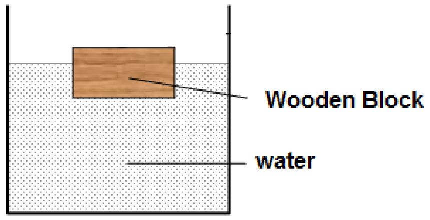
Tutorial 4 Forces

Self-Review Questions (Suggested Solutions)

S1. (a) The net force acting on the wooden block is zero (it is in translational equilibrium).



(b) The weight of the wooden block is

$W = mg = \rho_{block} V_{block} g$

$= (400)\ (0.030)\ (9.81) = 118$ N (down)

(c) By the principle of flotation,

|upthrust acting on block| = |weight of block|

Hence, the upthrust on the block is 118 N (upwards)

(d) Since the upthrust exerted by the water is $U = \rho_{water} V_{water} g = 118$ N,

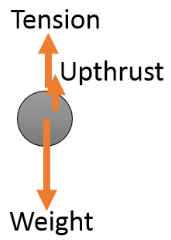
$$U = \rho_{water} V_{water} g$$
$$118 = (1000)\ V_{water}\ (9.81)$$
$$V_{water} = 0.012 \text{ m}^3$$

S2. Answer: **C**

Option E is wrong, because the pressure is the highest at the bottom of the container: at $x = 0$, p is the largest. Options A and B are wrong because above liquid L, there is atmospheric pressure and should not be assumed to be at zero pressure.

Recall that the pressure p in a liquid increases as $p = h\rho g$, where h is the depth below the liquid surface, ρ is the liquid's density, and g is the gravitational acceleration. Since liquid M is denser than liquid L, the pressure will change more rapidly with depth in M.

S3. By Newton's Second Law, taking upwards as positive,



$F_{net} = ma$

$T + U - W = 0$

$T = mg - V\rho g$

$= (0.180)\ (9.81) - (0.180 / 8000)\ (800)\ (9.81)$

$= 1.59$ N,

where $V = (0.180 / 8000) = m_{iron} \rho_{iron}$ is the volume of the iron object.

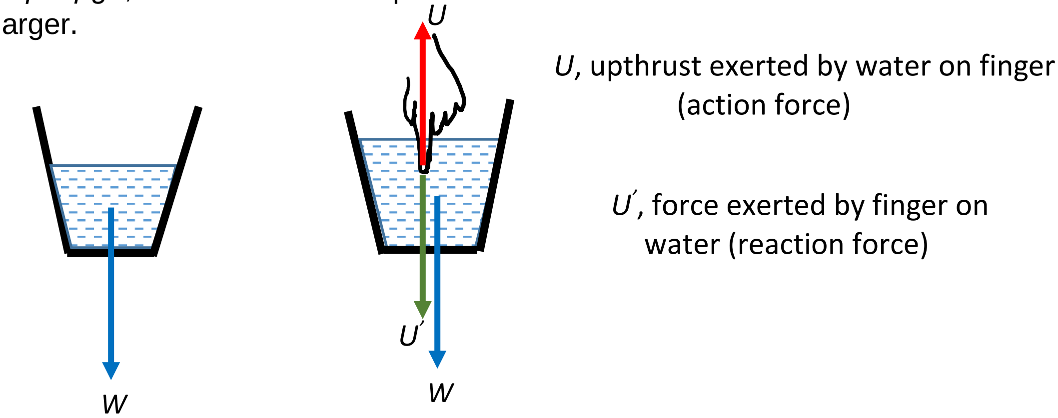
S4. Answer: **C**

Consider the forces that act on the cup with water. Before the finger is inserted into the water, there are only two forces, the weight of the cup with water W_{water} and the normal contact force by the weighing scale on the cup with water N: initially, $N = W_{water}$.

With the finger in the water, since water exerts an upthrust U on the finger, by Newton's Third Law, the finger exerts a downward force U' on the water. As the cup with water is still in equilibrium, we now have $W + U' = N'$, where N' is the new normal contact force.

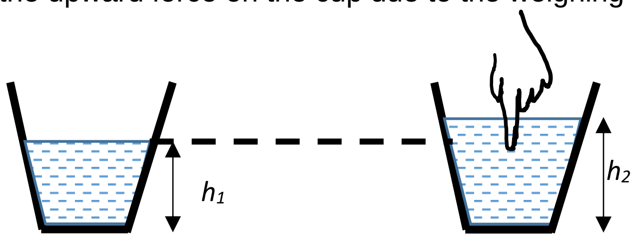
Hence, we find that $N' > N$. The reading on the weighing scale N' is equal to the magnitude of the force that the weighing scale exerts on the cup with water. Hence, with the finger in the water, the reading is $N' = W_{water} + U$.

