ЗМІСТ

LABORATORY EXERCISES

MATHEMATICAL APPENDIX

ПЕРЕДМОВА

Даний навчальний посібник авторів V.Boyko, P.Ilyin, O.Godlevska розроблений для підготовки студентів, що слухають лекції англійською мовою для агробіологічних спеціальностей. У цій розробці автори надають можливість студентам вивчити англомовну термінологію в галузі фізики. При цьому, для кращого розуміння матеріалу, надані методики виконання лабораторних робіт українською та англійською мовами. Також наведені англійською мовою найбільш важливі положення і закони з основних розділів загального курсу фізики: механіки, молекулярної фізики і термодинаміки, електрики та магнетизму, оптики, ядерної фізики.

Необхідність видання обумовлена потребою забезпечення літературою студентів спеціальностей «Екології та охорони навколишнього середовища», «Біотехнології та біоінженерії», «Захисту і карантину рослин», «Ветеринарної медицини» 1 курсу, що вивчають дисципліну англійською мовою та відсутністю подібної літератури в бібліотеці. Вивчення дисципліни «Фізика» англійською мовою дає можливість розширити мовну практику та ознайомитись з сучасною англійською науковою термінологією.

Topic 1 Kinematics of Particles

The list of issues to be considered

1. Particle, frame of reference, mechanical motion
2. Velocity and acceleration, normal acceleration and tangential acceleration
3. The motion of a particle on a circle. Angular motion parameters

1. Particle, frame of reference, mechanical motion

A *material point*, or *particle*, is a body whose size and shape are of consequence in the problem being considered. It is treated as a point, an object without extend.

A *system of particles* or bodies (material system) is the conception of a singled-out complex of particles or bodies which, in the general case, interact with one another, as well as with bodies not included in the system.

Mechanical motion is made up of the changes in the relative positions of bodies, or their parts, in space in the course of time.

A *perfectly rigid body,* or simply, rigid body, is one in which the distance between any two points remains constant in time. In other words, the size and shape of a rigid body do not change while it is in motion. Any rigid body can be conceived of as being broken down into a sufficiently large number of elementary parts in such a manner that the size of each part is much less than that of the whole body. Consequently, a rigid body is often regarded as a system of particles rigidly connected to one another.

A *frame of reference* is a real or conditionally rigid body with respect to which the motion of the body being studied is to be considered. Rigidly fixed in the frame of reference is some kind of coordinate system so that the position of each point of a moving body can be uniquely determined by the three coordinates of the point. Moreover, the frame of reference should be furnished with a "clock" by means of which the instants of time, corresponding to the various positions of the moving body in space, are uniquely determined (with accuracy to an arbitrary constant addend which depends on the time reference point). The right-handed Cartesian rectangular system of coordinates is most frequently employed in mechanics.

The motion of a particle is completely specified if a single-valued law is indicated for the variations in time t of its spatial coordinates. Thus in case of Cartesian coordinates

$$x = x(t); \qquad y = y(t); \qquad z = z(t).$$

These equations are equivalent to the single vector equation

$$\vec{r} = \vec{r}(t),$$

where $\vec{r}$ is the radius vector (position vector) connecting the origin of the coordinates with the moving particle $M(x, y, z)$:

$$\vec{r} = x\vec{i} + y\vec{j} + z\vec{k},$$

where $\vec{i}$, $\vec{j}$ and $\vec{k}$ are unit vectors which coincide with the positive directions of the corresponding axes OX, OY and OZ, and the vectors $x\vec{i}$, $y\vec{j}$ and $z\vec{k}$ are the components of vector $\vec{r}$ along these axes (Figure 1.1).

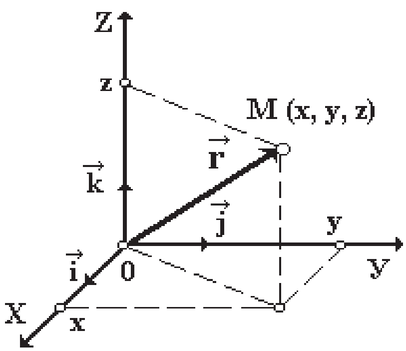

Figure 1.1 $\vec{r}$ is the radius vector (position vector) connecting the origin of the coordinates with the moving particle $M(x, y, z)$.

