Worksheet: Kinetic Energy ($E_k = 0.5 \times m \times v^2$)

PhysicsSheets

Specification: GCSE Physics (AQA 4.1.1.1 / Edexcel SP3)

Kinetic Energy Formula: $E_k = \frac{1}{2}mv^2$

Rearranged Forms: $m = \frac{2E_k}{v^2}$ | $v = \sqrt{\frac{2E_k}{m}}$

Units: E_k (Kinetic energy, Joules, J), m (Mass, kilograms, kg), v (Speed, metres per second, m/s)

Section A: Formula Recall, Rearranging & Unit Conversions

1. Complete the table below with the correct SI unit and its symbol for each variable in the kinetic energy formula:

Variable	SI Unit Name	SI Unit Symbol
Kinetic Energy (E_k)	**Joules**	**J**
Mass (m)	**kilograms**	**kg**
Speed (v)	**metres per second**	**m/s**

2. Rearrange the formula $E_k = \frac{1}{2}mv^2$ to make:

a) Mass (m) the subject: $m = \frac{2E_k}{v^2}$

b) Speed (v) the subject: $v = \sqrt{\frac{2E_k}{m}}$

3. Convert the following values into their standard SI units. Show your working where appropriate.

a) 250 g = **0.25** kg

b) 1.5 kJ = **1500** J

c) 72 km/h = **20** m/s (*Hint:* 1 $km = 1000$ m, 1 $h = 3600$ s)

d) 50 cm/s = **0.5** m/s

Section B: Practice Calculations

Show all your working clearly, including the equation, substitution, and final answer with units. Round your final answers to an appropriate number of significant figures.

1. A car of mass 1200 kg travels at a speed of 25 m/s.

a) Calculate the kinetic energy of the car.

Model Answer:
$E_k = \frac{1}{2}mv^2 = \frac{1}{2} \times 1200 \text{ kg} \times (25 \text{ m/s})^2 = 600 \times 625 = 375000 \text{ J}$

2. A tennis ball has a kinetic energy of 15 J when moving at 30 m/s.

a) Calculate the mass of the tennis ball.

Model Answer:
$m = \frac{2E_k}{v^2} = \frac{2 \times 15 \text{ J}}{(30 \text{ m/s})^2} = \frac{30}{900} = 0.03333... \text{ kg} \approx 0.0333 \text{ kg (3 s.f.)}$

3. A bullet of mass 0.01 kg has 2000 J of kinetic energy.

a) Calculate the speed of the bullet. Give your answer to 3 significant figures.

Model Answer:
$v = \sqrt{\frac{2E_k}{m}} = \sqrt{\frac{2 \times 2000 \text{ J}}{0.01 \text{ kg}}} = \sqrt{\frac{4000}{0.01}} = \sqrt{400000} = 632.455... \approx 632 \text{ m/s (3 s.f.)}$

4. A cyclist and their bike have a combined mass of 80 kg. They are travelling at 10 m/s.

a) If the cyclist doubles their speed, what happens to their kinetic energy? Calculate the new kinetic energy.

Model Answer:
Initial $E_k = \frac{1}{2} \times 80 \text{ kg} \times (10 \text{ m/s})^2 = 40 \times 100 = 4000 \text{ J}$.
If speed doubles to 20 m/s, new $E_k = \frac{1}{2} \times 80 \text{ kg} \times (20 \text{ m/s})^2 = 40 \times 400 = 16000 \text{ J}$.
The kinetic energy increases by a factor of four (it quadruples) because E_k is proportional to v^2.

Section C: Challenge Context

Figure 1 shows a car and a lorry.

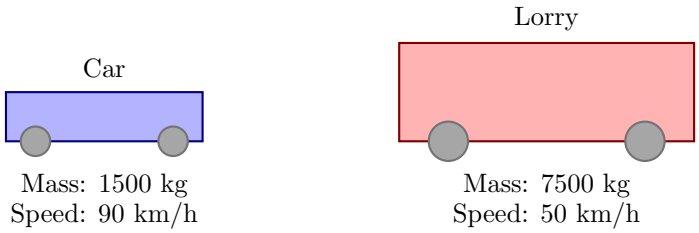

Figure 1: A car and a lorry

1.

a) Calculate the kinetic energy of the car. Show all working, including unit conversions. Give your answer in kilojoules (kJ) to 3 significant figures.

Model Answer:
First, convert car speed to m/s: $90 \text{ km/h} = \frac{90 \times 1000 \text{ m}}{3600 \text{ s}} = 25 \text{ m/s}$.
$E_k = \frac{1}{2}mv^2 = \frac{1}{2} \times 1500 \text{ kg} \times (25 \text{ m/s})^2 = 750 \times 625 = 468750 \text{ J}$.
Convert to kilojoules: $E_k = \frac{468750}{1000} \text{ kJ} = 468.75 \text{ kJ} \approx 469 \text{ kJ}$ (3 s.f.)

b) Compare the kinetic energy of the lorry to that of the car. Explain which vehicle has more kinetic energy and why, referring to the formula $E_k = \frac{1}{2}mv^2$.

Model Answer:
First, convert lorry speed to m/s: $50 \text{ km/h} = \frac{50 \times 1000 \text{ m}}{3600 \text{ s}} = 13.888... \text{ m/s}$.
Calculate lorry $E_k = \frac{1}{2} \times 7500 \text{ kg} \times (13.888... \text{ m/s})^2 = 3750 \times 192.901... = 723379.6... \text{ J} \approx 723 \text{ kJ}$.
The lorry has more kinetic energy (723 kJ) than the car (469 kJ). This is because kinetic energy is directly proportional to mass and proportional to the square of speed. Although the lorry is slower, its mass is significantly greater (5 times the car's mass). The larger mass has a greater impact on the overall kinetic energy than the lower speed, making the lorry's kinetic energy higher.