# TOPIC 2B- ACCELERATION DUE TO GRAVITY (SINGLE AXIS)

## Skill 14 - Acceleration due to gravity Dropped objects

When an object is dropped it has an initial velocity of zero but it speeds up due to the pull of the Earth's gravitational field. The strength of the Earth's field is 9.81 Newtons per kilogram or 9.81N/kg (A Newton is a unit of force that will be explained later in greater detail). Strength of the gravitational field or acceleration due to gravity is symbolized by "g" (Lower case is important)

**g = 9.81 N/kg  or 9.81m/s$^2$  (Downward)**

(GRAVITY ALWAYS PULLS MASSES TOGETHER – SO TOWARD EARTH)

**UNIVERSAL GRAVITATIONAL FIELD**

The gravitational field causes all objects, regardless of mass, to accelerate at "9.81m/s each second" (9.81m/s$^2$) when they are in "FREE FALL". FREE FALL means that the only force acting on the object is the gravitational field. In other words.... In the absence of air resistance, a penny and a bowling ball dropped from the same height will reach the ground at the same time with the same speed. Therefore the mass of the object is not involved in calculations for position, velocity or time for a dropped object.

**TRACKING FREE FALL**

Kinematics equations or "Head-Problems" can be used to solve for position and velocity after each second of free fall:

THIS CHART PROVIDES "BENCHMARKS" FOR POSITION AND VELOCITY AT THE END OF EACH SECOND (For 0-1 second at 0.1s intervals use same coefficient but change meters to centimeters. 0.2s = 20cm)

| Vi | Vf | $\bar{v}$ | D | a | t |
|---|---|---|---|---|---|
| | ($v_f$=at) | $\bar{v}=\frac{d}{t}$ $\bar{v}=\frac{v_i+v_f}{2}$ | $d=\cancel{v_i t}+\frac{1}{2}at^2$ d=$\bar{v}$t | g | |
| 0 | 9.81m/s (~10m/s) | 4.9m/s | 4.9m (~5m) | 9.8m/s$^2$ (~10m/s$^2$) | 1 second mark |
| 0 | 19.6 m/s (~20m/s) | 9.8m/s | 19.6m (~20m) | | 2 second mark |
| 0 | 29.4 m/s (~30m/s) | 14.7 m/s | 44.1m (~45m) | | 3 second mark |
| 0 | 39.2 m/s (~40 m/s) | 19.6 m/s | 78.4m (~80m) | | 4 second mark |
| 0 | 49.0 m/s (~50 m/s) | 24.5 m/s | 122.5m (~125m) | | 5 second mark |
| 0 | 58.8 m/s (~60 m/s) | 29.4 m/s | 176.4m (~180m | | 6 second mark |
| 0 | 68.6 m/s (~70 m/s) | 34.3 m/s | 240.1m (~250m) | | 7 second mark |
| 0 | 78.4 m/s (~80 m/s) | 39.2 m/s | 313.6m (~320m) | | 8 second mark |
| 0 | 88.2 m/s (~90 m/s) | 44.1 m/s | 396.9m (~405m) | | 9 second mark |
| 0 | 98 m/s (~100 m/s) | 49 m/s | 490m (~500m) | | 10 second mark |

Note: the numbers in parentheses are calculated using g=10m/s$^2$.

Since $v_i$=0 the kinematics equations can be abbreviated as follows:

$d=\cancel{v_i t}+\frac{1}{2}at^2$ becomes $d=\frac{1}{2}at^2$ where $t=\sqrt{\frac{2d}{a}}$ and $a=\frac{2d}{t^2}$

${v_f}^2=\cancel{{v_i}^2}+2ad$ becomes $v_f=\sqrt{2ad}$ where $d=\frac{{v_f}^2}{2a}$

$v_f=v_i+at$ becomes $v_f=at$ or $v_f=\Delta v$

For Free-fall a=g so if estimating answer $d=\frac{1}{2}at^2$ can be substituted with d=$(5\frac{m}{s^2})t^2$

# Examples:

1. An object is dropped by a bird from a height of 60m? How much time is it in the air? What is the final velocity (impact speed) of the object?

**Givens and Knowns**

$v_i=0$

d=h= 60m

a =g= 9.81 m/s$^2$

**Unknown:**

t=?

$v_f$=?

**Equations and Substitution:**

$d=\cancel{v_i t}+\frac{1}{2}at^2$ rearranged for $t=\sqrt{\frac{2d}{a}}$

$t=\sqrt{\frac{2(60m)}{9.8m/s^2}}$ =3.5s

(When checked vs "benchmarks". 3.5s makes sense
45m=3seconds     80m=4seconds)

$v_f^2=v_i^2+2ad$ simplified for $v_f=\sqrt{2ad}$

$v_f$=34.2 m/s

(makes sense since $v_f$=at = (9.8m/s$^2$)(3.5s))

2. A penny dropped from rest, impacts the ground with a speed of 27 m/s. What is the height from which the penny was dropped?

**Givens and Knowns:**

$v_i=0$

$v_f$ = 27m/s

a=g=9.81m/s$^2$

**Unknown:**

d=?

**Equations and Substitutions:**

$v_f^2=\cancel{v_i^2}+2ad$ simplifies and rearranges to $d=\frac{v_f^2}{2a}$

$d=\frac{v_f^2}{2a}$ so $d=\frac{(27\frac{m}{s})^2}{19.6\frac{m}{s^2}}$ = 37.1m

ALTERNATE SOLUTION

| Δv | $v_i$ | $v_f$ | $\bar{v}$ | d | a | t |
|---|---|---|---|---|---|---|
| 27 m/s | 0 m/s | 27 m/s | 13.5 m/s | **37.8 m** | 9.8 m/s$^2$ | **2.8 s** |

$\bar{v}=\frac{v_i+v_f}{2}$ $\bar{v}=\frac{0+27m/s}{2}=13.5m/s$

$t=\frac{\Delta v}{a}=\frac{27m/s}{9.8m/s^2}=2.8s$

$\bar{v}=\frac{d}{t}$ d=$\bar{v}t$ = (13.5m/s)(2.8s)=37.8 m

(time was rounded so answer varies slightly between methods. Both answers are right)