PHYSICS 534

ANSWERS

EXE[illegible]-36 **Kinetic Energy Part-1 /3**

Werner Heisenberg was awarded the Nobel prize for physics in 1932 for his work in Quantum Mechanics.

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Kinetic energy is energy of motion. The faster an object is moving, the more kinetic energy it possesses. This is because the energy required to increase the velocity of an object (the work done) goes to the object in the form of kinetic energy.

The following formula is used to calculate the kinetic energy of an object:

$E_K = ½ mv^2$ where E_K is the kinetic energy in joules (J)
m is the mass of the object in kilograms (kg)
v is the velocity of the object in m/s

Note that the velocity is the velocity at any time (or instance) and is known as the ***instantaneous*** velocity.

When an object is accelerated, work is being done. When an object is decelerated, the kinetic energy is has must be dissipated (reduced to zero). When stopping a car, work is done by the brakes (friction) to dissipate the energy (the E_K of the car is transformed into heat and sound).

The fact that the kinetic energy of an object is proportional to the square of its speed has important consequences. Doubling the speed of a car, for example, quadruples its kinetic energy (2^2). If the velocity increases ten times, the E_K becomes 100 times greater (10^2). This explains the highway slogan reminding us that "***speed kills***".

- Remember: To find the work done (energy used) to accelerate an object, find the change in the object's kinetic energy as shown below:

$$\Delta E_K = E_{K\,(final)} - E_{K\,(initial)} = ½ mv_f^2 - ½ mv_i^2$$

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1. Is kinetic energy a scalar or a vector quantity?

Scalar

2. In terms of basic units (L, M and T), what are the dimensions of kinetic energy?

$$E_K = \frac{1}{2}mv^2 = mv^2 = M(L/T)^2 = ML^2T^{-2}$$

3. Where does the energy used to accelerate an object go?

To the object in the form of kinetic energy.

4. A 20 kg object has a velocity of 10 m/s. What is its kinetic energy? [1000 J]

$$E_K = \frac{1}{2}mv^2 = \frac{mv^2}{2} = \frac{(20\ kg)(10\ m/s)^2}{2} = 1000\ kg \cdot m^2/s^2 = 1000\ J$$

➢ ***Note***: **To keep the math as simple as possible, use a value of 10 m/s² (rather than 9.8 m/s²) for the acceleration due to gravity.**

5. An object having a mass of 5 kg is traveling at 6 m/s. It accelerates to a velocity of 12 m/s. How much work was done to accelerate the object? [270 J]

$$\Delta K_E = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = \frac{1}{2}(5\text{ kg})(12\text{ m/s})^2 - \frac{1}{2}(5\text{ kg})(6\text{ m/s})^2$$

$$= 360\text{ J} - 90\text{ J} = 270\text{ J}$$

6. A 20 g bullet has a velocity of 25 000 cm/s. Calculate its kinetic energy. [625 J]

$$E_K = \frac{1}{2}mv^2 = \frac{1}{2}(0.02\text{ kg})(250\text{ m/s})^2 = 625\text{ J}$$

7. An object having a mass of 5 kg is dropped from a height of 20 m. How much kinetic energy does it have at the instant it strikes the ground? [1 000 J]

Calculation of final velocity:

$$2as = v_f^2 - v_i^2$$
$$v_f^2 = 2as + v_i^2$$
$$v_f^2 = 2(10\text{ m/s}^2)(20\text{ m}) + 0$$
$$v_f^2 = 400\text{ m}^2/\text{s}^2$$
$$v_f = 20\text{ m/s}$$

Calculation of Kinetic Energy:

$$E_K = \frac{1}{2}mv^2$$
$$= \frac{1}{2}(5\text{ kg})(20\text{ m/s})^2$$
$$= 1000\text{ kg}\cdot\text{m}^2/\text{s}^2 = 1000\text{ J}$$

8. A 2 kg object is thrown in the air with such a velocity that its kinetic energy is 25 J. How high does the object rise? [1.25 m]

$$E_K = \frac{1}{2}mv^2$$
$$v^2 = \frac{2E_K}{m}$$
$$= \frac{2(25\text{ J})}{2\text{ kg}}$$
$$= 25\text{ m}^2/\text{s}^2$$
$$v = 5\text{ m/s}$$

$$a = \frac{\Delta v}{t}$$
$$= \frac{v_f - v_i}{t}$$
$$\therefore\ t = \frac{v_f - v_i}{a}$$
$$= \frac{0 - 5\text{ m/s}}{-10\text{ m/s}^2}$$
$$= 0.5\text{ s}$$

$$s = v_i t + \frac{1}{2}at^2$$
$$= (5\text{ m/s})(0.5\text{s}) + \frac{1}{2}(-10\text{ m/s}^2)(0.5\text{ s})^2$$
$$= 2.5\text{ m} - 1.25\text{ m}$$
$$= 1.25\text{ m}$$

