THE UNIVERSITY OF NEWCASTLE AUSTRALIA

SCIENCE IN PRACTICE 2020

MOTION IN ONE AND TWO DIRECTION

Student Workbook

2020

This resource was developed by Dr Renee Goreham, a University of Newcastle physics lecturer with expertise in nanoparticle synthesis, characterisation and applications in biomedical systems. Renee is passionate about breaking down barriers that prevent students from engaging with science, particularly those in regional and remote communities.

Why study physics?

Physics is crucial to understanding the world around us, the world inside us, and the world beyond us. It is the most basic and fundamental science. Physics challenges our imaginations with concepts like relativity and string theory, and it leads to great discoveries, like computers and lasers, that change our lives. Physics encompasses the study of the universe from the largest galaxies to the smallest subatomic particles. It is the basis of many other sciences, including chemistry, oceanography, seismology, and astronomy. All are easily accessible with a bachelor's degree in physics.

Physicists are turning their talents to molecular biology, biochemistry, and biology itself. Even medicine has a niche for physicists, and since medical physicists are hard to come by, they are much in demand.

Physics also supports many new technologies. Cell phones, the Internet, and MRIs are only a few examples of the physics-based technological developments that have revolutionized our world. A physics education equips a person to work in many different and interesting places in industrial and government labs, on college campuses, and in the astronaut corps. Many theoretical and experimental physicists work as engineers, and many engineers have physics degrees.

Many physics graduates leave the lab behind and work at newspapers and magazines, in governmental departments—places where their problem-solving abilities and analytical skills are great assets.

Physics is interesting, relevant, and it can prepare you for great jobs in a wide variety of places.

Opportunities for further studies in Physics:

The Bachelor of Science offered at the Faculty of Science, University of Newcastle, provides a foundation of knowledge, skills and attributes that allows graduates to be employable not just today but into the future and to contribute actively and responsibly to society. Majoring in Physics, you have the opportunity to sample and/or specialise in any one of the following:

- Biophysics
- Computational Physics
- Geophysics
- Medical Physics
- Nanotechnology
- Optical Physics
- Research Physics
- Space Physics/Radar/Surveillance
- Optical Physics
- Optical Physics/Laser Engineering/Photonics Engineering

Research in Physics at the University of Newcastle:

There are various groups here at the University which are committed to research in physics. Groups include:

- Centre for Space Physics
- Medical Physics Group
- Surface and Nanoscience Group
- Research Centre for Organic Electronics
- Research Centre for Advanced Fluids

Careers in Physics:

The Faculty of Science cares about our students and is interested in giving as much direction as possible to those making career choices and beyond. The possible career paths listed below include a range of opportunities for graduates at degree, honours, and post graduate study levels.

- Acoustical Physicist
- Astronomer/ Astrophysicist
- Biophysicist
- Cosmologist
- Fluid Dynamics Analyst
- Geophysicist
- Graduate Trainee
- Health Physicist
- Laboratory Analyst
- Laboratory/Research Assistant
- Nanotechnologist
- Nuclear Physicist
- Optical Physicist
- Plasma Physicist
- Research Scientist
- Risk Analyst
- Science Information/ Education Officer
- Science/ Physics Teacher
- Science Technician
- Scientific Patent Attorney/ Technical Advisor
- Scientific Policy Officer
- Scientific Writer
- Software Engineer/ Tester
- University Lecturer/ Academic

For more information please visit the University's website: www.newcastle.edu.au

MOTION IN ONE AND TWO DIRECTION

Background

In physics we classify different types of motion so that we can predict where things will end up. Usually, study of motion in physics begins by considering distance and speed where

$$\textbf{Distance} = \textbf{speed} \times \textbf{time} \qquad (1)$$

This will predict a car's distance travelled provided the car neither speeds up nor slows down, i.e. for a constant speed. Speed is a scalar quantity (it only has a size or magnitude). If we give the speed a direction as well as a magnitude then we make a vector quantity called velocity. Distance is also a scalar quantity while displacement is a vector quantity.

If the car accelerates uniformly with acceleration, a, then the distance travelled in a time, t, is

$$\textbf{Distance} = \boldsymbol{u\,t} + \frac{\mathbf{1}}{\mathbf{2}}\,\boldsymbol{a\,t^2} \qquad (2)$$

Equation (2) also allows for the case where the car has an initial constant speed, u, and then accelerates. We now have the main ingredients for examining motion on two dimensions.

Objects in freefall

Watch the video here, or see the extract below.

In a fructose induced rage, you throw your favourite rubber chicken in the air. You watch it go up in the air, and then slowly fall back down. You start to calm from your frenzy and ponder, what physics are in play. The rubber chicken is in freefall. This is a special case where the chicken has constant acceleration due to gravity, which is always down towards to Earth. This is even true is it has zero velocity.

