YEAR 7-8 AND 10 | STUDENT FACT SHEET

LEARNING AREA: SCIENCE

Investigating Thoroughbred Energy, Motion, and Movement

Primary Industries Education Foundation Australia

TBA Thoroughbred Breeders Australia

Investigating Thoroughbred Energy, Motion, and Movement

A thoroughbred horse can be used as an excellent example of a powerful animal whose movement can be studied to help us understand various physics concepts. From its explosive acceleration at the start of a race, to its high-speed gallop, the horse's motion can be explained through Newton's Laws of Motion.

How a horse moves

A thoroughbred horse moves using powerful muscle contractions and precise coordination of their limbs or legs. A horse has four main gaits that vary in speed, coordination of the legs, and amount of energy used.

A **walk** is a slow, four-beat gait where each hoof hits the ground one at a time.

A **trot** is a two-beat gait where diagonal pairs of legs move together, creating a rhythmic movement.

A **canter** is a three-beat gait that is faster than the trot but slower than the gallop, with one leading leg.

A **gallop** is the fastest gait, a four-beat movement where each leg hits the ground separately. This is the gait used in racing.

During galloping, each leg moves independently. The hind leg muscles generate thrust, and the forelegs maintain balance and extend the stride. The horse's back and neck aid momentum, and breathing is synchronised with the stride for optimal oxygen intake. This

Scan the QR code or click on the link to view the video to observe the different gaits of a horse.

Horses: How Horses Move (1:04)

https://www.pbs.org/video/horses-horse-moves-opzrbl/

Energy transformations in horse movement

As a thoroughbred horse gallops, several energy transformations take place to create and sustain movement. Chemical energy stored in the horse's muscles (derived from food) is converted into mechanical energy through muscle contractions. The muscles exert force on the tendons and ligaments, driving the bones of the legs forward. During each stride, the tendons act like springs, temporarily storing elastic potential energy when stretched and then releasing it as kinetic energy to propel the horse forward.

Not all of the energy is used to propel the horse. Some energy is transformed into thermal (heat) energy as a by-product of muscle activity, and is lost as heat from a horses body.

Scan the QR code or click on the link to watch a horse galloping in slow motion.

Ultimate Horsepower in Super Slow Motion | BBC Earth Unplugged (4:57)

https://www.youtube.com/watch?v=86Zu8mqd8LM

Distances of thoroughbred horse races

Australian thoroughbred flat races range from around 1,000 metres to 3,200 metres in length, testing the horse's speed and stamina as well as the skill of the jockey. The distances of races can also be measured in furlongs. A furlong is a unit of distance commonly used in horse racing, equivalent to 201.168 metres or 220 yards. There are eight furlongs in a mile, so a furlong is one-eighth of a mile.

Speeds of thoroughbred racehorses

Australian thoroughbreds generally peak between the ages of four and five, and in sprint races (e.g., 1000–1200 m) can reach speeds of 40 km/h at the start, with top speeds recorded at approximately 65 km/h during the race. Elite sprinters have achieved speeds exceeding 70 km/h in top-level competitions (Racing Australia, 2022). Winx, one of Australia's most successful racehorses, won 33 consecutive races, including 25 Group 1 races, showing her incredible consistency and athleticism. In her peak years, Winx regularly achieved speeds exceeding 60 km/h in middle-distance races (Australian Turf Club, 2019). Her top speed was recorded at 70.37 km/h (Racing Australia, 2019).

Newton's laws of motion and thoroughbred horse movement

Newton's laws of motion apply to Australian thoroughbred horses. They describe how forces affect the motion of a horse and its jockey and can be used to understand the dynamics of horse movement, both during training and while racing. The unit of force is a Newton.

Newton's first law (the law of inertia)

An object at rest will remain at rest, and an object in motion will continue in motion at constant velocity (the same direction and speed) unless acted upon by an unbalanced force.

A horse at rest (standing still) will not begin moving unless a force is applied, such as it deciding to begin moving, a jockey urging it forward, or being released from the starting gate and exerting a force on the ground.

When the horse is in motion (e.g., galloping), it will continue in the same direction and at the same speed unless acted upon by forces such as friction from the ground, air resistance, or a change in the rider's control.

During training, the rider must exert a force, urging the horse to initiate motion or change its pace. When the horse reaches its stride in a race, it maintains its speed until fatigue or environmental forces (like wind or friction from the track surface) slow it down.

Newton's second law (the law of acceleration)

The acceleration of an object depends on the mass of the object and the force applied to it (Force = mass x acceleration; F = ma).

The greater the force exerted by the horse's muscles (or the jockey urging the horse), the faster the horse will accelerate. However, the horse's mass (and its rider) plays a significant role - a heavier horse requires more force to achieve the same acceleration as a lighter one.

A jockey uses various signals and techniques to adjust a horse's pace, effectively applying more force to cause acceleration or easing off to cause deceleration. The horse's legs generate the primary force needed to move forward, and the friction between the horses hooves and the ground surface (whether it's firm or soft) impacts how much force is needed to accelerate.