The *path* is the line described by a moving particle in space. The geometric shape of the path depends upon the selected frame of reference.

Depending upon the shape of the path, distinction is made between *rectilinear* and *curvilinear motion* of particles. The motion of a particle is said to be *plane* if all the parts of its path lie in a single plane. Usually, this plane is taken as the coordinate plane $z = 0$.

The position of the moving particle at any fixed instant of time $t = t_0$ is called its *initial position* and described by radius vector $\vec{r}_0$ (Figure 1.2). Owing to the arbitrary nature of the time reference point, it is usually assumed that $t_0 = 0$. At a later time t let a particle be at the position described by radius vector $\vec{r}_1$. The displacement vector describing the change in position of the particle is $\Delta\vec{r} = \vec{r}_1 - \vec{r}_0$.

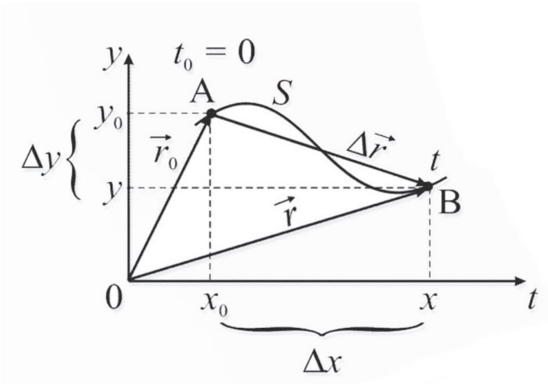

Figure 1.2 The displacement vector describing the change in position of the particle is $\Delta\vec{r} = \vec{r}_1 - \vec{r}_0$.

The *path length* s is the sum of the lengths of all the portions of the path passed through by the particle in the considered interval of time from t_0 to t.

The length of the path travelled by the point from the initial position is a scalar function of time: $s = s(t)$.

The SI unit for length s is the meter (abbreviated m).

The SI unit for time t is the second (abbreviated s).

2. Velocity and acceleration, normal acceleration and tangential acceleration

Velocity (or *instantaneous velocity)* is the vector quantity $\vec{\upsilon}$ equal to the first time derivative of the radius vector $\vec{r}$ of the moving particle. Thus

$$\vec{\upsilon} = \frac{d\vec{r}}{dt}.$$

The velocity is directed along the tangent to the path toward the motion of the particle (Figure 1.3).

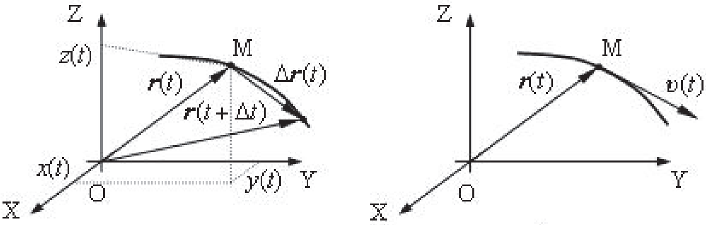

Figure 1.3 The velocity is directed along the tangent to the path toward the motion of the particle.

The velocity is numerically equal to the first derivative of the path length with respect to time:

$$\upsilon = \frac{ds}{dt}.$$

The magnitude υ of the velocity is sometimes called the *speed.* The projections υ_x, υ_y and υ_z of the velocity on the axes of Cartesian coordinates are equal to the first time derivatives of the corresponding coordinates of the moving point. Thus

$$\upsilon_x = \frac{dx}{dt}; \quad \upsilon_y = \frac{dy}{dt}; \quad \upsilon_z = \frac{dz}{dt}.$$

$$\upsilon = \sqrt{\upsilon_x^{\,2} + \upsilon_y^{\,2} + \upsilon_z^{\,2}},$$

$$\vec{\upsilon} = \upsilon_x\vec{i} + \upsilon_y\vec{j} + \upsilon_z\vec{k}.$$

The SI unit for velocity is meters per second or m/s, but many other units, such as km/h, mi/h (also written as mph), and cm/s, are in common use.

