Potential energy, mechanical energy and conservation of mechanical energy

Starter

1. To jump start Olivia's old car, of mass 700 kg, she needs to get it rolling at 1 m/s. She always parks it on a slight initial incline so that when she releases the hand brake, the car moves off at 0.2 m/s. The resistance to motion is 400 N. Given that the average person can push with a force of 120 N, calculate the minimum number of people needed to push the car from the bottom of the slight incline in order to get it started before the main road which is 50 m away.

Working: WD by driving force $-$ WD against resistance $=$ Change in KE

$$50D - 200 \times 50 = \frac{1}{2} \times 700 \times (1^2 - 0.5^2)$$

$$D = 406.72 \text{ N}$$

$$\text{Number of people needed } = \frac{406.72}{120} = 3.4$$

So 4 people are needed.

E.g. 1 A mountaineer of mass 65 kg scales a peak 3.2 km high. Calculate her gain in potential energy.

Working: GPE gain $= 65 \times 9.8 \times 3200 = 2038400$ J $= 2038$ kJ

N.B. This equals her work done against gravity.

E.g. 2 A stone of mass 0.8 kg is thrown vertically upwards with speed 10 m/s. By considering energy, calculate the initial kinetic energy and the height to which the stone will rise.

Working: Initial KE $= \frac{1}{2} \times 0.8 \times 10^2 = 40$

Gain in GPE $=$ Loss in KE: $\quad 0.8gh = 40$

$$h = \frac{50}{g} \approx 5.10$$

The initial kinetic energy is 40 J and the height to which the stone will rise is 5.10 m (3 s.f.)

E.g. 3 A particle of mass 2 kg falls freely from rest. Calculate the kinetic energy of the particle after it has descended 20 m and hence its velocity

Working: KE gained = GPE lost $= 2 \times 9.8 \times 20 = 392$

KE $= \frac{1}{2}mv^2$: $\quad \frac{1}{2} \times 2 \times v^2 = 392 \quad \Rightarrow \quad v = 14\sqrt{2} \approx 19.8$

The kinetic energy of the particle is 392 J and its velocity is 19.8 m/s (3 s.f.)

E.g. 4 A skier of mass 70 kg sets off with initial speed of 5 m/s down a hill of constant slope, inclined at 20° to the horizontal. The hill is 80 m long.

(a) Ignoring resistive forces forces, calculate the speed of the skier at the bottom of the slope.

(b) If instead the skier reaches the bottom with a speed of 6 m/s, calculate the magnitude of the constant resistive forces.

Working:

(a) Final KE = Initial KE + Initial GPE:

$$\frac{1}{2} \times 70 \times v^2 = \frac{1}{2} \times 70 \times 5^2 + 70 \times 9.8 \times 80 \sin 20$$

$$v \approx 23.7 \text{ J } 23.7 \text{ m/s}$$

The speed of the skier at the bottom of the slope is 23.7 m/s.

(b) Let the resistive forces be F.

WD against Friction + Final KE = Initial GPE + Initial KE

$$80F + \frac{1}{2} \times 70 \times 6^2 = \frac{1}{2} \times 70 \times 5^2 + 70 \times 9.8 \times 80 \sin 20$$

$$F \approx 229.8$$

The magnitude of the constant resistive forces is 230 N (3 s.f.)

Video: Gravitational potential energy

Work-energy principle EQ

Solutions to Starter and E.g.s

Exercise

p12 1C Qu 1-10