PORT REVEL Shiphandling

UNIT 1 – Monday morning

SIMILARITY PRINCIPLES

Video Scales

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Many famous scientists, hydraulics engineers and naval architects have been relying on scale model tests for decades, and especially towing tank tests. These concerned the ships, however, not the men handling them, and the idea of training pilots and ships' masters on scale models was initiated in the sixties.

Similitude is not a vague approximate likeness, but has a very definite, precise meaning.

Although the similitude conditions discussed here may seem complicated, they are in fact quite simple and **intuitive**, being based on natural physical laws.

35 years of experience have shown that students quickly get the feel of their models in the same way as the real ships they are accustomed to handling; this is really the way to get fully effective results from the Course at Port Revel.

There are several aspects of similitude, which we shall now consider in turn.

SCALES
Length

$$\text{LENGTH} = S_L = \frac{1}{25}$$

$$\text{AREA} = S_A = \left(\frac{1}{25}\right)^2 = \frac{1}{625}$$

$$\text{VOLUME} = S_V = \left(\frac{1}{25}\right)^3 = \frac{1}{15.625}$$

N.B. : The block coefficient is not affected by the scale factor

Prototype / EUROPE	Model ship / EUROPE
Lpp = 1075’ (330 m)	l = 43’ (13 m)
B = 170’ (52 m)	b = 7’ (2 m)
D = 66 ’ (20 m)	d = 2.6’ (0.80 m)

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A model has exactly the same shape as the real ship. In other words, all the dimensions of the latter, e.g. its length, breadth, draught, etc. are divided by the same factor to give the model dimensions. This factor is called the "scale factor" $S_{(L)}$, the value of which is 25 in the case considered here, i.e. **the scale is 1/25**.

A point to note here is that ratios, such as L/B, L/d, or the block coefficient, are the same on both the model and ship. And, as angles are length ratios, they are the same as well.

SCALES
Mass

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MASS (Volume × Density) : $S_M = S_V \times 1$

N.B. : density is the same for the prototype and the model

$S_d = 1$

Prototype/EUROPE	**Model ship**
Displt : 290 000 t	**Displt : 18.6 t**

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A model ship to be used for training not only has to look like the real ship, but it must move like her as well (if subject to similar forces).

The scale factor for mass and displacement is the same as for volumes, as sea water and the water in our lake have very nearly the same specific gravity.

Hence : $S_{(M)} = S_{(L)}{}^3 = 25^3 = 15{,}625$

SCALES
Time

According to FROUDE Law :