The motion of a particle is said to be *uniform* if the magnitude of its velocity is independent of time ($\upsilon = \text{const}$). The length of the path traveled by a uniformly moving particle is a linear function of time:

$$s = \upsilon(t - t_0) .$$

The *average velocity* of a particle in the interval of time from t to $t + \Delta t$ is denoted by the scalar $< \upsilon >$, which is equal to the ratio of the path length Δs traveled by the particle during this time interval, to the increment of time Δt. Thus

$$< \upsilon > = \frac{\Delta s}{\Delta t} = \frac{s(t + \Delta t) - s(t)}{\Delta t}$$

In the case of uniform motion $< \upsilon > = \upsilon$.

The *average velocity vector* $< \vec{\upsilon} >$, of a particle in the interval of time from t to $t + \Delta t$ is the ratio of the increment $\Delta \vec{r}$ of the radius vector of the particle, during the time interval, to the increment of time Δt :

$$< \vec{\upsilon} > = \frac{\Delta \vec{r}}{\Delta t} = \frac{\vec{r}(t + \Delta t) - \vec{r}(t)}{\Delta t} .$$

In uniform rectilinear motion of the particle, $< \vec{\upsilon} > = \vec{\upsilon}$.

Acceleration (or *instantaneous acceleration)* is the vector quantity a defined as the rate of change of the velocity of a moving particle. It is equal to the first time derivative of the velocity:

$$\vec{a} = \frac{d\vec{\upsilon}}{dt} \quad \text{or} \quad \vec{a} = \frac{d^2\vec{r}}{dt^2} .$$

The acceleration vector lies in the osculating plane passing through the principal normal and tangent to the path, and is directed toward the concavity of the path.

The projections a_x, a_y and a_z of the acceleration on the axes of a system of Cartesian coordinates equal

$$a_x = \frac{dv_x}{dt}, \quad a_y = \frac{dv_y}{dt}, \quad a_z = \frac{dv_z}{dt},$$

from which

$$a = \sqrt{a_x{}^2 + a_y{}^2 + a_z{}^2},$$

$$\vec{a} = a_x \vec{i} + a_y \vec{j} + a_z \vec{k}.$$

In an osculating plane, passing through an arbitrary point of the path, the acceleration vector $\vec{a}$ can be resolved into two mutually perpendicular components $\vec{a}_n$ and $\vec{a}_\tau$ (Figure 1.4). Thus

$$\vec{a} = \vec{a}_n + \vec{a}_\tau ,$$

and

$$a = \sqrt{a_n^2 + a_\tau^2} .$$

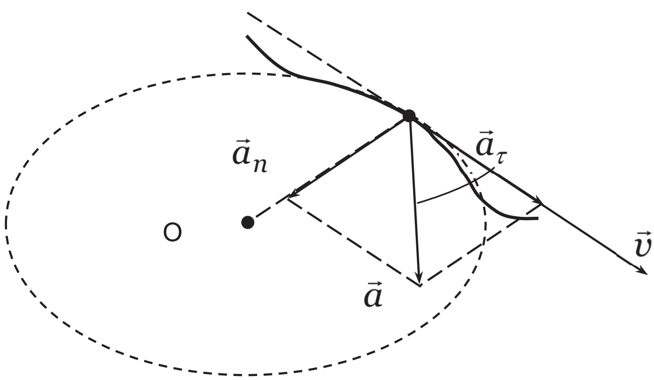

Figure 1.4 The acceleration vector $\vec{a}$ can be resolved into two mutually perpendicular components $\vec{a}_n$ and $\vec{a}_\tau$.

The component $\vec{a}_n$, directed along the principal normal to the path, is called the *normal acceleration.* The normal acceleration $\vec{a}_n$ is always directed toward the center of curvature of the path.

The component $\vec{a}_\tau$, directed along the tangent to the path, is called the *tangential acceleration.* Their magnitudes are

$$a_n = \frac{\upsilon^2}{R} \text{ and } a_\tau = \frac{d\upsilon}{dt} .$$

where υ is the speed, R is the radius of curvature of the path.