9. Object-A, of mass m, is moving with a velocity v. Object-B, of mass 2m, is moving with a velocity 2v. What is the value of the following ratio?

$$\frac{E_K \text{ of object} - A}{E_K \text{ of object} - B}$$

$$\frac{E_{K\text{ of A}}}{E_{K\text{ of B}}} = \frac{\frac{1}{2}m_A v_A^2}{\frac{1}{2}m_B v_B^2} = \frac{m_A v_A^2}{m_B v_B^2} = \frac{mv^2}{2m(2v)^2} = \frac{mv^2}{2m(4\,v^2)} = \frac{mv^2}{8mv^2} = \frac{1}{8}$$

10. An 80 kg mass, moving with a velocity of 10 m/s, has its kinetic energy increased by 1.6 x 10^3 J. What is the value of the final E_K of the mass? [5 600 J]

$$E_{K\text{ Total}} = E_K + E_{K\text{ Increase}} = \frac{1}{2}mv^2 + 1.6\times10^3\text{ J}$$

$$= \frac{1}{2}(80\text{ kg})(10\text{ m/s})^2 + 1.6\times10^3\text{ J}$$

$$= 4\times10^3\text{ J} + 1.6\times10^3\text{ J}$$

$$= 5.6\times10^3\text{ J}$$

11. A 1000 kg car is traveling at 10 m/s. If the brakes stop the car in 7 seconds, calculate the initial kinetic energy of the car. [50 000 J]

$$E_K = \frac{1}{2}mv^2 = \frac{1}{2}(1000\text{ kg})(10\text{ m/s})^2 = (500\text{ kg})(100\text{ m}^2/\text{s}^2) = 50\,000\text{ J}$$

12. How much energy is required to get a 40 kg cart from rest to a velocity of 25 m/s? [12 500 J]

$$E_K = \frac{1}{2}mv^2 = \frac{1}{2}(40\ \text{kg})(25\ \text{m/s}^2) = 12\,500\ \text{J}$$

13. How much energy is required to increase the velocity of a 40 kg cart from 10 m/s to 30 m/s? [16 000 J]

$$\Delta E_K = E_{K\ \text{Final}} - E_{K\ \text{Initial}}$$

$$= \frac{1}{2}(40\ \text{kg})(30\ \text{m/s})^2 - \frac{1}{2}(40\ \text{kg})(10\ \text{m/s})^2$$

$$= 18000\ \text{J} - 2000\ \text{J} = 16000\ \text{J}$$

14. Assuming that the coefficient of friction between the tires and the road is 0.70, calculate the distance required to stop a 1500 kg car traveling at: a) 25 km/h b) 50 km/h

a) 25 km/h
[3.4 m]

Calculate frictional force:

$$f = kN = (0.70)(1500\ \text{kg})(10\ \text{m/s}^2) = 10\,500\ \text{N}$$

Calculate the kinetic energy:

$$E_K = \frac{1}{2}mv^2 = \frac{1}{2}(1500\ \text{kg})(25\ \text{km/h} \times \frac{1000\ \text{m}}{3600\ \text{s}})^2 = 35\,707.5\ \text{J}$$

Calculate distance: (Use W = Fs)

$$W = Fs$$

$$s = \frac{W}{F} = \frac{35\,707.5\ \text{J}}{10\,500\ \text{N}} = 3.4\ \text{m}$$

b) 50 km/h
[13.8 m]

Calculate the kinetic energy:

$$E_K = \frac{1}{2}mv^2 = \frac{1}{2}(1500\ \text{kg})(50\ \text{km/h} \times \frac{1000\ \text{m}}{3600\ \text{s}})^2 = 144\,907.5\ \text{J}$$

Calculate distance: (Use W = Fs)

$$W = Fs$$

$$s = \frac{W}{F} = \frac{144\,907.5\ \text{J}}{10\,500\ \text{N}} = 13.8\ \text{m}$$

