Chapter 6

Work and Energy

continued

Seat reassignments

• Gram	J14
• Weber	C22
• Hardecki	B5
• Pilallis	B18
• Murray	B19
• White	B20
• Ogden	C1
• Phan	C2
• Vites	C3
• Mccrate	C4

6.3 Gravitational Potential Energy

GRAVITATIONAL POTENTIAL ENERGY

Energy of mass m due to its position relative to the surface of the earth.
Position measured by the height h of mass relative to an arbitrary zero level:

$$\text{PE} = mgh$$

PE replaces Work by gravity in the Work-Energy Theorem

Work-Energy Theorem becomes Mechanical Energy Conservation:

$$\text{KE}_f + \text{PE}_f = \text{KE}_0 + \text{PE}_0$$
$$\text{E}_f = \text{E}_0$$

Initial total energy, $\text{E}_0 = \text{KE}_0 + \text{PE}_0$ doesn't change.
It is the same as final total energy, $\text{E}_f = \text{KE}_f + \text{PE}_f$.

Another way (equivalent) to look at Mechanical Energy Conservation:

$$\left(\text{KE}_f - \text{KE}_0\right) + \left(\text{PE}_f - \text{PE}_0\right) = 0$$
$$\Delta\text{KE} + \Delta\text{PE} = 0$$

Any increase (decrease) in KE is balanced by a decrease (increase) in PE.

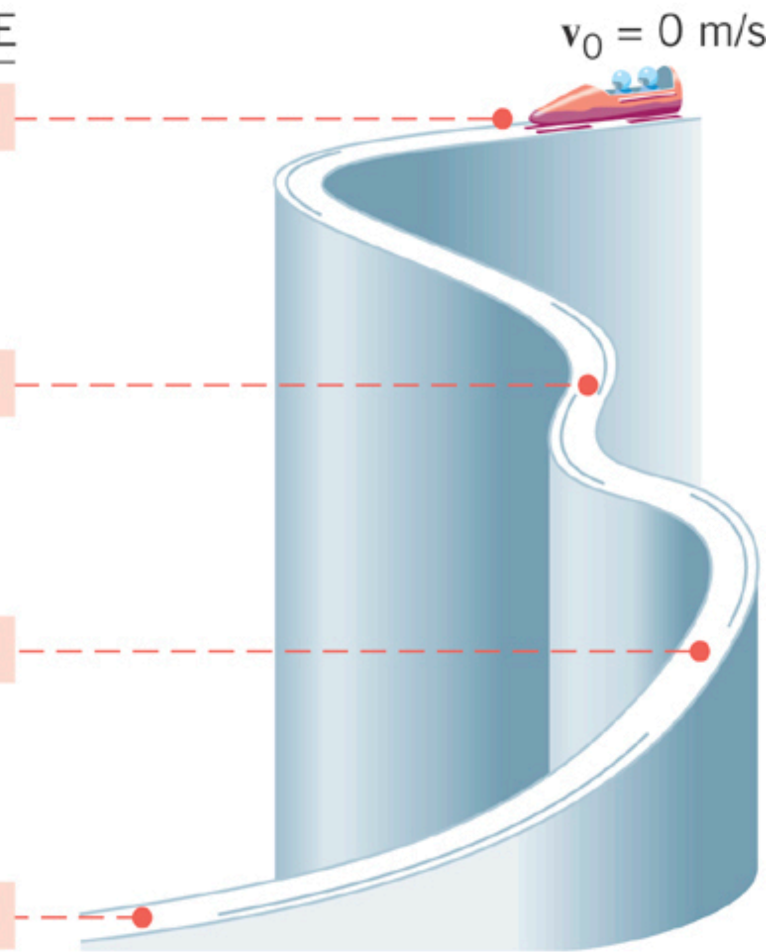
These are used if only Conservative Forces act on the mass.
(Gravity, Ideal Springs, Electric forces)

6.5 The Conservation of Mechanical Energy

Sliding without friction: only gravity does work.

Normal force of ice is always perpendicular to displacements.