During training, horses are conditioned to increase their speed and muscular and cardiovascular fitness, improving their ability to apply greater force for greater acceleration during races.

Newton's third law (action and reaction)

For every action, there is an equal and opposite reaction.

When a horse pushes against the ground with its legs as it is in motion, the ground pushes back with an equal and opposite force. This reaction propels the horse forward. The stronger and more efficient the push against the ground, the faster and further the horse moves

When the jockey shifts their weight or pulls on the reins, the horse reacts by changing direction or speed in response to the force exerted. The communication between the horse and rider relies on this principle.

During racing, a thoroughbred's speed and stride efficiency depend on optimising these actions and reactions. The faster the horse pushes off the ground, the greater the ground's reaction force, propelling the horse forward at high speed.

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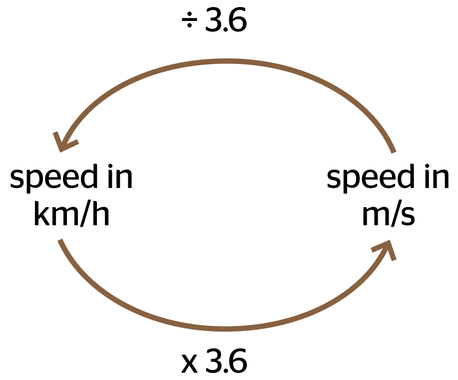
Speed and distance

a) The Standard International unit (SI) for speed is metres per second: m/s. However, speed of cars and horses are often given in kilometres per hour: km/h. Speeds can be converted from m/s into km/h and from km/h into m/s by multiplying or dividing by 3.6 as shown.



i) Convert 3 m/s into km/h

ii) Convert 60 km/h into m/s

b) How many metres are there in one furlong?

c) How many furlongs are there in the Melbourne Cup, a 3200 m horse race?

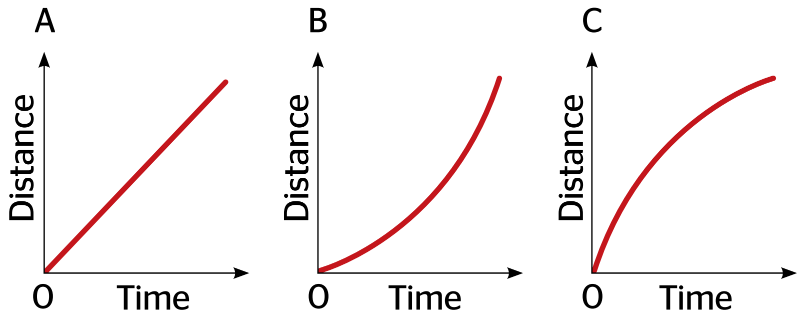
d) In the 2018 Turnbull Stakes, Winx completed the final furlong in 10.6 seconds. Use the formula speed = distance/ time to calculate the speed (in m/s) of Winx over this distance.

e) Look at the distance-time graphs below to determine which shows a thoroughbred horse:

i) slowing down (decelerating)?

ii) speeding up (accelerating)?

iii) travelling at a constant speed?



f) Which distance-time graph would you expect to use to describe a horse coming out of the gates, during the middle of the race, and after the finish line? Justify your answer.

Newton's laws of motion

g) State Newton's three laws of motion.

Newton's second law of motion can be expressed mathematically using the equation

$Force_{net}$ = mass x acceleration (F = ma).

F_{net} is total force acting on an object, measured in Newtons (N)

m is the mass of the object (kg)
a is acceleration of the object (m/s^2)

Example: Calculate the accceleration of the thoroughbred horse shown.

Mass of horse = 500 kg

$F_{net} = ma$

The horse has unbalanced forces on it and it is moving to the right as there is a greater force acting in this direction.

F_{net} = 1500 N - 300 N =1200 N to the right.

So the horse will travel with acceleration: rearrange the equation $a = \frac{F_{net}}{m}$

$a = \frac{1200}{500} = 2.4 m/s^2$

The horse will travel with acceleration of $2.4 m/s^2$

h) Calculate the acceleration of the thoroughbred horse in the diagram below.

Mass of horse = 502 kg

i) Calculate the net force a 486kg thoroughbred horse exerts to accelerate 3.0 m/s^2.

Learning Area | Australian Curriculum Content:

Science
Investigate and represent balanced and unbalanced forces, including gravitational force, acting on objects, and relate changes in an object's motion to its mass and the magnitude and direction of forces acting on it (AC9S7U04)

Classify different types of energy as kinetic or potential and investigate energy transfer and transformations in simple systems (AC9S8U05)

Investigate Newton's laws of motion and quantitatively analyse the relationship between force, mass and acceleration of objects (AC9S10U05)

ATTRIBUTION, CREDIT & SHARING

This resource was produced by Primary Industries Education Foundation Australia (PIEFA) in collaboration with Thoroughbred Breeders Australia. Primary Industries Education Foundation Australia's resources support and facilitate effective teaching and learning about Australia's food and fibre industries. We are grateful for the support of our industry and member organisations for assisting in our research efforts and providing industry-specific information and imagery to benefit the development and accuracy of this educational resource.

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