

FIFTH EDITION

INTRODUCTION TO NAVAL ARCHITECTURE

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Butterworth-Heinemann is an imprint of Elsevier.
The Boulevard, Langford Lane, Kidlington, Oxford, OX5 1GB
225 Wyman Street, Waltham, MA 02451, USA

First published as *Naval Architecture for Marine Engineers*, 1975

Reprinted 1978, 1981

Second edition published as *Muckle's Naval Architecture*, 1987

Third edition published as *Introduction to Naval Architecture*, 1996

Revised reprint 2000

Fourth edition 2004

Fifth edition 2013

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British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library

Library of Congress Cataloguing in Publication Data

A catalogue record for this book is available from the Library of Congress

ISBN: 978-0-08-098237-3

For information on all Elsevier Butterworth-Heinemann publications visit our website at <http://books.elsevier.com>

Typeset by MPS Limited, Chennai, India

www.adi-mps.com

Printed and bound in Great Britain

13 14 15 16 10 9 8 7 6 5

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is $IB^3/12$. With a centre division the sum of the second moments of area of the two tanks is $(I/12)(B/2)^3 \times 2 = IB^3/48$. The introduction of a centre division has reduced the free surface effect to a quarter of its original value. Using two bulkheads to divide the tank into three equal width sections reduces the free surface to a ninth of its original value. Thus subdivision is very effective and it is common to subdivide the double bottom of ships. The main tanks of ships carrying liquid cargoes must be designed taking free surface effects into account and their breadths are reduced by providing centreline or wing bulkheads. Some particulate cargoes, such as grain, carried in bulk can move as the ship heels causing a similar effect to a free surface as discussed later.

Free surface effects must be taken into account in ship design and operators must be aware of their significance and use the tanks in ways intended. Both transverse and longitudinal stability will be affected. The importance of free surfaces to a ship's stability was shown by the loss of the *Herald of Free Enterprise* in 1987. In this case the free surface was that of water entering through the bow doors and covering the vehicle deck.

THE INCLINING EXPERIMENT

As the position of the centre of gravity is so important for stability it must be established accurately for the ship as completed. During design it is determined by calculation by considering all weights making up the ship — steel, outfit, fittings, machinery and systems — and assessing their individual centres of gravity. These data lead to the displacement and centre of gravity of the lightship. For particular conditions of loading the weights of all items to be carried must then be added at their appropriate centres of gravity to give the loaded displacement and centre of gravity. There are many fittings in a ship and it is difficult to account for all items accurately in such calculations, and the lightship weight and centre of gravity are measured experimentally.

The experiment, the *inclining experiment*, involves causing the ship to heel to small angles by moving known weights known distances transversely across the deck and observing the angles of inclination. The draughts of the ship are noted together with the water density. Ideally the experiment is conducted when the ship is complete, but this is not generally possible. There will usually be a number of items both to go on and to come off the ship (e.g. staging and tools). The weights and centres of gravity of these must be assessed and the condition of the ship as inclined corrected.

A typical setup is shown in Figure 5.4. Two sets of two weights, all of w , are placed on each side of the ship at about amidships, the port and starboard sets being h apart. Set 1 is moved a distance h to a position