KE	PE	E = KE + PE
0 J	600 000 J	600 000 J
200 000 J	400 000 J	600 000 J
400 000 J	200 000 J	600 000 J
600 000 J	0 J	600 000 J



6.4 Conservative Versus Nonconservative Forces

In many situations both conservative and non-conservative forces act simultaneously on an object, so the work done by the net external force can be written as

$$W_{\text{Net}} = W_{\text{C}} + W_{\text{NC}}$$

W_{C} = work by conservative force such as work by gravity W_{G}

But replacing W_{C} with $-(\text{PE}_{\text{f}} - \text{PE}_{0})$

Work-Energy Theorem becomes:

$$\text{KE}_{\text{f}} + \text{PE}_{\text{f}} = \text{KE}_{0} + \text{PE}_{0} + W_{\text{NC}}$$
$$\text{E}_{\text{f}} = \text{E}_{0} + W_{\text{NC}}$$

work by non-conservative forces will add or remove energy from the mass

$$\text{E}_{\text{f}} = \text{KE}_{\text{f}} + \text{PE}_{\text{f}} \neq \text{E}_{0} = \text{KE}_{0} + \text{PE}_{0}$$

Another (equivalent) way to think about it:

$$\left(\text{KE}_{\text{f}} - \text{KE}_{0}\right) + \left(\text{PE}_{\text{f}} - \text{PE}_{0}\right) = W_{\text{NC}}$$
$$\Delta\text{KE} + \Delta\text{PE} = W_{\text{NC}}$$

if non-conservative forces do work on the mass, energy changes will not sum to zero

But all you need is this:

$$\mathrm{KE_f} + \mathrm{PE_f} = \mathrm{KE_0} + \mathrm{PE_0} + W_{\mathrm{NC}}$$

non-conservative forces add or remove energy

$$\text{If } W_{\mathrm{NC}} \neq 0, \text{ then } \mathrm{E_f} \neq \mathrm{E_0}$$

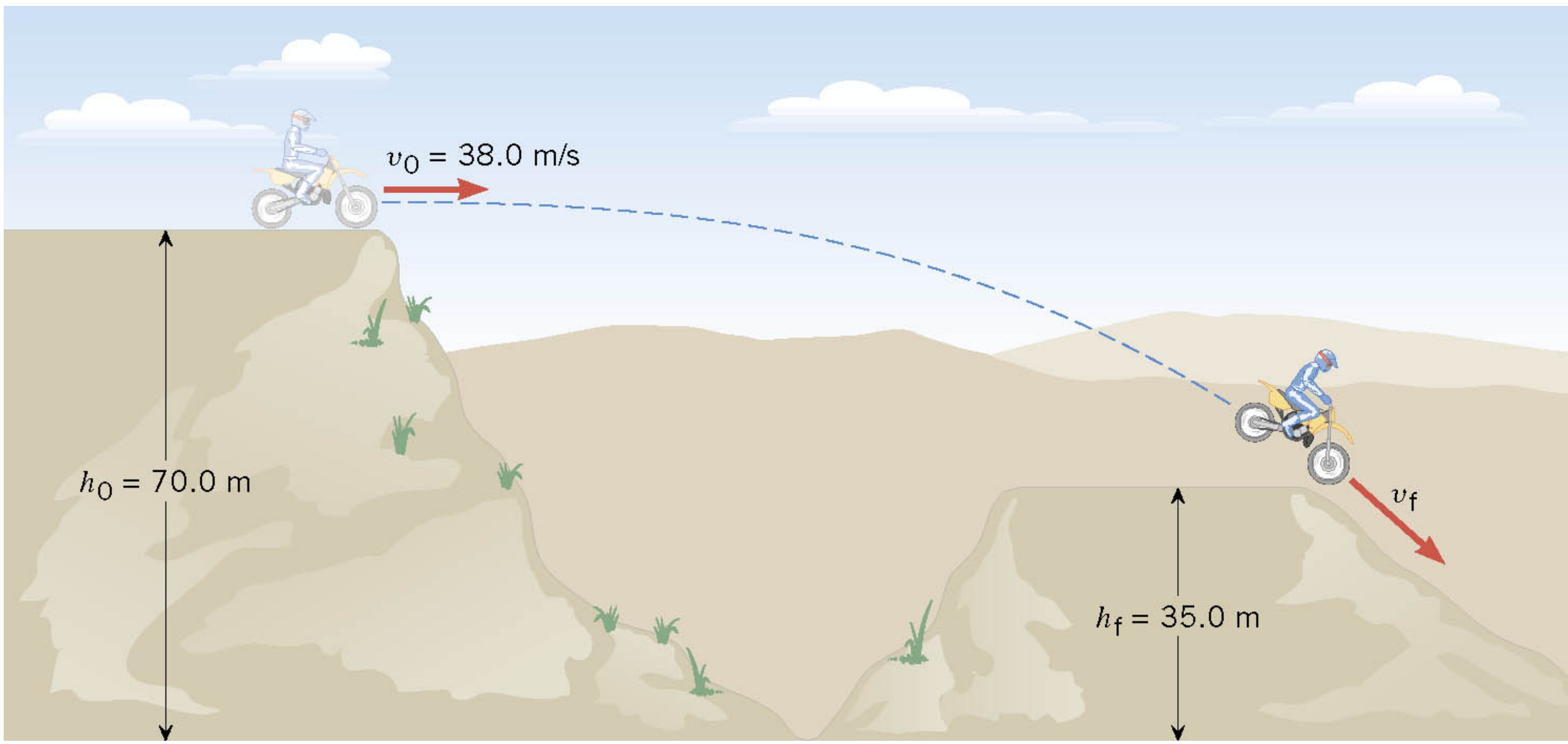
If the net work on a mass by non-conservative forces is zero, then its total energy does not change:

$$\text{If } W_{\mathrm{NC}} = 0, \text{ then } \mathrm{E_f} = \mathrm{E_0}$$

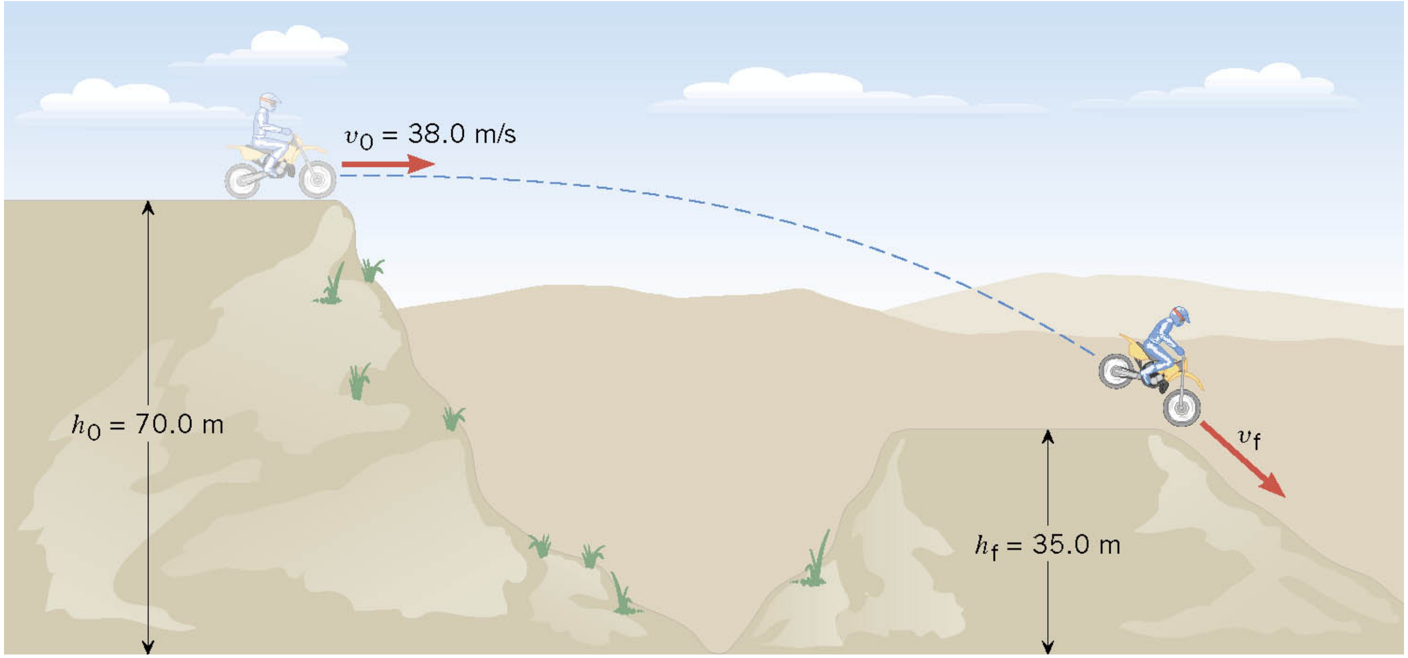
$$\mathrm{KE_f} + \mathrm{PE_f} = \mathrm{KE_0} + \mathrm{PE_0}$$

Example 8 A Daredevil Motorcyclist

A motorcyclist is trying to leap across the canyon by driving horizontally off a cliff 38.0 m/s. Ignoring air resistance, find the speed with which the cycle strikes the ground on the other side.



