CAUTION
Change in PE is what is physically meaningful

What is physically important in any situation is the *change* in potential energy, ΔPE, because that is what is related to the work done, Eqs. 6–7; and it is ΔPE that can be measured. We can thus choose to measure y from any reference point that is convenient, but we must choose the reference point at the start and be consistent throughout a calculation. The *change* in potential energy between any two points does not depend on this choice.

Grav. PE depends on vertical *height*

An important result we discussed earlier (see Example 6–2 and Fig. 6–4) concerns the gravity force, which does work only in the vertical direction: the work done by gravity depends only on the vertical height h, and not on the path taken, whether it be purely vertical motion or, say, motion along an incline. Thus, from Eqs. 6–7 we see that changes in gravitational potential energy depend only on the change in vertical height and not on the path taken.

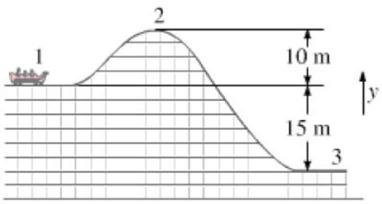

FIGURE 6–12 Example 6–7.

EXAMPLE 6–7 Potential energy changes for a roller coaster. A 1000-kg roller-coaster car moves from point 1, Fig. 6–12, to point 2 and then to point 3. (*a*) What is the gravitational potential energy at 2 and 3 relative to point 1? That is, take $y = 0$ at point 1. (*b*) What is the change in potential energy when the car goes from point 2 to point 3? (*c*) Repeat parts (*a*) and (*b*), but take the reference point ($y = 0$) to be at point 3.

APPROACH We are interested in the potential energy of the car–Earth system. We take upward as the positive y direction, and use the definition of gravitational potential energy to calculate PE.

SOLUTION (*a*) We measure heights from point 1, which means initially that the gravitational potential energy is zero. At point 2, where $y_2 = 10\text{ m}$,

$$\text{PE}_2 = mgy_2 = (1000\text{ kg})(9.8\text{ m/s}^2)(10\text{ m}) = 9.8 \times 10^4\text{ J}.$$

At point 3, $y_3 = -15\text{ m}$, since point 3 is below point 1. Therefore,

$$\text{PE}_3 = mgy_3 = (1000\text{ kg})(9.8\text{ m/s}^2)(-15\text{ m}) = -1.5 \times 10^5\text{ J}.$$

(*b*) In going from point 2 to point 3, the potential energy change $(\text{PE}_{\text{final}} - \text{PE}_{\text{initial}})$ is

$$\begin{aligned}\text{PE}_3 - \text{PE}_2 &= (-1.5 \times 10^5\text{ J}) - (9.8 \times 10^4\text{ J}) \\ &= -2.5 \times 10^5\text{ J}.\end{aligned}$$

The gravitational potential energy decreases by 2.5×10^5 J.
(*c*) In this instance, $y_1 = +15\text{ m}$ at point 1, so the potential energy initially (at point 1) is

$$\text{PE}_1 = (1000\text{ kg})(9.8\text{ m/s}^2)(15\text{ m}) = 1.5 \times 10^5\text{ J}.$$

At point 2, $y_2 = 25\text{ m}$, so the potential energy is

$$\text{PE}_2 = 2.5 \times 10^5\text{ J}.$$

At point 3, $y_3 = 0$, so the potential energy is zero. The change in potential energy going from point 2 to point 3 is

$$\text{PE}_3 - \text{PE}_2 = 0 - 2.5 \times 10^5\text{ J} = -2.5 \times 10^5\text{ J},$$

which is the same as in part (*b*).

PE defined in general

There are other kinds of potential energy besides gravitational. Each form of potential energy is associated with a particular force, and can be defined analogously to gravitational potential energy. In general, the *change in potential energy associated with a particular force is equal to the negative of the work done by that force if the object is moved from one point to a second point* (as in Eq. 6–7b for gravity). Alternatively, because of Newton's third law, we can define the *change in potential energy as the work required of an external force to move the object without acceleration between the two points*, as in Eq. 6–7a.