Name: **Index No:**

Date: **Class:**

Assignment 04b: Newton's laws of motion (IP)

1. (a) The metal head of a hammer is loose. To tighten it, it is being dropped down onto a table.

To do so **most efficiently**, should we

- drop the hammer with handle end down,
- drop the hammer with the head down, or
- either way will give us the same results? Explain your answer. [2]

Drop hammer with handle down. [1]

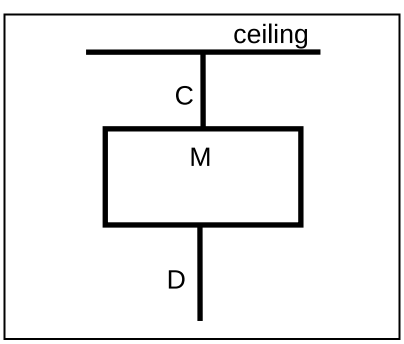
[1]: Either one explanation below

When the handle hits table, it suddenly stops moving but the inertia of the hammer head causes the head to continue moving. Since the hammer head has a greater mass, it moves more downward and tightens the head to handle more efficiently.

Or

When the head hits the table, it suddenly stops moving but the inertia of the handle also causes the handle to continue moving. Since the hammer handle has a smaller mass, it moves downward to a smaller extent and tightens the head to the handle less efficiently.

(b) An inelastic cord C is suspended from the ceiling on one end and tied to a block of mass M on the other end. Another cord D is attached to the bottom of the block.



Explain, using Newton's 1st law, why *"If you give a sudden jerk to D, it will break first, but if you pull D with a gradually increasing force, C will break first"*. [2]

If a sudden jerk is given to D, inertia of M prevents M from moving. Tension in string at D (or pull force acts on D only) will cause D to break.

If D is pulled with a gradual increasing force, M tends to move. Tension in string at C is equal to applied force and weight of M will cause C to break instead.

2. A 110 kg motorbike carrying a 50.0 kg rider coasts to a stop in 51 m. It was originally travelling at 15 m s^{-1}. Calculate the braking force exerted by the road on the motorbike and rider. [3]

$v^2 = u^2 + 2a(\Delta s)$

$0 = (15 \text{ m s}^{-1})^2 + 2a(51 \text{ m})$ [1]

$a = -\ 2.2 \text{ m s}^{-2}$

$F_{net} = ma$

$= (110 \text{ kg} + 50.0 \text{ kg})(-\ 2.206 \text{ m s}^{-2})$ [1]

$= -\ 350$ N (to 2 s.f.) $\therefore$ braking force = <u>350 N</u> [1]

3. Fig. 3.1 shows the horizontal forces acting on a moving car of mass 9.0×10^2 kg. The forward driving force **remains constant** throughout its journey.

Fig. 3.1

Fig. 3.2 shows the total resistive force that acts on the car as time passes.

Fig. 3.3 shows the speed-time graph for the first 24 s of the motion of the car along a straight road.

Fig. 3.2:

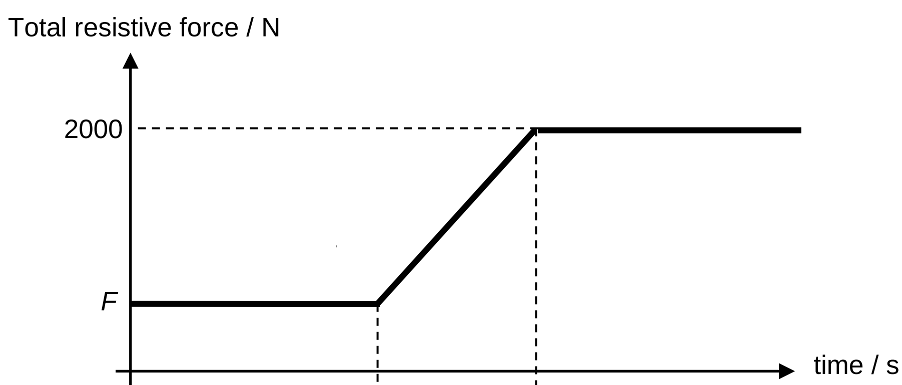
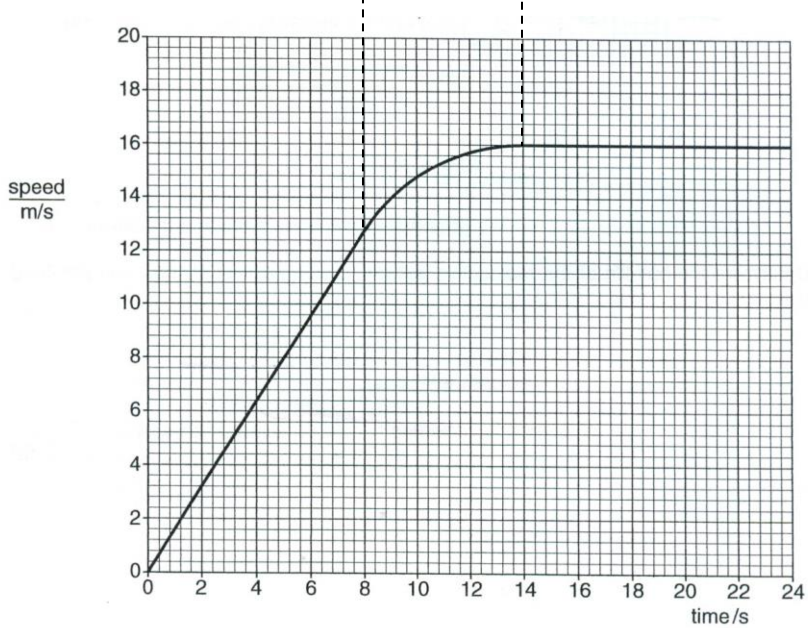