6.5 The Conservation of Mechanical Energy

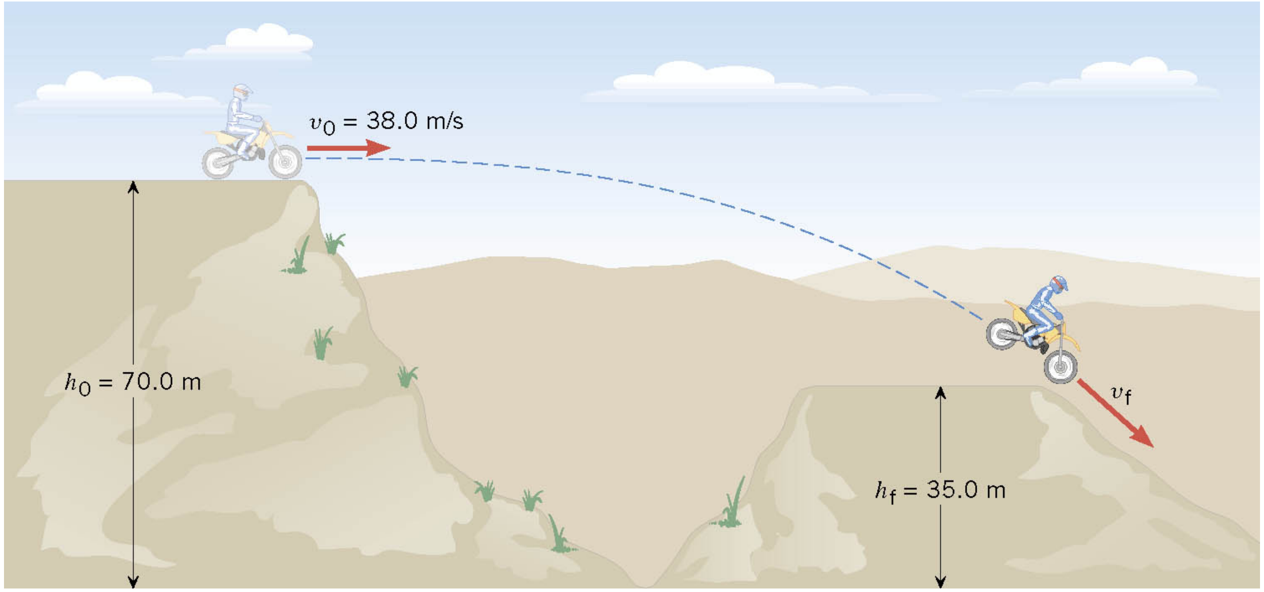


$$E_f = E_o$$

$$mgh_f + \tfrac{1}{2}mv_f^2 = mgh_0 + \tfrac{1}{2}mv_0^2$$

$$gh_f + \tfrac{1}{2}v_f^2 = gh_0 + \tfrac{1}{2}v_0^2$$

6.5 The Conservation of Mechanical Energy



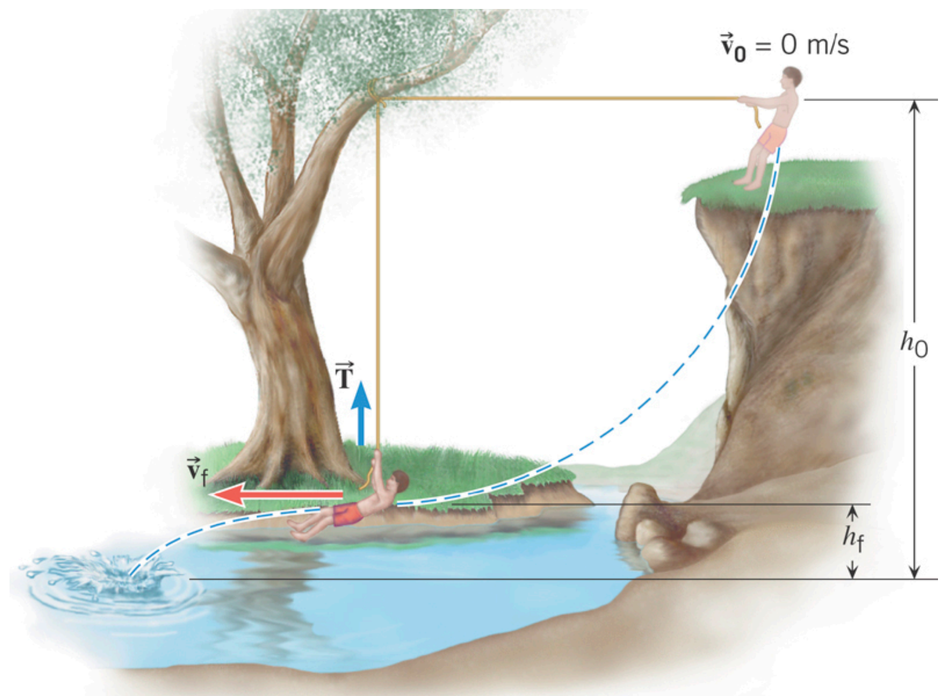
$$gh_f + \tfrac{1}{2}v_f^2 = gh_0 + \tfrac{1}{2}v_0^2$$

$$v_f = \sqrt{2g\left(h_0 - h_f\right) + v_0^2}$$

$$v_f = \sqrt{2\left(9.8\,\text{m/s}^2\right)\left(35.0\,\text{m}\right) + \left(38.0\,\text{m/s}\right)^2} = 46.2\,\text{m/s}$$

