Mike Phillp December 2015

Effects of Blade Size on Performance

Over the years many coaches (including the author) have exhorted paddlers to drive the boat forward by pulling themselves past a 'planted' paddle blade, rather than 'throwing water backwards'. Examining the situation using classic Newtonian physics shows what is really happening. When any object is propelled forwards, an 'equal and opposite reaction' requires another mass is propelled 'backwards'. In the case of paddling, the mass being propelled backwards is part of the water (in contact with the paddle) being paddled through.

The multi-flash image below demonstrates this action, showing the bottom part of the blade moving 'backwards' 25–30 cm during the paddle stroke, and by its action propelling water backwards. (Any canoeist who has 'wash hung' behind a motor boat will be aware the propeller is blasting a lot of water backwards, and not simply 'screwing' itself forward through stationary water).

The image also shows how when viewed at the surface, the paddle blade appears to enter and leave the water pretty much in the same spot. (This may have led to a commonly held belief that the wing paddle does not move backwards during the stroke).

(Image courtesy of Keith Robinson)

Once we are comfortable with the idea the boat is propelled forward by 'throwing' a mass of water backwards (we're happy to go with Sir Isaac Newton on this one), aspects relating to acceleration, momentum, and kinetic energy associated with this mass of water can be examined.

The propulsive force of the paddle stroke is derived by changing the momentum of (some of) the water being paddled through.

Newton's 2nd Law   Force = Mass X Acceleration

(Units - Newtons = kg X metres per second^2)

Varying the mass and the acceleration need make no difference to the force derived, as long as the 'product' remains the same. Hence to generate a force of say 90 Newton's, one could -

Accelerate 5kg at 18 m / s^2

or   18kg at 5 m / s^2 both results giving 90 Newtons (force)

Looking at the kinetic energy ($=\frac{1}{2}mv^2$) 'gained' by the mass (of water) being accelerated to generate this force for 1 second, (interestingly) things aren't so equal.

For the first scenario, the kinetic energy = (½ X 5) X 18^2 = 810 Joules

For the second scenario, the kinetic energy = (½ X 18) X 5^2 = 225 Joules

The science is clear (but not intuitive), it is more energy efficient to generate the force on the paddle by 'throwing' a larger mass of water backwards slowly, rather than a small mass quickly.

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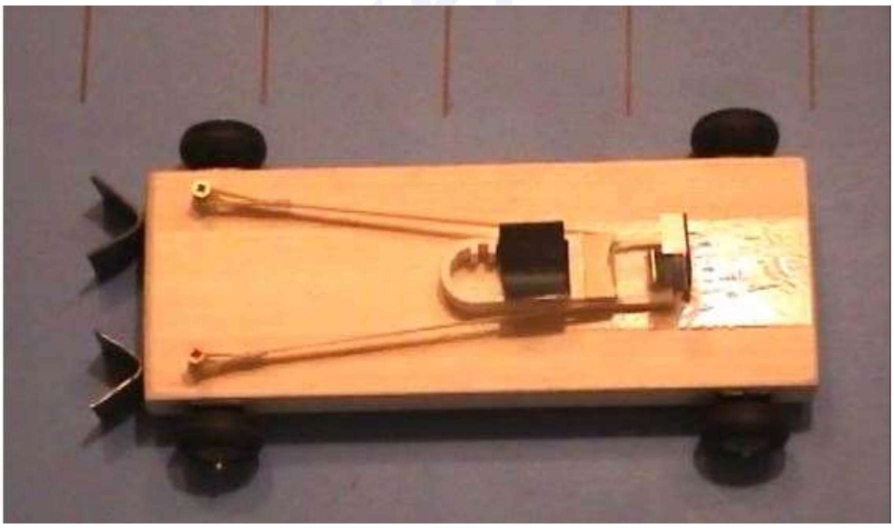
Practical Demonstration of Mass, Acceleration, & Force Effects

To help convince those coaches and paddlers who are perhaps not so comfortable with Newtonian physics, kinetic energy and force calculations, a practical demonstration was devised.

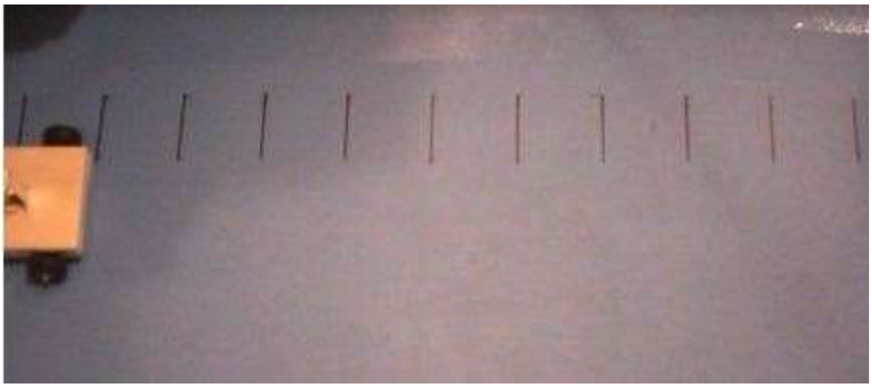
A lightweight four-wheeled carriage weighing approx 150gms (shown below) was constructed with an 'elastic mechanism' allowing a lead weight to be 'shot' off the back of it. The resulting 'reaction' driving the carriage in the opposite direction to the lead weight (Newton's second law, every action has an equal and opposite reaction).



