Useful Physics Formulae

Stefan Countryman

November 6, 2017

Contents

1 Kinematics

There are only two equations you should memorize from kinematics.

1.1 Position

$$x = \frac{1}{2}at^2 + v_0t + x_0$$

1.2 Speed

$$v = at + v_0$$

2 Energy

2.1 Conservation of energy

Explanation: The final total energy of a system (the sum of all kinetic (K_f) and potential (U_f) energy terms) will be exactly the same as the initial total energy plus the work (W) done on the system by an external force.

$$\Sigma U_i + \Sigma K_i + W = \Sigma U_f + \Sigma K_f$$

2.2 Work done by a force

Explanation: If a force acts on an object while the object is moving, then the work done on the object is just the product of the force F, the total distance traveled d, and the cosine of the angle between the displacement and the force (θ). This is true even if the motion was not in a straight line; d is just the total change in position.

$$W = Fdcos(\theta)$$

2.3 Relationship between work and potential energy

Explanation: The work done by a conservative force is simply the change in **potential energy**, albeit with a negative sign in front (since the energy *lost* by the potential is *gained* by the system, or vice versa).

$$W = -\Delta U = -(U_f - U_i)$$

3 Springs

3.1 Force (Hooke's Law)

Explanation: The force due to a spring is proportional to the spring constant k and the displacement from equilibrium x. The negative sign comes from the fact that springs always want to return to their equilibrium length when disturbed; a positive displacement x will therefore result in a force F_s in the negative direction. A stiffer spring will have a larger spring constant k.

$$F_s = -kx$$

3.2 Potential Energy

Explanation: Again, k is the spring constant and x is the displacement from equilibrium.

$$U_s = kx^2$$

4 Momentum

4.1 Center of Mass

4.2 Definition of Impulse

4.3 Impulse in terms of Force

4.4 Definition of Momentum

4.5 Conservation of Momentum

4.6 Elastic collision equations

5 Rotation

Notice that the *translational* variables for position, speed, and acceleration are all just R times the corresponding *rotational* variables: angle (θ), speed (ω), and angular acceleration (α).

5.1 Position

$$\Delta x = R\Delta\theta$$

5.2 Speed

$$v = R\omega$$

5.3 Acceleration

$$a = R\alpha$$

5.4 Torque vs. Force

$$\tau = Frsin\theta$$

5.5 Moment of Inertia

Moment of Inertia I is like mass m in translational motion. There are different formulas for different shapes, but otherwise it behaves just like the mass: the bigger it is, the greater the force/torque you need to accelerate the object.

5.6 Angular Momentum

Angular momentum L is like momentum p.

5.7 Centripetal Acceleration

$$a_{centripetal} = \frac{v^2}{r}$$

5.8 Parallel Axis Theorem

$$I = I_{CM} + Md^2$$

6 Gravitation

It's just conservation of energy, summing forces, and circular motion plus a new equation for *force* and a new equation for *potential energy*.

6.1 Force (Newton)

$$F_g = \frac{Gm_1m_2}{r^2}$$

6.2 Potential Energy

$$U_g = -\frac{Gm_1m_2}{r}$$

6.3 Gravitational Acceleration (g vs. G)

This is just the acceleration due to gravity; we have been using the value at Earth's surface, $g = 9.8m/s$. In the below equation, M is the mass of the large object (like the earth) and r is the distance to the center of the large object. Notice that this is just the same as the force due to gravity, F_g, but without the smaller mass.

$$g = \frac{GM}{r^2}$$

6.4 Kepler's Laws

Don't worry about these for now. They are less important. We can discuss them a bit tomorrow.