TOPIC 4: FORCES QUIZ **Time: 30 minutes** **Score: /19**

Name:_____ **CG:** _____

1 Forces act along the edges of a square as shown in Fig. 1 below.

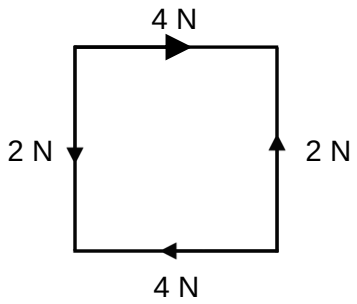


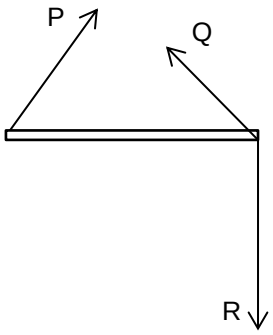
Fig. 1

The simplest system to which these forces are equivalent is

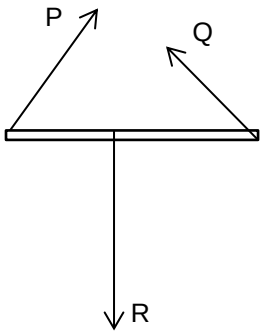
A a single force
B a single couple
C a resultant force and a couple
D two couples

2 A light rod is acted upon by three forces P, Q, and R. Which diagram could show the position and direction of each of the forces when the rod is in equilibrium?

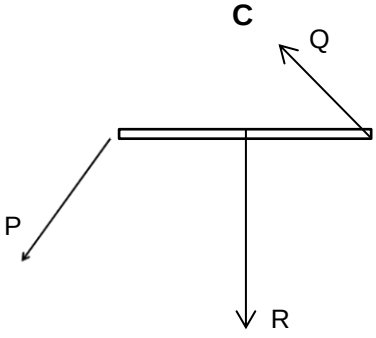
A



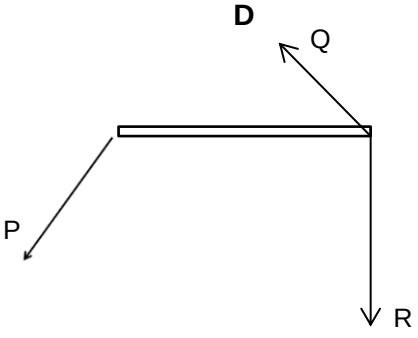
B



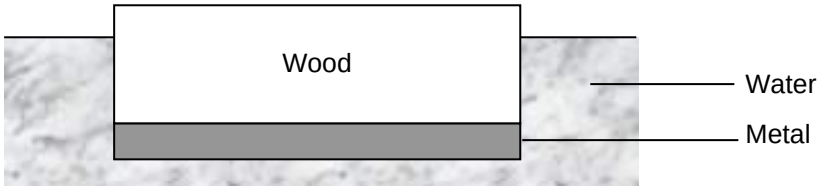
C



D



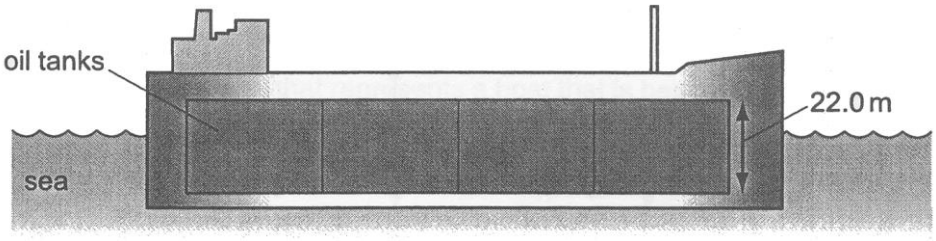
3 A cuboid is made of a piece of metal of density 3000 kg m^{-3} and a piece of wood of density 400 kg m^{-3}. The cuboid is submerged in water of density 1000 kg m^{-3} as shown in the diagram. 20% of the cuboid remains above the water line.



