



Oxford Cambridge and RSA

Monday 20 June 2022 – Morning

**A Level in Design and Technology:
Design Engineering**

H404/02 Problem Solving in Design Engineering

Resource Booklet

Time allowed: 1 hour 45 minutes



INSTRUCTIONS

- Use the Resource Booklet to answer all the questions.
- You should spend **35 minutes** reading this Resource Booklet.
- Do **not** send this Resource Booklet for marking. Keep it in the centre or recycle it.

INFORMATION

- This document has **8** pages.

ADVICE

- Read this Resource Booklet carefully before you start your answers.

The stimulus in this booklet relates to issues and opportunities connected with the growth in popularity of paddle boarding.

Stand-up Paddle Boarding (SUP)

SUP has rapidly grown in popularity in recent years, with the global market doubling from 5 billion dollars to 10 billion dollars in the last five years. For most people, SUP is unfamiliar and for many this is enough for them to want to give it a try. It is estimated that 1 million people try SUP in the United Kingdom (UK) each summer. These days, more and more SUP schools are popping up on beaches, lakesides and rivers around the world. While some see it as a new leisure activity to become involved in, others view it as a sport and a challenge to master. SUP has also become a professional sport, attracting large crowds of participants and spectators all over the world.



Fig. 1

Retailers have reported a recent growth in sales of up to 300%, which inevitably leads to supply problems where manufacturers cannot keep up with the demand from customers. Market analysts have warned, however, of the inevitable decline in sales once the market has been saturated and the challenges that come from finding innovative ways of sustaining the demand for stand-up paddle boards.

Along with the increase in the number of stand-up paddle boarders comes concerns for the safety of novice users and the need for adequate training and tuition. There have been reports of people taking to the sea on a stand-up paddle board with little knowledge of tidal currents and inadequate personal protective equipment. Other beach users sometimes complain of stand-up paddle boarders being a danger to swimmers and wandering into areas where jet-skis and boats are operating.

As with any trend, SUP offers real potential for associated products and merchandise, which entrepreneurs are keen to profit from.

The Different Types of Stand-Up Paddle Board

There are several styles of stand-up paddle board, with the main differences between them being their shape and their construction. During the early days of the sport, stand-up paddle boards were similar to surfboards, constructed from a one-piece rigid foam core covered in glass-reinforced plastic (GRP). Many high-end bespoke boards are still made in this way to increase their stiffness. As the popularity has increased, the need to make the stand-up paddle board more portable has given birth to the inflatable stand-up paddle board. Able to be rolled-up and carried in a back-pack and inflated by the user once they reach the water, this has led to more people being able to access the sport.



Fig. 2

Touring Stand-Up Paddle Boards

Typically costing between £700–£2000, these boards have a more pointed nose than other boards and can be narrower than an all-around stand-up paddle board. A touring stand-up paddle board can be used for surfing too and is great for people who want to catch waves and be in rougher water.

All-Around Stand-Up Paddle Boards

This style of board can cost anything between £300 and £2000. These have a much more rounded nose and tend to be shorter and wider, increasing their stability in the water and making them more suitable for beginners. This also makes them easier to learn on whatever the user's age. They can also be used for more advanced techniques such as white-water paddling, racing, surfing, fishing and even yoga.

Correct Stance for SUP

The correct technique for SUP is critical to ensure maximum efficiency through the water and reduce the chance of injury. Common injuries experienced by paddle boarders include back aches due to poor posture and shoulder issues from using incorrect paddle lengths.



Fig. 3

Choice of Paddle

Depending on the ability of the user, using the correct paddle can really enhance the SUP experience. The best paddle will be light enough to be used all day and strong enough to handle any conditions. It should be comfortable and the correct length for the user to enjoy their time on the water. Choosing the correct paddle will also help to protect from any injuries as well as giving maximum comfort and efficiency when paddling.

An efficient paddle should be around 20cm taller than the user's own height. This length can be shortened if surfing in a more crouched stance, which may occur if the user is trying to avoid being blown by the wind.

Blade sizes for adult paddlers should ideally range from 550 cm² to 612 cm². A smaller blade leads to a faster paddling cadence (number of strokes over a period of time), while a larger blade allows for slower but more powerful strokes.

Paddles can be constructed from various materials:

- Aluminium shaft paddles are for beginners. They are cheap but heavy (3 kg). Polymer blades are often attached.
- GRP paddles are lighter and more expensive than aluminium (1.3 kg).
- Carbon/GRP blend paddles can vary in quality and performance substantially.
- 100% carbon fibre reinforced plastic (CFRP) paddles are the most expensive, but they are extremely lightweight (<1 kg) and are the gold standard by most criteria.
- The entire shaft and paddle can also be made from laminated and carved woods such as ash or cedar.