Alternatively, note that, with the finger dipped into the water, the water level in the cup is higher. Since $p = \rho gh$, this means that the pressure due to the water at the bottom of the cup is now larger.



Reading = W, weight of water	Reading = $W + U'$ weight of water

As $p = F/A$ and the area is fixed, the force due to the water pressure acting downward on the bottom of the cup is now also larger. Since the cup is still in equilibrium, this means that the upward force on the cup due to the weighing scale must also be larger.

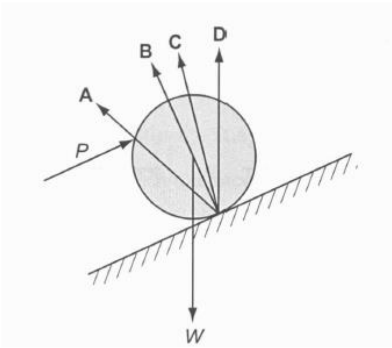


$$p_1 = \rho g h_1 \quad < \quad p_2 = \rho g h_2$$

$$F_1 = p_1 A \quad < \quad F_2 = p_2 A$$

S5. Answer: **C**

Since the barrel is in rotational equilibrium, the net moment about the centre of mass must be zero. Since its weight produces no moment and the force *P* produces a clockwise moment, the remaining force by the ramp on the barrel must generate an anticlockwise moment. Hence, the answer cannot be A or B.



Since the barrel is in translational equilibrium, the net force on it is zero. For option D, force *P* would be the only force with a horizontal component and the barrel would not be in translational equilibrium (horizontally).

or

If three non-parallel forces act on an object and the object is in equilibrium, the lines of action must pass through a single point. The line of action of C passes through the point where *P* and *W* intersect.

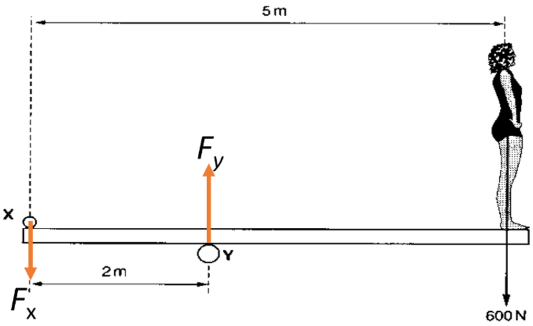
(Note that the force indicated by C is the vector sum of the frictional force and the normal contact force exerted by the ramp on the barrel.)

S6. Answer: **D**

Take moments about x,

$$\text{Sum of anticlockwise moments} = \text{Sum of clockwise moments}$$
$$F_y \times 2 = 600 \times 5$$
$$F_y = 1500\text{ N upwards}$$

Since $\sum F_{\text{vertical}} = 0$,
$F_x = 1500\text{ N} - 600\text{ N} = 900\text{ N downwards}$



S7. (a) The mass in the boat is not uniformly distributed. Based on the figure, more mass is present on the left hand side of the boat.

(b) The net force acting on the boat must be zero as the boat is being lifted with a constant speed upwards (translational equilibrium). The net torque on the body about any point must be zero to ensure that the boat does not rotate as it is being lifted upwards (rotational equilibrium).

(c) Taking moments about point P,
total clockwise moment = total anticlockwise moment,
T_1 (2.00) = (15000) (1.25) → T_1 = 9375 N = 9380 N (3 s.f.)
Taking moments about O,
total clockwise moment = total anticlockwise moment,
(15000) (0.75) = T_2 (2.00) → T_2 = 5625 N = 5630 N (3 s.f.)
Sanity check:
$T_1 + T_2$ = (9375) + (5625) = 15000 N = weight of boat (vertical equilibrium)

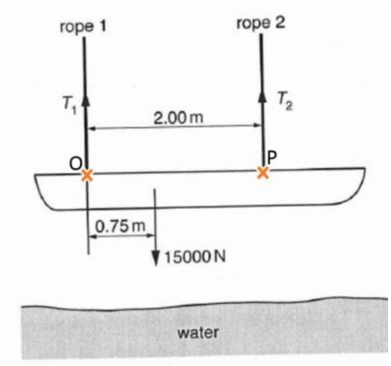


Fig. 3.1