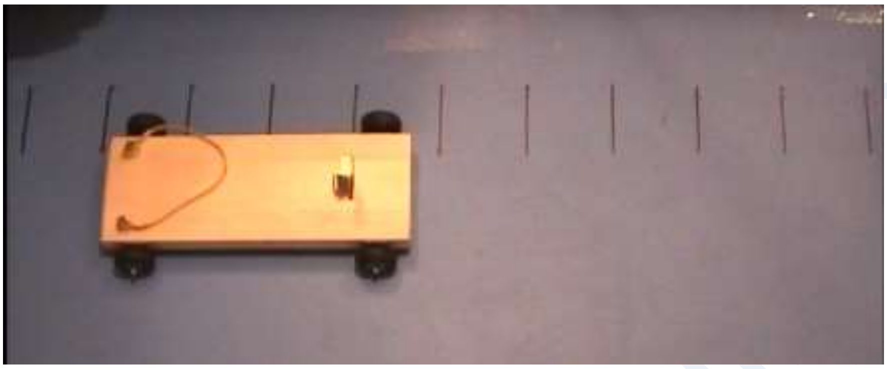
The carriage was placed at the bottom of a sloping board (approximately 5% slope) and the distance travelled observed when 'firing off' 40, 80 & 120gm lead weights.

The elastic is 'stretched' an identical amount for each 'firing', and hence the power available for each 'firing' is the same.

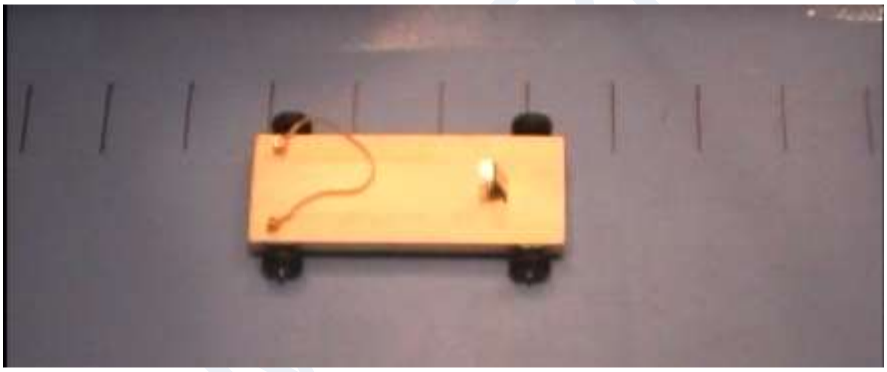
The ‘stills’ below from a video of the test show the results.



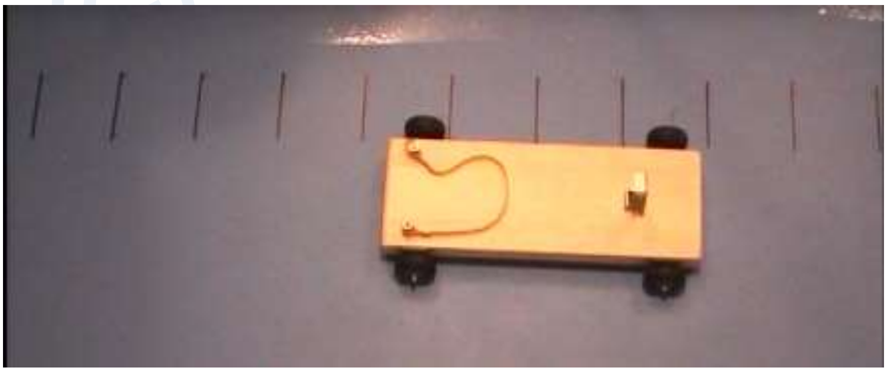
Start Position **Board sloping upwards** →



Finish Position (40gm weight)



Finish Position (80gm weight)



Finish Position (120gm weight)

Although the changes in mass used in the demonstration are many orders of magnitude larger than might be achieved by changing paddle blades, the somewhat non-intuitive relationship between kinetic energy and force can clearly be seen. Hence:-

As long as the paddler is 'comfortable' using the paddle -

It's generally better to use a larger area paddle blade (to shift a larger 'mass' of water), and adjust the paddle 'gearing' by shortening the shaft length (to slow down the acceleration / speed of the water thrown backwards).

Blade Area Considerations

These comments are intended for elite paddlers who are already 'settled' on their paddle length.

Increases in blade area require the paddle shaft be shortened an appropriate amount to allow the paddler to maintain their normal load and cadence*.

It is considered undesirable to reduce the paddle length by more than about 2 cm (1 cm 'each side'), as changes to stroke geometry / dynamics need to be kept to a minimum, to avoid affecting performance in a manner we can't measure (by time trialing). This limits increases of 'effective blade size' to maximum of around 10%. (As an example, the Braca website indicates a Braca I Max has a 10% larger area than Braca IV Max).

Allowing for the appropriate angles, a 2cm shaft reduction is equivalent to the blade being about 8mm further above the water at the catch than previously. To completely eliminate any chance of paddling technique / geometry changes, the paddler could sit 8mm lower, making the boat a little more stable in the process. (We're not actually aware of anyone worrying too much about potential paddling technique / geometry changes when changing seat height by no more than a few cms).

Over the past 18 months a method for comparing the performance impact of varying paddle geometry (*PaddlingScience 'Paddle Design Tool'*) has been developed, based on a significant refinement of the 'Newtonian Approach' mentioned earlier. *The Paddle Design Tool indicates a performance improvement in the order of a third to half a second a minute, associated with a 10% increase in blade size.*

*See article on optimum stroke rate for why a paddler might want to change their normal cadence.