AL MUSTAQBAL UNIVERSITY

ENGINEERING TECHNICAL COLLEGE

DEPARTMENT OF BUILDING & CONSTRUCTION ENGINEERING

TECHNOLOGIES

ENGINEERING PHYSICS

FIRST CLASS

LECTURE NO. 6

ASST. LECTURER

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Kinetic Energy

The kinetic energy of a particle is one-half the product of the particle's mass m and the square of its speed v.

$$K = \frac{1}{2} m v^2$$

Kinetic energy is a scalar (it has magnitude but no direction); it is always a positive number; and it has SI units of $kg \cdot m^2/s^2$. This new combination of the basic SI units is known as the joule:

$$1 joule = 1J = 1 \frac{kg \cdot m^2}{s^2}$$

As we will see, the joule is also the unit of work W and potential energy U.

Work

When an object moves while a force is being exerted on it, then work is being done on the object by the force.

If an object moves through a displacement d while a constant force F is acting on it, the force does an amount of work equal to

$$W = F \cdot d = Fd \cos \phi$$

where ϕ is the angle between d and F.

Work is also a scalar and has units of $1\ N \cdot m$. But we can see that this is the same as the joule.

Work can be negative; this happens when the angle between force and displacement is larger than 90◦. It can also be zero; this happens if ϕ = 90◦.

If several different (constant) forces act on a mass while it moves though a displacement d, then we can talk about the net work done by the forces,

$$W_{net} = F_1 \cdot d + F_1 \cdot d + F_1 \cdot d + \cdots$$

$$W_{net} = (\sum F) \cdot d$$

$$W_{net} = F_{net} \cdot d$$

If the force which acts on the object is not constant while the object moves, then we must perform an integral (a sum) to find the work done. Suppose the object moves along a straight line (say, along the x axis, from x_i to x_f) while a force whose x component is $Fx(x)$ acts on it. (That is, we know the force Fx as a function of x.) Then the work done is

$$W = \int_{x_i}^{x_f} Fx(x)\, dx$$

The Work–Kinetic Energy Theorem

One can show that as a particle moves from point r_i to r_f , the change in kinetic energy of the object is equal to the net work done on it:

$$\Delta K = K_f - K_i = W_{net}$$

Power

In certain applications we are interested in the rate at which work is done by a force. If an amount of work W is done in a time Δt, then we say that the average power $\bar{P}$ due to the force is

$$\bar{\bar{P}} = \frac{W}{\Delta t}$$

In the limit in which both W and Δt is very small then we have the instantaneous power P, written as:

$$P_{ins} = \frac{dW}{dt}$$

The unit of power is the watt, defined by:

$$1watt = 1W = 1\frac{J}{s} = 1\frac{kg \cdot m^2}{s^3}$$

One can show that if a force F acts on a particle moving with velocity v then the instantaneous rate at which work is being done on the particle is

$$P = F \cdot v = Fv\cos\phi$$

where ϕ is the angle between the directions of F and v.

Potential Energy

For a conservative force it is possible to find a function of position called the potential energy, which we will write as $U(r)$, from which we can find the work done by the force. Suppose a particle moves from r_i to r_f . Then the work done on the particle by a conservative force is related to the corresponding potential energy function by

$$W_{r_i \to r_f} = -\Delta U = U(r_i) - U(r_f)$$

Example1: If a Saturn V rocket with an Apollo spacecraft attached has a combined mass of $2.9 \times 10^5 kg$ and is to reach a speed of $11.2\ \frac{km}{s}$ how much kinetic energy will it then have?

Solution:

$$v = \left(11.2\frac{km}{s}\right)\left(\frac{10^3 m}{1km}\right) = 1.12 \times 10^4 \frac{m}{s}$$

$$K = \frac{1}{2}mv^2 = \frac{1}{2}(2.9 \times 10^5 kg)\left(1.12 \times 10^4 \frac{m}{s}\right)^2 = 1.8 \times 10^{13} J$$

Example2: If an electron ($mass\ m = 9.11 \times 10^{-31} kg$) in copper near the lowest possible temperature has a kinetic energy of $6.7 \times 10^{-19} J$, what is the speed of the electron?

Solution:

$$K = \frac{1}{2} m v^2$$

$$6.7 \times 10^{-19} = \frac{1}{2}(9.11 \times 10^{-31}) v^2$$

$$v^2 = 1.47 \times 10^{12} \frac{m^2}{s^2}$$

$$v = 1.21 \times 10^6 \frac{m}{s}$$

Example2: What work is done by a force $F = (2xN)i + (3N)j$, with x in meters, that moves a particle from a position $r_i = (2m)i + (3m)j$ to a position

$r_f = -(4m)i - (3m)j$?

Solution:

We use the general definition of work (for a two–dimensional problem),

$$W = \int_{x_i}^{x_f} F_x(r) dx + \int_{y_i}^{y_f} F_y(r) dy$$

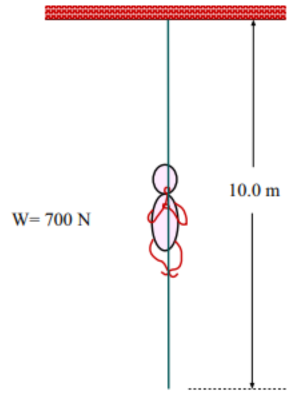
$$W = \int_{2m}^{-4m} 2x\ dx + \int_{3m}^{-3m} 3\ dy$$

$$= x^2 \Big|_{2\mathrm{m}}^{-4\mathrm{m}} + 3x \Big|_{3\mathrm{m}}^{-3\mathrm{m}}$$

$$= [(16) - (4)]\ J + [(-9) - (9)]\ J$$

$$= -6\ J$$

Example3: A $700N$ marine in basic training climbs a $10\ m$ vertical rope at a constant speed of $8\ s$ What is his power output?



Solution:

$$v = \frac{d}{t} = \frac{10\ m}{8\ s} = 1.25\frac{m}{s}$$

$$P = F \cdot v = (700N)\left(1.25\frac{m}{s}\right) = 875\ W$$