$$S_{time} = \sqrt{S_L} = \sqrt{\frac{1}{25}} = 1/5$$

Everything happens five times faster

Prototype	Model ship
60 min	12 min
30 sec (rudder)	6 sec

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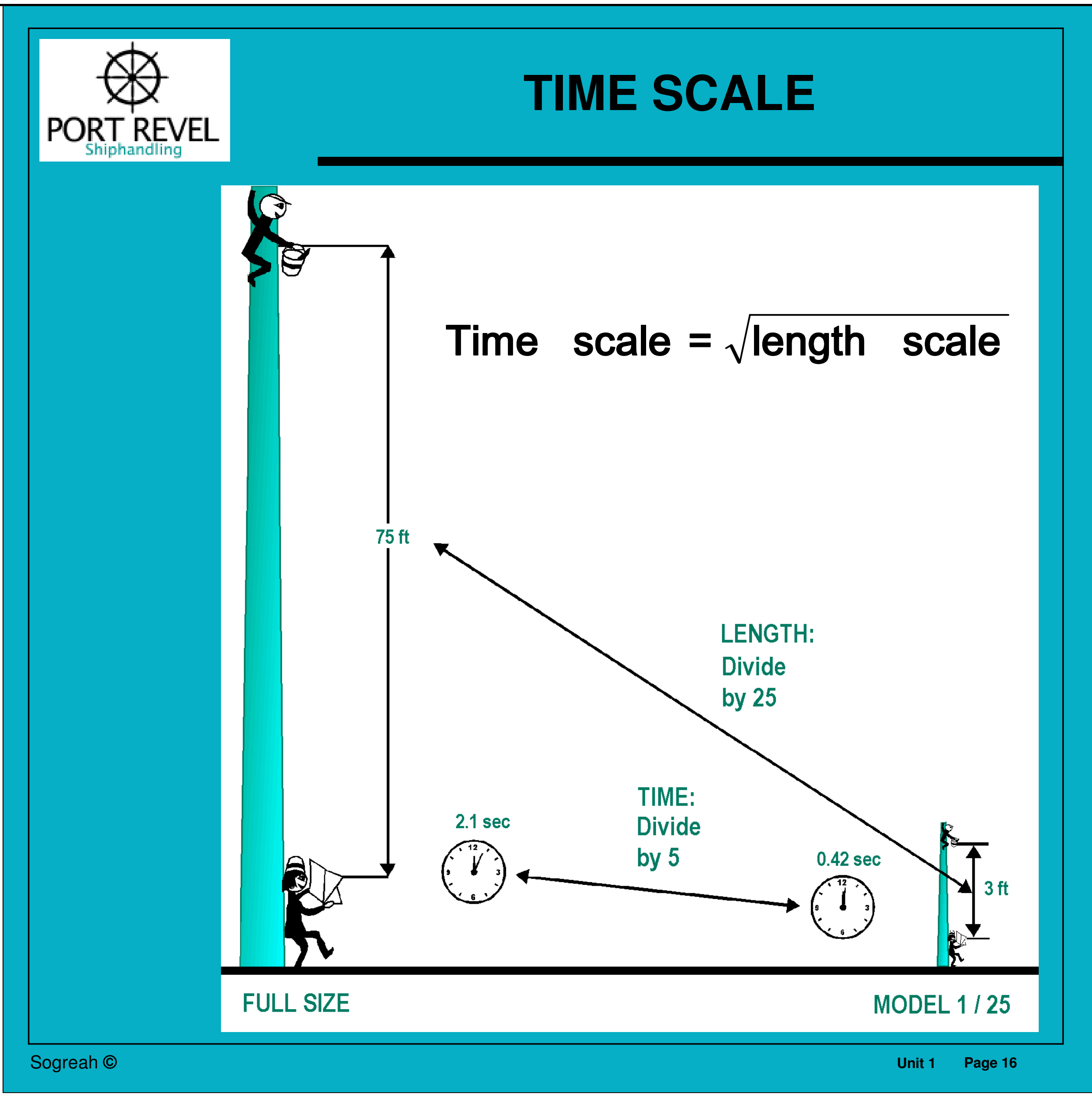
As the velocity scale is the square root of the length scale (according to Froude's law) the **model motions are five times slower** than the real thing, and, consequently, time is five times shorter than in nature.

Because of the time reduction on the model, the Master has to react about five times as fast as in real life, for the model equipment is adjusted to respond that much faster. Experience has shown, however, that students, by and large, very soon get used to this, one reason being that the time reduction is partly offset by a corresponding increase in the ship's angular velocity; the student feels angular motion and senses a change in heading much sooner on the model than on a real ship.

To sum up, therefore, **students will be expected to react faster on the models, but they will also be informed of what is happening sooner than on a real ship**.



If a man painting up the 75 foot topmast of the real ship drops his can of paint, the fellow reading his paper on deck underneath will get the paint all over him exactly 2.1 seconds later.

On a model with a mast 25 times shorter, i.e. 3 feet tall, we know both from elementary physics and experience that the "model man" at the foot of the man will get the can on his head 0.42 seconds after it was let go, i.e. in 1/5th of the full-scale time, not $1/25^{th}$.

