LESSON 4.1.3

Energy Changes

and Further Dynamics

Combine energy, momentum and force equations by choosing the right system and time interval. Each law answers a different question.

CHOOSE THE TOOL THAT MATCHES THE STAGE

ENERGY	Find speed from height, distance or work. Account for friction and other energy transfers.
MOMENTUM	Link velocities across a collision when the external impulse on the system is negligible.
FORCES	Find acceleration or contact forces at a particular instant. Resolve along the relevant direction.

WORK-ENERGY THEOREM: NET WORK CHANGES KINETIC ENERGY

$$W_{net} = \Delta K = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

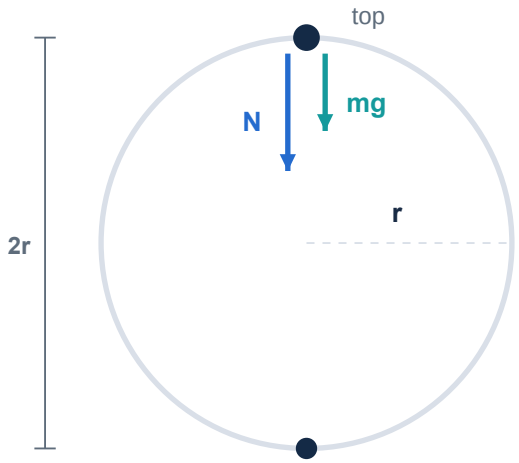
Constant force: $W = Fs\cos\theta$ **Instantaneous power: $P = Fv\cos\theta$**

θ is the angle between force and displacement (or velocity). Negative net work reduces kinetic energy. For a varying force, use the signed area under the force-component versus displacement graph.

Energy is a scalar. Momentum and force require directions.

1 Use energy first, then radial forces

Application: a small 0.200 kg body slides inside a smooth vertical circular track of radius 0.500 m.



bottom: speed 6.00 m/s

The height gain is 2r = 1.00 m. Treat the body as a particle, ignore air resistance and rolling, and use g = 9.81 m/s².

The normal reaction does no work on this fixed smooth track. Mechanical energy is conserved, but speed changes as gravitational potential energy changes.

At the top, both weight and normal reaction point towards the centre. N denotes the normal reaction, not an extra centripetal force.

1. FIND THE SPEED AT THE TOP

$$\frac{1}{2}mv_b^2 = \frac{1}{2}mv_t^2 + mg(2r)$$

$$v_t^2 = 6.00^2 - 4(9.81)(0.500) = 16.38\ m^2\ s^{-2}$$

Top speed = 4.05 m/s. Retain 16.38 for the force calculation.

2. FIND THE NORMAL REACTION AT THE TOP

$$N + mg = \frac{mv_t^2}{r} \qquad N = 4.59\ N$$

CHECK THAT CONTACT IS POSSIBLE

The track can push but cannot pull: N must be non-negative. At the limiting top speed, N = 0, giving $v^2 = gr$. Combining this with energy gives a minimum bottom speed of 4.95 m/s here.

The actual 6.00 m/s exceeds this limit; a negative N would invalidate the model.

2 Split a multi-stage problem

A 0.200 kg body moving at 6.00 m/s hits a stationary 0.400 kg body. They stick, then climb a ramp.

STAGE A: THE SHORT COLLISION

Choose both bodies as the system. Assume negligible external impulse during impact. The collision is perfectly inelastic: conserve momentum, not kinetic energy.

$$(0.200)(6.00) = (0.200 + 0.400)V$$

Common speed immediately after impact: V = 2.00 m/s

Kinetic energy falls from 3.60 J to 1.20 J. The 2.40 J decrease is transferred into internal energy, deformation and sound.

STAGE B: THE SMOOTH CLIMB

Ignore friction and air resistance. The normal reaction does no work. As the stuck bodies climb to rest, their post-collision kinetic energy becomes gravitational potential energy.

$$\frac{1}{2}MV^2 = Mgh \qquad h = \frac{2.00^2}{2 \times 9.81} = 0.204 \text{ m}$$

M = 0.600 kg. Momentum is not conserved during the climb.

IF THERE IS RESISTANCE, INCLUDE ITS WORK

$$K_i + U_i + W_{other} = K_f + U_f$$

U is potential energy. For constant opposing friction, W = -fs, where s is distance along the path. A rough ramp gives a smaller height. Do not count gravity both as work and as a potential-energy change.

Source: Pearson IAL Physics, Unit 1 pp. 16-17; Unit 4 p. 28. Linked applications.

Lesson numbering follows the Jimlaoshi course sequence. Examples are illustrative.