7.2 What is the total drag force acting on the car? (2)
7.3 The power output of the car's engine is then reduced to zero and the car begins to descend a hill which is inclined at 10° to the horizontal. It continues to travel at 8 $m \cdot s^{-1}$.
Calculate how much extra retarding force is needed to achieve this constant velocity. (5)

8 A person raises and lowers a dumb-bell of mass 2,5 kg through a vertical distance of 0,4 m, 50 times in 60 seconds.

8.1 Show that the useful work performed by the arm muscles in lifting the dumb-bell during this activity is 490 J. (4)
8.2 Calculate the rate of conversion of energy in the muscles for the person during this activity.
Assume that the muscles convert energy into useful work with an efficiency of 20%. (5)

Gravitational Potential Energy

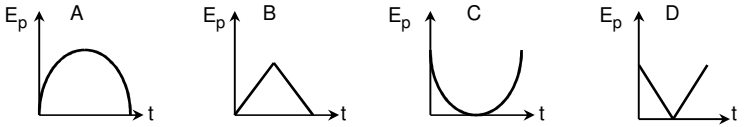
- **Gravitational potential energy $E_p = mgh$** (on data sheet) where
  E_p = gravitational potential energy in joule (U can also be used),
  m = mass of object in kilogram,
  g = gravitational acceleration in $m \cdot s^{-2}$ on that planet (9,8 $m \cdot s^{-2}$ on the earth) and
  h = height above the reference point (usually the ground).
- For an object falling freely ($v_i = 0$ and $a = g = 9{,}8\ m \cdot s^{-2}$, near the earth's surface).
  $\Delta y = v_i \Delta t + \frac{1}{2} a \Delta t^2 = \frac{1}{2} g \Delta t^2$, therefore $\Delta y \propto \Delta t^2$.
  Furthermore, with m and g both constant, $E_p \propto h$, therefore
  $E_p \propto h \propto \Delta t^2$, so that the **graph of E_p versus time is a parabola**.
  The graph of E_p versus **displacement** or **height** is a straight line, passing through the origin.
- Work done by an **external force F** lifting an object from point 1 to point 2 equals the change in gravitational potential energy, $\mathbf{\Delta E_p} = mgh_2 - mgh_1$, if **velocity** remains constant, therefore $\mathbf{W_F = \Delta E_p}$.
- Work done by **gravity** (conservative force) when an object is lifted at constant velocity from point 1 to point 2 higher up, is $\mathbf{W_G = -\Delta E_p}$.

Exercise 10:

1 Give ONE word/term for

1.1 the energy of an object due to its height above a point of reference. (1)
1.2 the energy of a stationary object due to its position above the surface of the earth. (1)

2 A ball is thrown vertically upwards. Which of the following potential energy-time graphs represents the change in the ball's gravitational potential energy from the moment it leaves the thrower's hand until it falls back to the same height again?



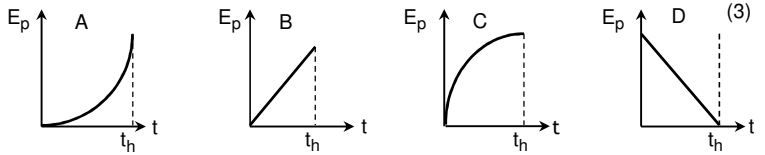
3 Which one of the following decreases when work is done by the force of gravity?

A Kinetic energy B Potential energy
C Heat D Momentum (3)

4 The downward velocity of a parachutist is constant.
Which one of the following statements about the parachutist is true?

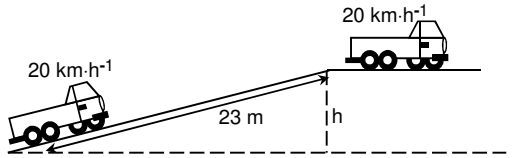
A Both his acceleration and his kinetic energy are zero.
B His kinetic energy increases and gravitational potential energy decreases.
C The sum of his gravitational potential energy and kinetic energy remains constant.
D His potential energy decreases, but his kinetic energy remains constant. (3)

5 Mary throws a netball vertically upwards. The ball reaches a maximum height h at time t_h.
Which graph best represents the variation in the potential energy E_p of the ball as a function of time?



(3)

6 In South Africa the transportation of goods by trucks adds to the traffic problems on our roads.
A 10 000 kg truck travels up a straight inclined road of length 23 m at constant speed of 20 $km \cdot h^{-1}$. The total work done by the engine of the truck to get there is 7×10^5 J.
The work done to overcome friction is $8{,}5 \times 10^4$ J.



6.1 Calculate the height, h, reached by the truck at the top of the road. (6)
6.2 Calculate the instantaneous power delivered by the engine of the truck. (6)
6.3 Arrestor beds are constructed as a safety measure to allow trucks to come to rest when their brakes fail whilst going downhill.
Write down TWO design features of such arrestor beds. (2)

Kinetic Energy

- **Kinetic energy $\mathbf{E_k = \frac{1}{2}mv^2}$** (on data sheet) where E_k = kinetic energy in joule (K can also be used), m = mass of the object in kg and v = speed of the object in $m \cdot s^{-1}$.
- If m remains constant, $E_k \propto v^2$, therefore when v increases by a factor 2, E_k increases by a factor $(2)^2 = 4$, etc.
- Furthermore, with $E_k \propto v^2$ and $v^2 \propto \Delta t^2$, the **graph of E_k versus t is a parabola**.
  For an object falling freely ($v_i = 0$ and $a = g = 9{,}8\ m \cdot s^{-2}$ near the earth's surface)
  $v_f = v_i + a \Delta t = g \Delta t$, so that $v_f \propto \Delta t$.
- Work done by an external force = change in kinetic energy if height, i.e. E_p, remains the same.
- **Work-energy theorem:** The work done by a **net force** on an object or system is equal to the **change in the kinetic energy** of the object or system: $\mathbf{W_{net} = \Delta E_k = \frac{1}{2} mv_f^2 - \frac{1}{2} mv_i^2}$

Exercise 11:

1 Give ONE word/term for

1.1 the energy of an object due to its motion. (1)

2 A stone is thrown vertically upwards and allowed to fall freely. (Ignore the effects of air resistance.)
Which graph best represents the kinetic energy of the stone as a function of time? (3)