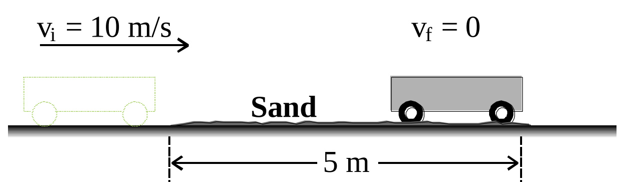
15. What distance does a 20 g bullet traveling at 150 m/s penetrate into a block of wood if the (average) force used to stop the bullet is 225 000 N? [0.001 m]

$$W = E_K = Fs$$

$$\text{or} \quad \frac{1}{2}mv^2 = Fs$$

$$\therefore \quad s = \frac{mv^2}{2(F)} = \frac{(0.02\ \text{kg})(150\ \text{m/s})^2}{2(225\,000\ \text{N})} = 0.001\ \text{m}$$

16. A 2 kg cart is traveling at 10 m/s on a horizontal surface towards some sand. The sand decelerates the cart to a stop in a distance of 5 m.



a) How much work did the sand do in stopping the cart? [100 J]

$$W = E_K = \frac{1}{2}mv^2 = \frac{1}{2}(2\ \text{kg})(10\ \text{m/s})^2 = 100\ \text{J}$$

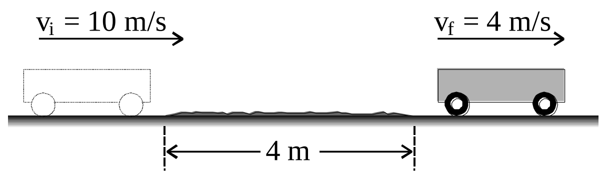
b) What was the (average) force exerted by the sand in stopping the cart? [20 N]

$$W = E_K = Fs$$

$$\therefore \quad F = \frac{E_K}{s} = \frac{100\ \text{J}}{5\ \text{m}} = 20\ \text{N}$$

c) What becomes of the kinetic energy of the cart? Lost to friction (heat and sound).

17. A 2 kg cart is traveling at 10 m/s on a horizontal surface towards some sand. After traversing the sandy area, a distance of 4 m, the velocity of the cart is 4 m/s.



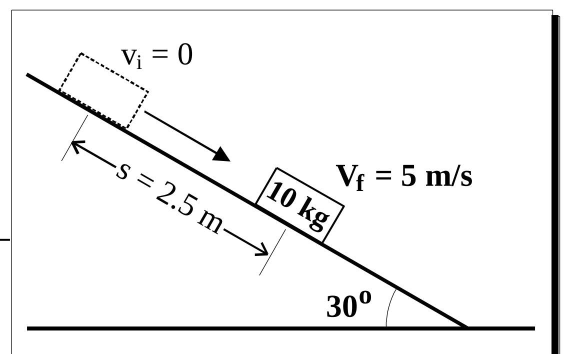
a) How much work did the sand do in slowing down the cart? [84 J]

$$W = \Delta E_K = E_{K\,(Final)} - E_{K\,(Initial)} = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$
$$= \frac{1}{2}(2\text{ kg})(4\text{ m/s})^2 - \frac{1}{2}(2\text{ kg})(10\text{ m/s})^2$$
$$= 16\text{ J} - 100\text{ J} = -84\text{ J}$$

b) What was the (average) force exerted by the sand in slowing down the cart? [21 N]

$$W = Fs$$
$$F = \frac{W}{s} = \frac{84\text{ J}}{4\text{ m}} = 21\text{ N}$$

18. Starting from rest, a 10 kg block of wood slides down a 30° incline plane as shown in the diagram on the right. Determine its kinetic energy at a point 2.5 m from its starting position (along the plane). [125 J]



$$a = g\,\text{Sin }A$$
$$= (10\text{ m/s}^2)(\text{Sin }30^\circ)$$
$$= 5\text{ m/s}^2$$

$$2as = v_f^2 - v_i^2$$

$$v_f^2 = 2as + v_i^2$$
$$= 2(5\text{ m/s}^2)(2.5\text{ m}) + 0$$
$$= 25\text{ m}^2/\text{s}^2$$
$$\therefore\ v_f = 5\text{ m/s}$$

$$E_K = \frac{1}{2}mv^2$$
$$= \frac{1}{2}(10\text{ kg})(5\text{ m/s})^2$$
$$= 125\text{ J}$$