Calculate the percentage of the volume of the cuboid that is made of wood.

percentage = …… % [3]

4 An oil tanker, with vertical sides, has an external cross-sectional area of 36500 m^2 in the plane of the sea.



The tanker carries oil of density 930 kg m^{-3} in its tanks, which have a constant cross-sectional area of 34,000 m^2 and depth 22.0 m. Sea water has density 1030 kg m^{-3}.

Calculate the rise in height of the tanker when it unloads 60% of the oil.

rise in height = ……………………… m [2]

5 In Fig. 5.1 below, **AB** represents the raised bonnet of a car, hinged freely at **A**. The bonnet is of mass 12 kg and its weight acts through the point **G** at its midpoint.

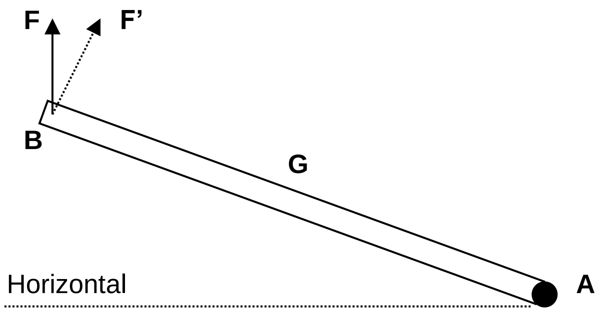


Fig. 5.1

(a) Calculate the value of the vertical force **F** that will just maintain the position of the bonnet.

F = ………………………… N [2]

(b) Explain why it is easier to raise the bonnet by applying a force **F'** in the direction shown than by applying the force **F**.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………[1]

6 Fig. 6.1 shows a simplified catapult used to hurl projectiles a long way.

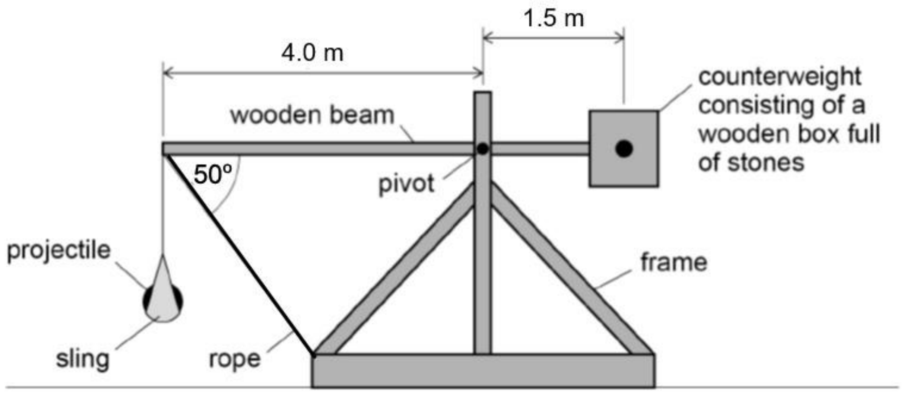


Fig. 6.1

The counterweight is a wooden box full of stones attached to one end of the beam. The projectile, usually a large rock, is in a sling hanging vertically from the other end of the beam. The weight of the sling is negligible.

(a) The catapult is designed so that the weight of the beam and the weight of the *empty* wooden box have no effect on the tension in the rope.

Suggest how the pivot position achieves this.

……..

……..

……..…

……. [2]

(b) The stones in the counterweight have a mass of 610 kg and the projectile weighs 250 N. The beam is held horizontal by a rope attached to the frame.

Calculate the tension in the rope.

tension = ……... N [3]

(c) For equilibrium to be reached, there is another force *R* acting on the beam at the pivot.

1. Sketch and label this force *R* on Fig. 6.1. [1]

2. Calculate the magnitude of the force *R*.
You may assume that the weight of the beam and empty box is negligible compared to the other forces.

R = ... N [4]

Forces Quiz Solutions

1 **Ans: B**
Net force in all directions is zero.
Net clockwise moment.