Conceptual Example 9 The Favorite Swimming Hole

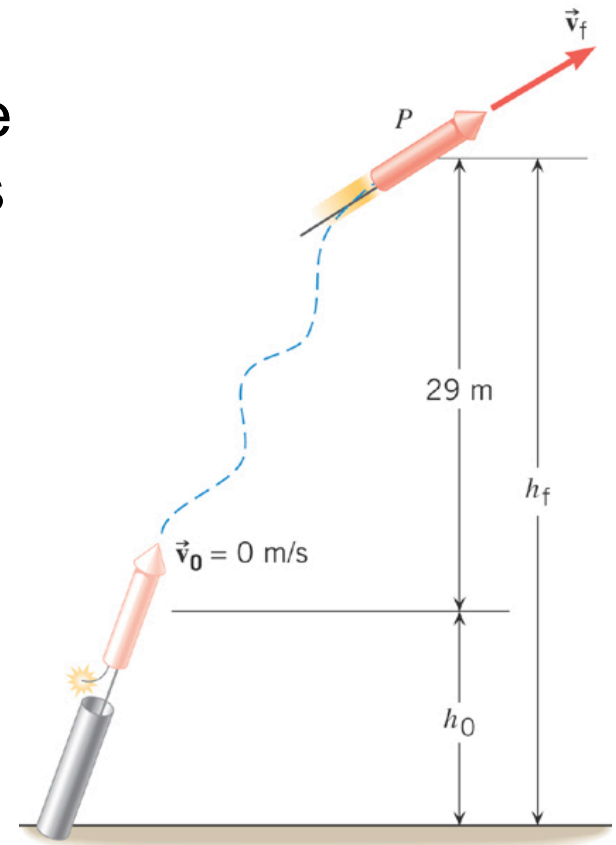
The person starts from rest, with the rope held in the horizontal position, swings downward, and then lets go of the rope, with no air resistance. Two forces act on him: gravity and the tension in the rope.



Note: tension in rope is always perpendicular to displacement, and so, does no work on the mass.

The principle of conservation of energy can be used to calculate his final speed.

Example 11 Fireworks



Assuming that the nonconservative force generated by the burning propellant does 425 J of work, what is the final speed of the rocket. Ignore air resistance.

$$E_f = E_0 + W_{NC}$$

$$W_{NC} = \left(mgh_f + \tfrac{1}{2}mv_f^2\right) - \left(mgh_0 + \tfrac{1}{2}mv_0^2\right)$$

$$= mg\left(h_f - h_0\right) + \tfrac{1}{2}mv_f^2 + 0$$

$$v_f^2 = 2W_{NC}/m - 2g\left(h_f - h_0\right)$$

$$= 2\left(425\text{ J}\right)/\left(0.20\text{ kg}\right) - 2\left(9.80\,\text{m/s}^2\right)\left(29.0\text{ m}\right)$$

$$v_f = 61\text{ m/s}$$

6.7 Power

DEFINITION OF AVERAGE POWER

Average power is the rate at which work is done, and it is obtained by dividing the work by the time required to perform the work.

$$\bar{P} = \frac{\text{Work}}{\text{Time}} = \frac{W}{t}$$

$$\text{joule/s} = \text{watt (W)}$$

Note: 1 horsepower = 745.7 watts

$$\bar{P} = \frac{\text{Change in energy}}{\text{Time}}$$

$$\bar{P} = \frac{W}{t} = \frac{Fs}{t} = F\left(\frac{s}{t}\right) = F\bar{v}$$

6.7 Power

Table 6.4 Human Metabolic Rates[a]

Activity	Rate (watts)
Running (15 km/h)	1340 W
Skiing	1050 W
Biking	530 W
Walking (5 km/h)	280 W
Sleeping	77 W

[a]For a young 70-kg male.

6.8 *Other Forms of Energy and the Conservation of Energy*

THE PRINCIPLE OF CONSERVATION OF ENERGY

Energy can neither be created not destroyed, but can only be converted from one form to another.

Heat energy is the kinetic or vibrational energy of molecules. The result of a non-conservative force is *often* to remove mechanical energy and transform it into heat.

Examples of heat generation: sliding friction, muscle forces.