When you first threw that chicken, the initial velocity is upward but the downward acceleration due to gravity pulls the chicken towards the Earth. This means the chicken slows, and slows, and slows until the velocity or speed is zero. The pull of the gravity then starts hurtling that chicken back towards the ground. The velocity starts increasing the closer is gets.

Let's try some problems, remember to ignore air resistance and answer so the coordinate system is positive in the up direction.

1. When you threw the rubber chicken upward, in the positive direction, the chicken falls freely under the influence of gravity. At the highest point in the ball's motion,

(a) its velocity is zero and its acceleration is zero.
(b) its velocity is zero and its acceleration is positive (upward).
(c) its velocity is zero and its acceleration is negative (downward).
(d) its velocity is positive (upward) and its acceleration is zero.
(e) its velocity is negative (downward) and its acceleration is zero.

2. You drop your rubber chicken and it takes 1.5 seconds to reach the ground. **What is the chicken's displacement?**

$$\boldsymbol{Initial\ velocity\ u = 0.0\ m/s}$$
$$\boldsymbol{final\ velocity\ v} = ?$$
$$\boldsymbol{acceleration\ a = -9.8\ m/s^2}$$
$$\boldsymbol{time\ t = 1.5\ s}$$
$$\boldsymbol{displacement\ \Delta y} = ?$$
$$\boldsymbol{\Delta y = ut + \frac{1}{2} a t_y^2}$$

3. Again, you toss your favourite rubber chicken in the air and catch it again at the same height. The chicken is in the air for 0.75 s. **What was the chicken's velocity at the moment it was tossed into the air?**

$$\boldsymbol{acceleration\ a = -9.8\ m/s^2}$$
$$\boldsymbol{time\ t = 0.75\ s}$$
$$\boldsymbol{displacement\ \Delta y = 0}$$
$$\boldsymbol{final\ velocity\ v = ?}$$
$$\boldsymbol{Initial\ velocity\ u = ?}$$
$$\boldsymbol{\Delta y = ut + \frac{1}{2}at_y^2}$$

