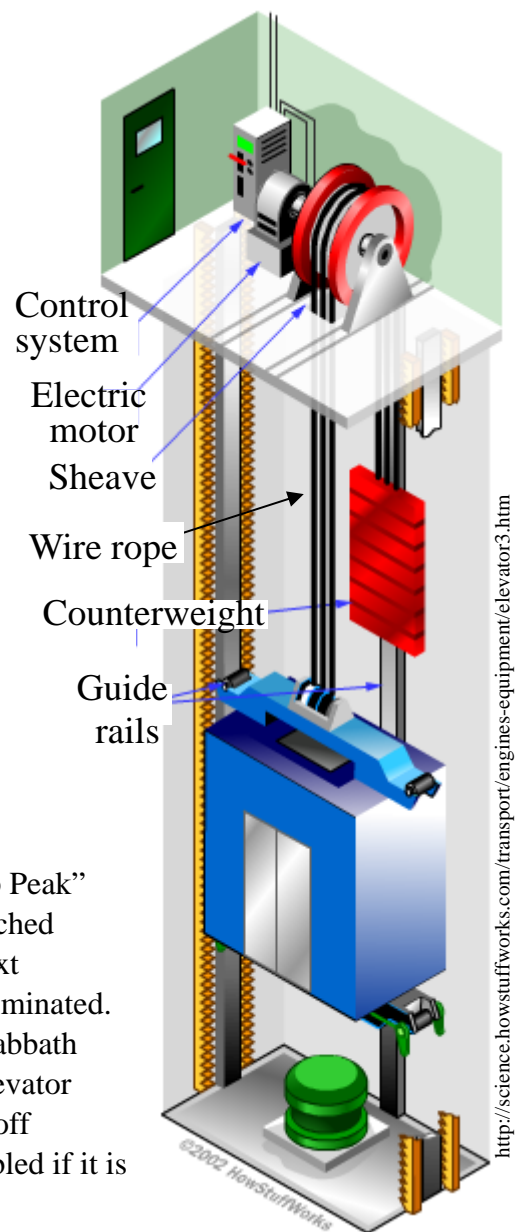
The schematic of an elevator system is shown on the right. The elevator car is moved by ropes looping around a motor-driven sheave. A sheave is just a pulley with grooves around the circumference. When the motor turns one way, the sheave raises the elevator; when the motor turns the other way, the sheave lowers the elevator. Conventionally the sheave, the motor and the control system are all housed in a machine room above the elevator shaft. Nowadays, machine-room-less elevators are gaining popularity.

The ropes that lift the car are also connected to a counterweight which weighs about 40% of the rated capacity of the elevator. The purpose of this balance is to conserve energy. With equal loads on each side of the sheave, it only takes a little bit of force to tip the balance one way or the other. Basically, the motor only has to overcome friction -- the weight on the other side does most of the work. Modern elevators may have regenerative systems to harvest the energy during braking and unbalanced movement of the car.

Both the elevator car and the counterweight ride on guide rails along the sides of the elevator shaft. The rails keep the car and counterweight from swaying back and forth, and they also work with the safety system to arrest the car in an emergency.

There are different elevator operating modes. For example, in the “Up Peak” mode, elevator cars in a group are recalled to the lobby and are dispatched one-by-one when they reach a pre-determined passenger load. The next elevator to be dispatched usually has a "this car leaving next" sign illuminated. An interesting mode is the “Sabbath mode” used in areas where the Sabbath prohibition against doing useful work is observed. In this mode, an elevator will stop automatically at every floor, allowing people to step on and off without having to press any buttons. Regenerative system is also disabled if it is normally used, shunting energy collected into a resistor network.

*(adapted from HowStuffWorks and The New World Encyclopedia)*



(1) Name two things that might happen if there is no guide rail. (5%)

- The car and counterweight may sway back and forth and may hit the wall or other components.
- There will be no emergency brake that can arrest the car in case the cable or motor malfunction.

(2) When do you think the “Up Peak” mode will most likely be used? (5%)

When there are a lot of people in the lobby waiting to go to different floors, such as in the morning when people come to work, or when they go back to work after lunch break.

- (3) Can you explain why the regenerative system interferes with Sabbath prohibitions? (5%)

Working is prohibited during the Sabbath. Regenerative system will do work (changing mechanical energy into chemical energy) and so is prohibited.

- (4) Tom is a diligent manager and is always the first one to arrive in early morning and the last one to leave in late evening. His office is on the tenth floor and the elevator has no regenerative system. As an environmentalist, Tom is willing to sacrifice riding the elevator once a day. Should you suggest him to give up riding up during arrival or riding down in the evening, please explain? (7%)

The counterweight is fixed and is normally chosen to balance the weight of the car and a certain number of people inside. Tom will probably ride alone (as he comes early and leaves late) and so the counterweight will be heavier than the car plus Tom. If Tom rides up, the motor need not do much work in excess of those limiting the speed of the car. If Tom rides down, the motor has to raise the heavier counterweight and do much more work. To save energy, Tom had better ride up.

(note, students may arrive at different answers if they further consider the energy involved when Tom may need to call the car and that after use the car will be called back to the ground floor. The key point is to show that they know the energy expended involve both the counterweight, the rider and the car and accessories)

- (5) In the world's tallest buildings (e.g. Burj Khalifa, The Shard), one cannot take a single elevator ride to go from ground to the top and has to change elevators at some intermediate level "Sky lobby", can you try to offer some explanations? (8%)

Since the weight of the cable increases with length and beyond a certain length, its weight will exceed its strength. This will put a upper limit of the allowable length of the cable.

(本題未限制作答語言，考生可自由選擇用中文或英文作答)