TIME SCALE CALCULATOR

Prototype

$D = 0.5 \times g \times T^2$

Model ship

$d = 0.5 \times g \times t^2$

$$D = 25\,d$$

$$0.5 \times g \times T^2 = 25 \times 0.5 \times g \times t^2$$

$$T^2 = 25\,t^2$$

$$T = 5\,t$$

$$\frac{T}{5} = t$$

$1^{hour} \rightarrow 12$ min

~6 days x 6^{hours} x 5 = 180^{hours} manoeuvring in real life

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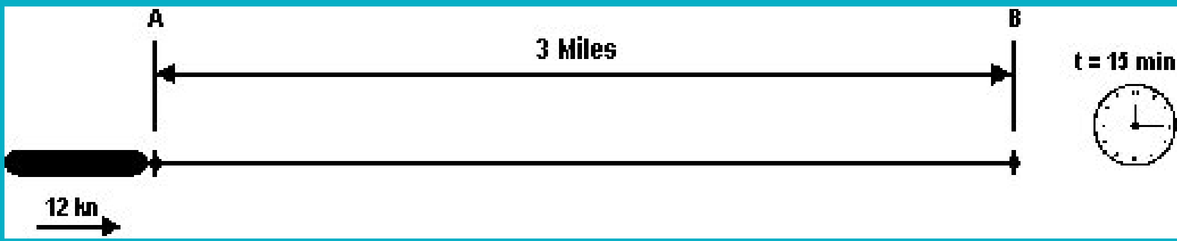
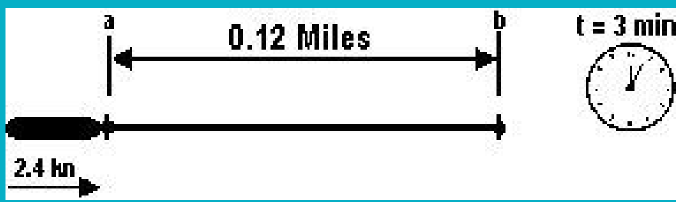
SCALES
Speed

$$S_{speed} = \frac{S_L}{S_t} = \frac{\frac{1}{25}}{\frac{1}{5}} = \frac{1}{5}$$

The behaviour of the model at 2 kn is the same as that of the prototype at 10 kn

SHIP UNDER WAY





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To illustrate the application of these various scales, we shall consider a 190,000 DWT **ship under way** maintaining a constant full speed of 12 knots at 65 r.p.m. (Fig. 2). It will thus cover 3 miles (about 18 ship's lengths) in 15 minutes.

The corresponding distance equivalent to 18 ship's lengths for the "BRITTANY" model is only of 0.12 mile (= 3/25), (i.e. roughly the length of the lake), which the model covers in about 3 minutes (15/5) at a speed of 12/5 = 2.4 knots at 65 x 5 = 325 r.p.m.

SCALES
Acceleration

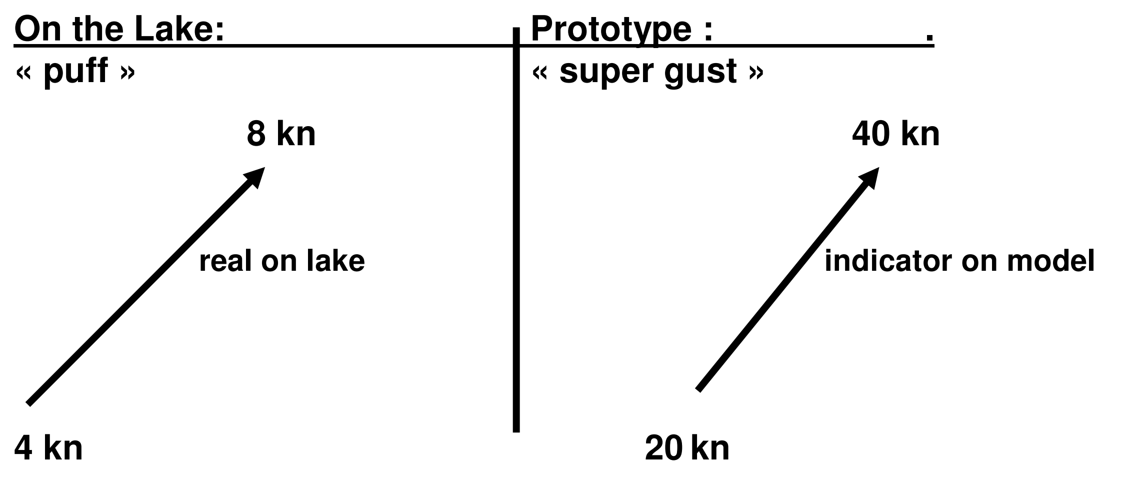
$$S_{acceleration} = \frac{S_{speed}}{S_{time}} = \frac{1/5}{1/5} = 1$$

Acceleration is unchanged.

N.B. : Also valid for "acceleration of gravity"

SCALES
Wind speed (Natural wind)

The model ship subjected to a 4 kn wind on the lake has the same behaviour as the prototype subjected to a 20 kn wind.



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Regarding wind, it should be borne in mind that owing to the speed factor of 5 a given wind speed on the lake is equivalent to one five times greater at sea. For example, a 10-knot wind on the lake will have the same effect on the model as a 50-knot wind on the real ship. Consequently, ripples on the water or leaves moving in the trees are not a reliable indication of wind strength.