Therefore a single couple is the simplest system.

2 **Ans: B**
For it to be in equilibrium, the lines of action of the 3 forces must pass through a common point, only B and C satisfy this condition. C is wrong because there is an unbalanced leftward horizontal force.

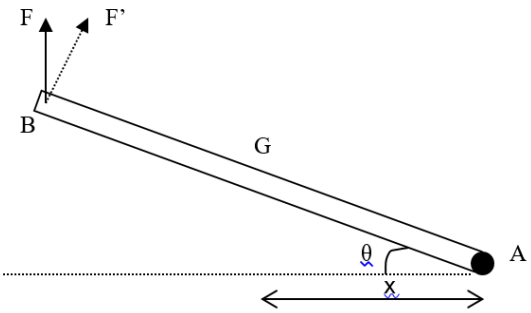
3 Let w be the percentage of volume from wood.

Density of the cuboid, $\rho_c = 3000(1-w) + 400w = 3000 - 2600w$ [1]

Since the cuboid is in equilibrium,
Weight of cuboid = Upthrust
$Mg = V\rho_f g$, where V is the volume of cuboid submerged = $0.8V_c$ [1]
$V_c\rho_c g = 0.8V_c\rho_f g$
$3000 – 2600w = 0.8(1000)$
$2200 = 2600w$
$w = 0.846 = 84.6\%$ [1]

4 Reduction in upthrust = reduction in weight of ship and load
$36500 \times h \times 1030 \times g = 0.6 \times 34000 \times 22 \times 930 \times g$ [1]
$h = 11.1$ m [1]

5



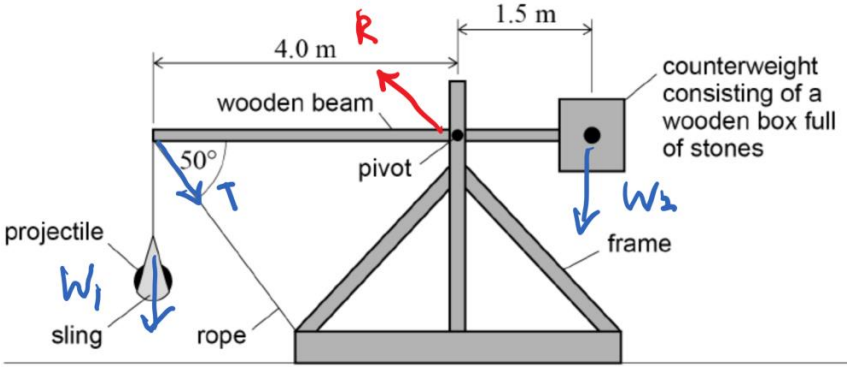
(a) By the Principle of Moments,
$(F)(2x) = (mg)(x)$, $m = 12$ kg [1]
$F = \underline{58.9\ N}$ [1]

(b) Since perpendicular distance of line of action of F' from A is larger than that of F, and anti-clockwise moment due to weight is constant, thus, F', will be less than F. [1]

6 **(a)** The centre of mass/gravity of the beam and box is at the pivot. [1]
For equilibrium, sum of the moments is zero about this position but the weight of the beam and box will not provide any moment. [1]

(b) Take moments about pivot, Clockwise moment = Anticlockwise moment [1]
$610 \times 9.81 \times 1.5 = 250 \times 4 + T \sin 50 \times 4.0$ [1]
$T = 2600$ N [1]

(c) **1.**



2. Assume that the weight of the beam and empty box is negligible compared to the other forces.

Balance forces in the x and y directions, (refer to free body diagram above)

$R_x = T \cos 50^o = 2600 \cos 50^o = 1671$ N [1]
$R_y = W_1 + W_2 + T\sin 50^o = 250 + 610\times 9.81 + T\sin 50^o = 8230$ N [1]
$R = (1671^2 + 8230^2)^{1/2}$ (use of Pythagoras theorem) [1]
$= 8400$ N [1]