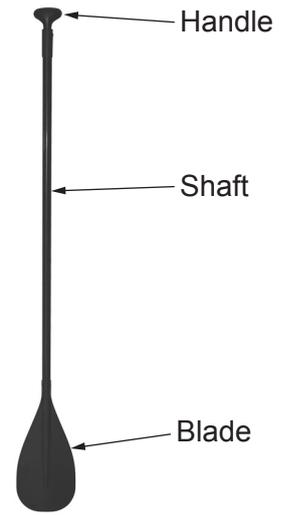


Fig. 4

Various paddle shaft configurations are available. The basic choices are:

- Fixed length (1 piece).
- Adjustable length (2 pieces).
- Adjustable length breakdown paddle (3 pieces) which can be taken apart to fit in the bag with an inflatable stand-up paddle board.

<p>SMALLER BLADE</p>	<p>LARGER BLADE</p>	<p>LONGER NARROWER BLADE</p>	<p>The design of the paddle blade depends on the application. Even with blade area being equal, the tear drop shaped blades are wider at the bottom and produce a more powerful stroke and are good for surf and flat water. Other blade differences include curves both in the tips and sides of the blade directing and increasing water flow speeds.</p>
<p>BEST FOR: Most People SUP Surfing All Around Paddling Endurance</p>	<p>BEST FOR: Strong Paddlers Waves Power</p>	<p>BEST FOR: SUP Racing/Touring High Speed More Power with less effort</p>	

Fig. 5

<ol style="list-style-type: none"> 1 Height 2 Eye level 3 Shoulder height 4 Elbow height 5 Hip height 6 Knuckle height (fist grip height) 7 Finger tip height 8 Vertical reach (standing position) 9 Forward grip reach (standing) 	<p>A line drawing of a human figure from the front. Vertical dashed lines with arrows indicate measurements from the ground to: 1 (top of head), 2 (eye level), 3 (shoulder), 4 (elbow), 5 (hip), 6 (knuckle), and 7 (finger tip).</p>	<p>A line drawing of a human figure in profile. Measurement 8 is the vertical reach from the ground to the top of the head with the arm raised. Measurement 9 is the forward reach from the shoulder to the tip of the hand with the arm extended horizontally.</p>
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Fig. 6

Choosing the Correct Size of Stand-Up Paddle Board

Choosing the correct size stand-up paddle board for the user's size and weight is vital to ensuring stability when riding, especially in open seas.

It is recommended that when standing on a paddle board in sea water the stand-up paddle board should be half submerged allowing for best contact with the water and increased stability. In this position, the stand-up paddle board will displace half of its own volume of sea water.

Archimedes' principle explains that an object floats when the weight of the water it displaces is the same as the weight of the object.

So, users with greater body weight require a stand-up paddle board with a larger volume so that sufficient weight of water is displaced when the stand-up paddle board is half submerged to balance the total weight on the paddle board.

The weight of displaced water is given by the equation:

$$B = \rho Vg$$

where:

- B is the weight of water displaced (N)
- ρ is the density of the water (kg/m^3)
- V is the volume of displaced water (m^3)
- g is the gravitational field strength (N/kg).

Density of sea water is $1025 \text{ kg}/\text{m}^3$

Gravitational field strength $g = 9.81 \text{ N}/\text{kg}$

Fig. 7 contains data for five stand-up paddle boards:

Name	Length (m)	Volume (litres)	Inflation pressure (bar)
Board-12	2.51	160	1.3
Board-13	2.77	165	1.1
Board-14	3.20	185	1.0
Board-15	3.40	217	0.8
Board-16	3.81	250	0.8

Fig. 7

Inflating a Stand-Up Paddle Board

The two main ways to inflate a stand-up paddle board are with a hand-operated pump or by using a purpose designed 12V electric pump, such as the NW20 air pump shown in **Fig. 8**.

The manufacturer of the NW20 air pump provides a performance graph to show how the pump raises the pressure inside a 100 litre vessel, plotted against time. The performance graph is shown in **Fig. 9**.