It must be noted also that similarity of gusts is not perfect: a puff on the lake reproduces a « super gust » as the increase from 20 kn to 40 kn of the example above will take place in a somewhat unrealistic short time. This is a so-called « scale effect ».

SCALES
Angle

$$S_{angle} = \frac{S_{bow}}{S_{radius}} = \frac{1/25}{1/25} = 1$$

The angular view is unchanged

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SCALES
Angular velocity

$$S_{\text{angular velocity or rate of turn}} = \frac{s_{\text{angle}}}{s_{\text{time}}} = \frac{1}{1/5} = 5$$

The rate of turn is **five times larger**

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Angular motion is five times faster on the model, e.g. the following:

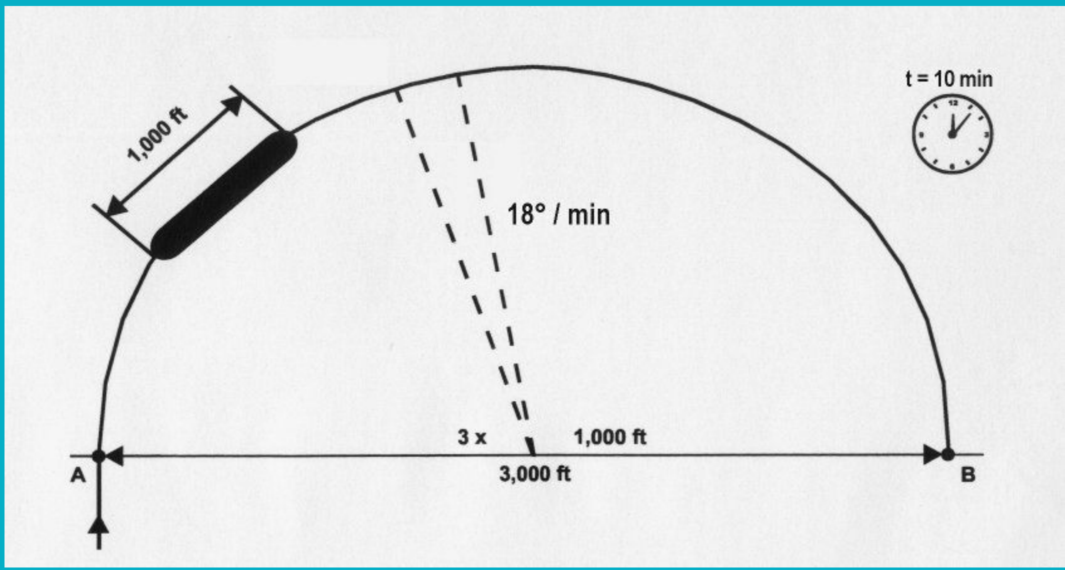
– angular rudder rate,

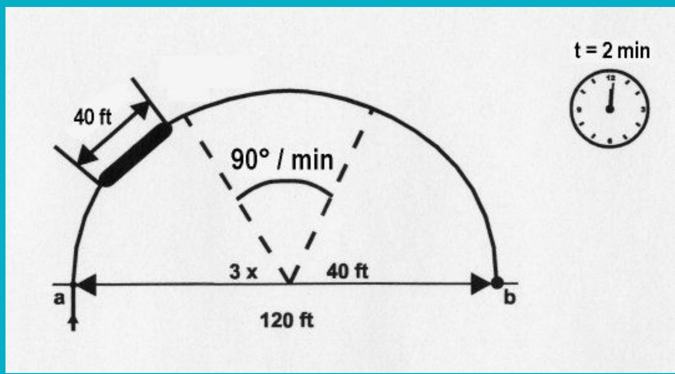
– ship's turning rate for a given rudder angle,

– yaw,

- r.p.m. (but the dials on the model give readings in real life).

RATE OF TURN





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Turning is another example. Supposing the same rudder angles (40°) are set simultaneously on the 190,000 ton tanker and the model travelling at 12 kn and 2.4 kn respectively; after 10 minutes, the real ship will have turned through 180 degrees, with a tactical diameter of about 3 ship lengths, i.e. 3,000 feet, whereas the model will only take 2 minutes (10/5) to turn through the same angle, with the same 3 ship length tactical diameter, but equivalent to 120 feet (3,000/25). The real ship's angular turning rate works out at 18 degrees/min, compared to 90 degrees/min (18°/min x 5) for the model.

Note that the Rate of Turn indicator on the Europe is at full scale, like all other instruments onboard.