4. If the rubber chicken was thrown in the air with a velocity of 1 m/s, **what was the maximum height?**

$$\boldsymbol{Initial\ velocity\ u = 1.0\ m/s}$$

$$\boldsymbol{displacement\ \Delta y = ?}$$

$$\boldsymbol{acceleration\ a = -9.8\ m/s^2}$$

$$\boldsymbol{final\ velocity\ v = 0.0\ m/s}$$

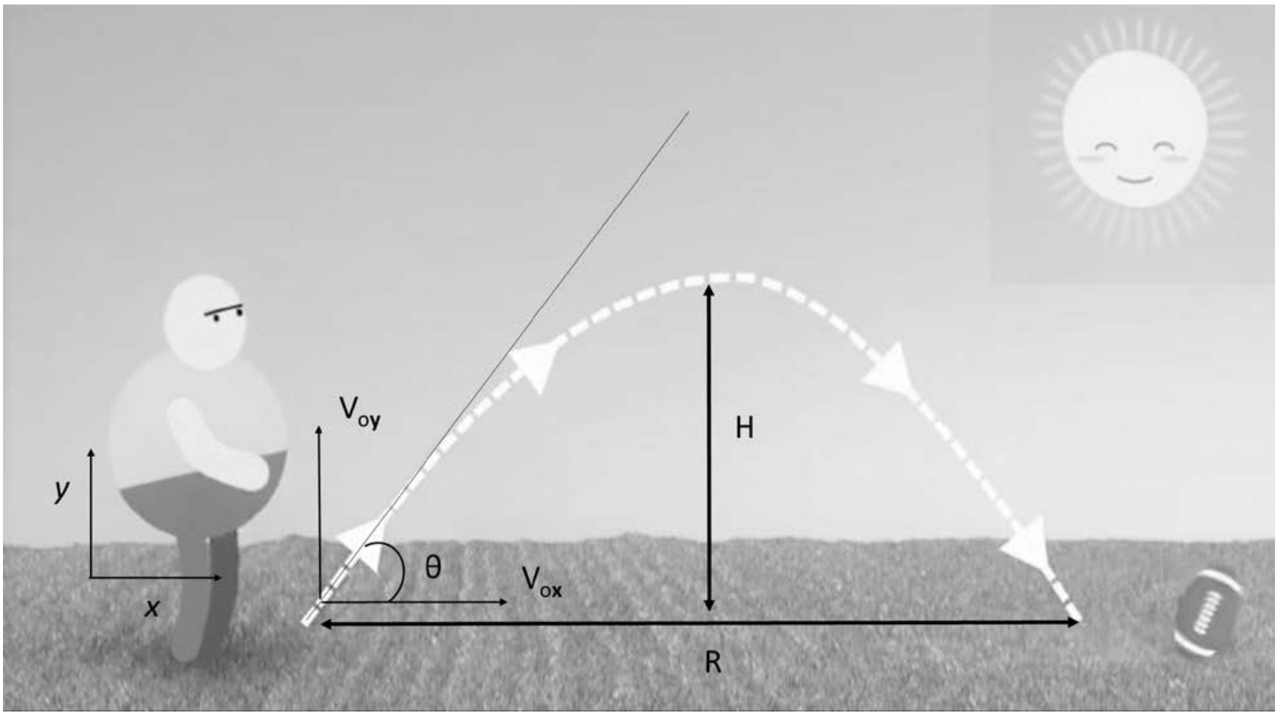
$$\boldsymbol{time\ t = 0.?}$$

$$\boldsymbol{v = u + at}$$

Objects in projectile motion

Watch the video here, or see the extract below.

It's a brilliant Sunday arvo and you're on the gridiron already. Your buddies are late and you've got only a rugby ball to muddle with. What do you do? Set it up and go for a merry kick. What do you see? The ball flies up in the air, gets to a certain height and starts falling back towards the ground. This motion or rather the trajectory the ball follows is called a projectile. From the ball to the ballistic missiles, nothing thrown on earth escapes the projectile fate. Things can be easy for you if you keep in mind one thing though. No matter how complex the trajectory seems, once you resolve the vectors in horizontal (x) and vertical (y) directions, life gets much simpler.



Once you kick the ball with let's say an initial velocity u, depending on the angle of elevation (ϑ) of your pro kick, the velocity can be resolved into u_x in the horizontal axis and u_y in the vertical axis. Remember kiddo, there is no acceleration in the x direction, u_x is all the ball has got to travel as far as it can (R). Also remember, there is the big burly earth's gravity, pulling the ball down with an acceleration g. So your kick's u_y is always opposed by g in the vertical direction. Max u_y, max H.

Considering this, equation (2) can be written separately for *x* and *y* as follows,

$$\Delta \mathrm{x} = \mathrm{u}\,\mathrm{t}_{\mathrm{x}} \tag{3}$$

$$\Delta y = u\,t + \frac{1}{2}\,a\,t_y^2 \tag{4}$$

Then equations (3) and (4) can be solved to determine the maximum height, H, reached and the maximum horizontal distance, R, travelled before the object returns to its original height.

$$H = \frac{u_y^2}{2g} \tag{5}$$

$$R = 2\,u_x\,u_y/g \tag{6}$$

Just like last time, let's try some problems. Again, air resistance is too weak for your kicks, so better ignore. Upward is positive and downward is negative (y). Forward is positive and backward is negative (x).

Once you solve these you're a rugby physics champ.

1. When you kick the ball, it flies up only to a certain point and then starts falling down, although always moving forward. At the highest point in the trajectory;

a) Velocity in *x* is same as initial, velocity in *y* is maximum
b) Velocity in *x* is zero, velocity in *y* is maximum
c) Velocity in *x* is same as initial, velocity in *y* zero
d) Velocity in *x* is maximum, velocity in *y* is maximum
e) Velocity in *x* is minimum, velocity in *y* is minimum

2. Your friend Bob is not too bad at rugby either. He kicks the ball with a horizontal velocity u_y = 9.8 m/s. **How high do you think the ball goes?**

$$\boldsymbol{Vertical\ initial\ velocity\ uy = 9.8\ m/s}$$
$$\boldsymbol{acceleration\ a = -9.8\ m/s^2}$$
$$\boldsymbol{Vertical\ displacement}\ \mathbf{H} = ?$$
$$\boldsymbol{H = \frac{u_y^2}{2g}}$$

3. It's your turn now and you want to kick the ball pretty far. Your horizontal velocity u_x is 9.8 m/s and vertical velocity is u_y is 6 m/s. **How far do you kick the ball?**

$$\boldsymbol{Vertical\ initial\ velocity\ uy = 6\ m/s}$$
$$\boldsymbol{Horizontal\ initial\ velocity\ ux = 9.8\ m/s}$$
$$\boldsymbol{acceleration\ a = -9.8\ m/s^2}$$
$$\boldsymbol{Horizontal\ displacement}\ \mathbf{R} = ?$$
$$\boldsymbol{R = 2\ u_x\ u_y/g}$$

4. Do you think you kicked it higher than Bob though?

$$\boldsymbol{Vertical\ initial\ velocity\ uy = 6\ m/s}$$
$$\boldsymbol{acceleration\ a = \ -9.8\ m/s^2}$$
$$\boldsymbol{Vertical\ displacement\ \mathrm{H} = ?}$$
$$\boldsymbol{H = \frac{u_y^2}{2g}}$$