Fig. 8

Performance graph for NW20 air pump filling a 100 litre vessel

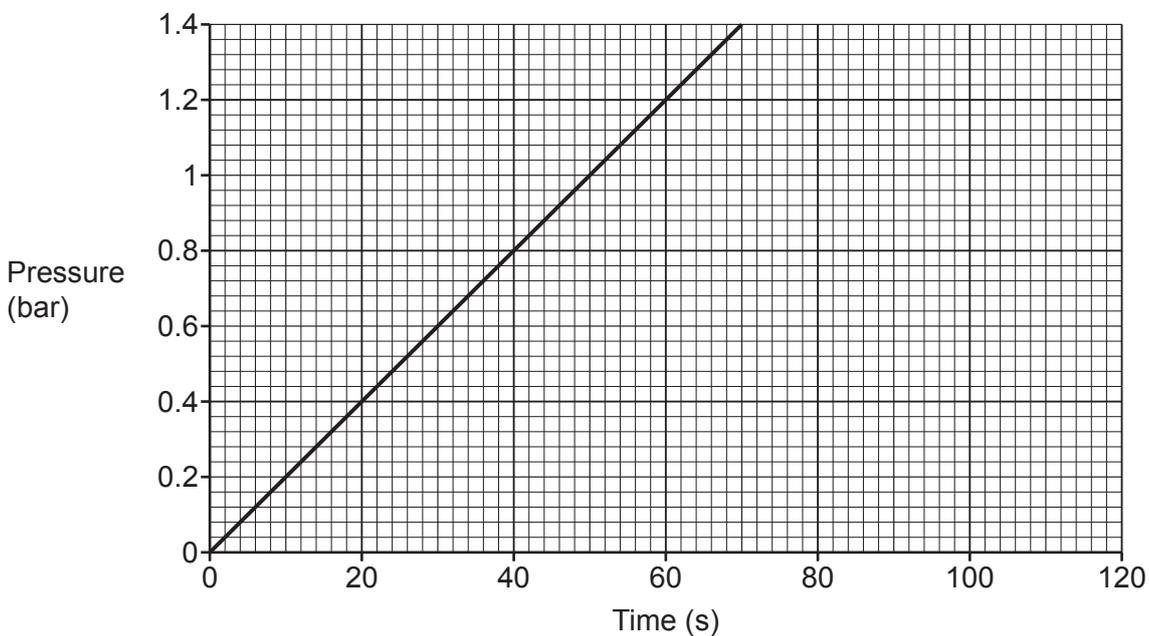


Fig. 9

The NW20 air pump is powered from a 12V car battery. The specification for the air pump is shown in **Fig. 10**.

Operating voltage	12V
Operating current	10 000 mA
Filter	Dual filter
Inflation range	0–1.5 bar
Max pumping rate	2.3 litres/sec

Fig. 10

Energy is calculated as Energy $E = \text{power } P \times \text{time } t = \text{voltage } V \times \text{current } I \times \text{time } t$

The Paddle Board (PB) Speedometer

The PB Speedometer is a proposed electronic device intended to give the user an indication of their speed through the water whilst using a stand-up paddle board. The PB Speedometer will consist of a speed sensor, a microcontroller and a display.

The output display will use the multi-coloured 5-LED bar graph shown in **Fig. 11**.

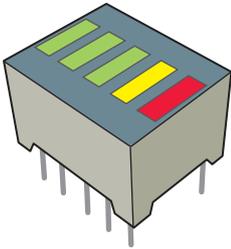


Fig. 11

In operation, the LED lights will turn on incrementally, starting with a single green LED at low speed. When the stand-up paddle board is travelling at high speed, all the LEDs will be lit.

The PB Speedometer will use a GENIE-14 microcontroller. The circuit symbol for the GENIE-14, the input/output and power connections are shown in **Fig. 12**.

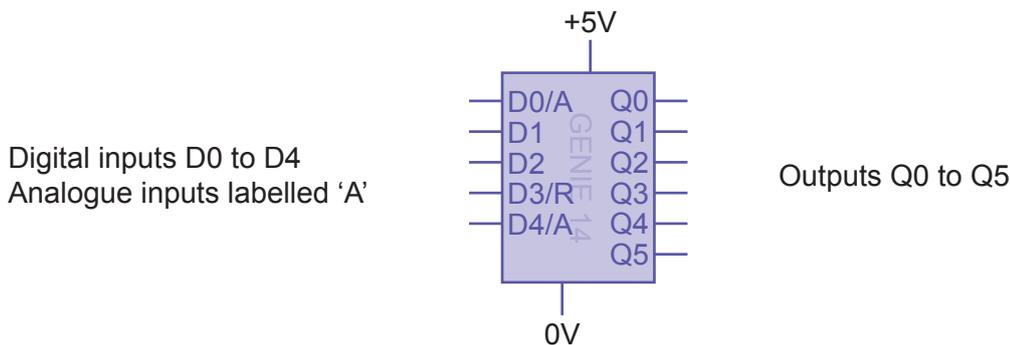


Fig. 12

Driving Development

Companies need to gain investment when developing a product. The method of investment needs to be appropriate for the product's market. The amount a company expects to invest and the expected return are also important considerations. Many successful companies have used a variety of entrepreneurial strategies to set themselves up and gain investment to develop their products further. This is demonstrated in the popular BBC programme, Dragons' Den, where start-up companies pitch for the investment and expertise of established companies.

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