SCALES
Force

FORCE (Mass × Gravity) : $S_F = S_M \times 1$

N.B. : Gravity is the same everywhere : $S_g = 1$

Hence : $S_F = S_V = 1/15.625$

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If in addition to shape, mass and inertia, the forces causing ship motion are "similar", the motion will also be "similar".

Such forces are caused by sea or weather conditions, e.g. wind, current and waves or are generated by the ship herself, e.g. propeller thrust, rudder moment, or else they may be due to hydraulic effects caused by the sea bed or a canal bank. They will be correctly reproduced if they are to the same scale as mass.

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SCALES
Power

$$S_{power} = \frac{S_{force} \times S_{length}}{S_{time}}$$

$$S_{power} = S_{force} \times S_{speed} = \left(\frac{1}{25}\right)^3 \times \left(\frac{1}{25}\right)^{0.5}$$

$$S_{power} = \frac{1}{25}^{3.5} = \frac{1}{78.125}$$

Prototype/EUROPE	Model Ship
F.S.S. = 32.000^{HP}	F.S.S. = 0.41^{HP}
F.M.S.= 16.000^{HP}	F.M.S. = 0.20^{HP}
F.Ast = 7 800^{HP}	F.Ast = 0.10^{HP}

CALCULATION OF THE SCALE FACTOR OF POWER

$$Power = \frac{Work}{Time}$$ a work is a Force x length

$$Power = \frac{F \times L}{T}$$ a Force is a Mass x accelerati on (δ)

$$Power = \frac{M \times \delta \times L}{T}$$ a Mass is a Volume x density

$$Power = V \times d \times \frac{S}{T} \times \frac{L}{T}$$ an Accelerat ion is a Speed divided by Time

$$P = V \times d \times S \times L \times \frac{1}{T^2}$$ P = Master

$$p = v \times d \times s \times l \times \frac{1}{t^2}$$ p = model

$$p = \frac{V}{25^3} \times 1 \times \frac{S}{5} \times \frac{L}{25} \times \frac{1}{\left(\frac{T}{5}\right)^2} = V \times S \times L \times \frac{1}{T^2} \times \frac{1}{25^3} \times \frac{1}{5} \times \frac{1}{25} \times 25$$

$$p = P \times \frac{1}{25^3} \times \frac{1}{5} = \frac{P}{5 \times 15625} \times \frac{P}{78125}$$

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CALCULATION OF THE SCALE FACTOR OF FORCE

$$F = M \times acceleration = M \times \frac{S}{T}$$

$$f = m \times \frac{s}{t} = \frac{M}{25^3} \times \frac{S}{5} \times \frac{5}{T}$$

$$f = M \times \frac{S}{T} \times \frac{1}{25^3} = \frac{F}{15625}$$

$$1\,Kg = 15.6\,Tons$$

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CHANGE THE SCALE …

SHIP	LENGTH (m)			POWER (SHP)		
	1/25	1/36	1/16	1/25	1/36	1/16
Pembroke	159	229	102	6 400	22 932	1 342
Berlin	201	289	129	17 500	62 706	3 670
Grenoble	191	275	122	17 500	62 706	3 670
Gilda	269	387	172	24 000	85 996	5 033
Brittany	305	439	195	32 000	114 662	6 711
Europe	329	474	211	32 000	114 662	6 711
Antifer	337	485	216	45 000	161 243	9 437
Ben Franklin	256	369	164	32 000	114 662	6 711
Normandie	261	376	167	52 000	186 325	10 905

Most ships of the fleet are quite realistic at other scales.

However, Antifer and Normandie have too much power at scale 1/36, as is not considered realistic to have much more than 100 000 HP on a single screw ship.

Do not forget about the time scale: 1/6 at length scale 1/36, and 1/4 at scale 1/16.

CAUTIONS

Forget everything about scale and similarity,

and believe you are on a ship :

- compare the distance with the length or width of the ship
- have a look abeam and check the log
- keep the cover (cockpit) closed (wind)
- do not stand up to see better
- do not argue with your partner
- do not use steady as she goes
- do not use the stern thruster (barring emergency)
- use the bow thruster only for docking and undocking
- do not use the Y bow thruster (Gilda) after a grounding

- in case of trouble (rudder or engine failure) blow 3 long blasts

- in case of danger for the propeller or rudder (buoy, pier, stones, etc) :
  1. put the telegraph on stop
  2. put the wheel amidships
  3. then switch off the main engine