Because acceleration is velocity in m/s divided by time in s, the SI units for acceleration are m/s^2, meters per second squared or meters per second per second, which literally means by how many meters per second the velocity changes every second.

The motion of a particle is said to be *accelerated* if its speed increases in the course of time. It is said to be *decelerated* if its speed decreases in the course of time. With uniform motion, $a_\tau = 0$. In accelerated motion, vector $\vec{a}_\tau$ coincides in direction with the velocity vector $\vec{\upsilon}$ of the motion of the particle; in decelerated motion its direction is opposite to that of vector $\vec{\upsilon}$. The values $\vec{a}_\tau$ and $\vec{a}_n$ characterize the rates of change of the magnitude and direction, respectively, of the velocity of a moving particle. Motion in which the magnitude of the tangential acceleration is constant is called *uniformly accelerated curvilinear motion.*

The *average acceleration* in the time interval from t to $t + \Delta t$ is the vector $<\vec{a}>$, which is equal to the ratio of the increment $\Delta\vec{\upsilon}$ of the velocity $\vec{\upsilon}$ of the particle, during the time interval, to the increment of time Δt *:*

$$<\vec{a}> = \frac{\Delta\vec{\upsilon}}{\Delta t} = \frac{\vec{\upsilon}(t+\Delta t) - \vec{\upsilon}(t)}{\Delta t}.$$

3. The motion of a particle on a circle. Angular motion parameters

Upon rotation of a particle about a fixed point *O*, it describe circle. Its position can be completely determined by specifying the angle of rotation φ from some initial position.

The angular velocity of rotation of a particle is the vector $\vec{\omega}$, equal in magnitude to the first time derivative of the angle of rotation

$$\omega = \frac{d\varphi}{dt}$$

and directed along the axis of rotation in such a way that from its end the rotation of the body is seen as occurring counterclockwise (Figure 1.5).

The direction of vector to coincides with that of the translatory motion of a gimlet or corkscrew rotating together with the body.

The *linear velocity* $\vec{\upsilon}$ of a particle is determined by the *Euler formula* :

$$\vec{\upsilon} = [\vec{\omega}\,\vec{r}].$$

where $\vec{r}$ is a radius vector drawn to the particle from the point O.

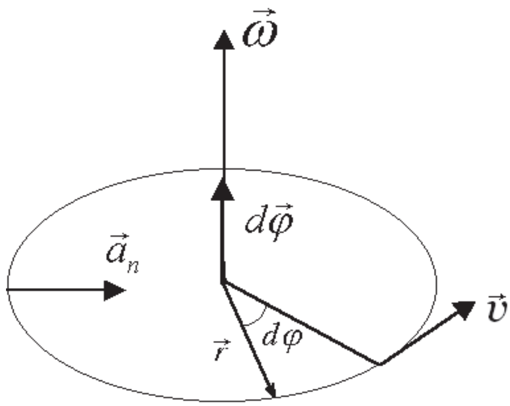

Figure 1.5 The direction of vector $\vec{\omega}$ to coincides with that of the translatory motion of a gimlet or corkscrew rotating together with the body.

The *period of revolution* T of a particle is the time required for it to rotate about a fixed point *O* through the angle $\varphi = 2\pi$.

The angular acceleration is the vector $\vec{\beta}$, equal to the first time derivative of the angular velocity:

$$\vec{\beta} = \frac{d\vec{\omega}}{dt} .$$

The angular acceleration indicates the rate of change of the angular velocity vector with time. Upon rotation about a fixed axis, the direction of vector to remains unchanged and

$$\beta = \frac{d\omega}{dt} .$$

Vector $\vec{\beta}$ coincides in direction with $\vec{\omega}$ in the case of accelerated rotation ($\frac{d\omega}{dt} > 0$) and is opposite in direction in the case of decelerated rotation ($\frac{d\omega}{dt} < 0$).

The *linear* (*tangential) acceleration* of an arbitrary point M of a rotating body is equal to

$$a_\tau = \beta r .$$

The *normal acceleration* equal to

$$a_n = \omega^2 r .$$