Fig. 3.3:



(a) State the terminal ~~velocity~~ (speed) of the car. [1]

<u>16 m s^{-1}</u> [1]

(b) Hence, state the (magnitude of) forward driving force of the car. [1]

When the speed is constant, forward driving force = total resistive force

= <u>2000 N</u> [1]

(c) For the first 8.0 s of its journey, calculate

(i) the acceleration of the car, [1]

$a = (v - u)/(\Delta t)$

$= (12.8 - 0)/8.0$

$=$ <u>1.6 m s^{-2}</u> (to 2 s.f.) [1]

(ii) the total resistive force, F, on the car. [2]

forward driving force – total resistive force = ma

2000 N – total resistive force = $(9.0 \times 10^2$ kg$)(1.6$ m s$^{-2})$ [1]

total resistive force = <u>560 N</u> (to 2 s.f.) [1]

(d) Complete the following statements and underline the correct answer to describe the acceleration and forces experienced by the car for the whole journey. [6]

Assume rightward direction to be positive velocity.

From 0 to 8 s, its acceleration is …**constant and positive**……………………………………… [1]

Since the constant total resistive force is (**<u>smaller than</u>/greater than/equal to**) the constant forward driving force, the net force acting on the car is …**constant and positive**…………….. [1]

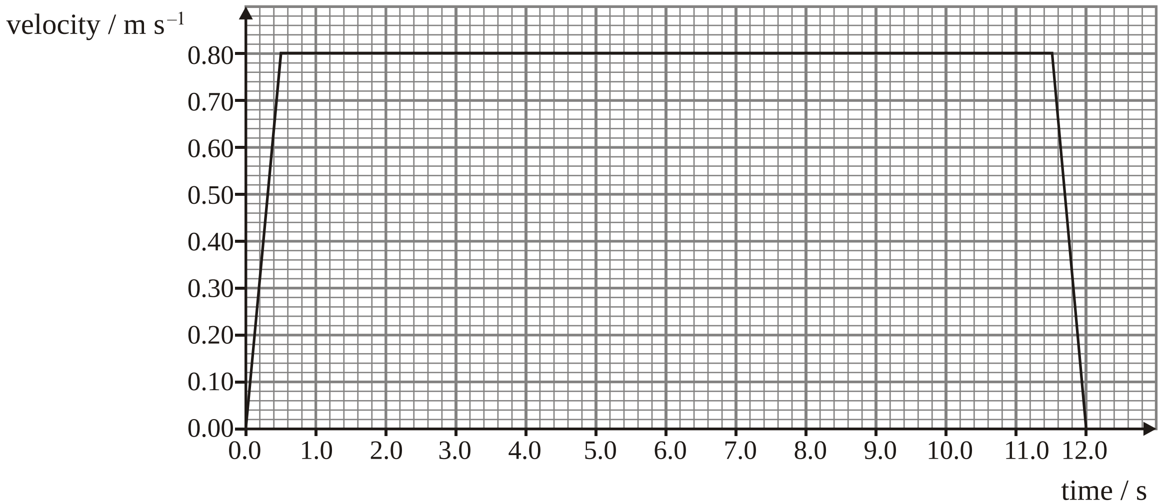
From 8 to 14 s, its acceleration is ...**decreasing and positive**…...…………………………..……. [1]

Since the total resistive force (**decreases/<u>increases</u>/remains constant**) as the speed increases while forward driving force remains constant, thus net force acting on the car (**<u>decreases</u>/increases/remains constant**). [1]

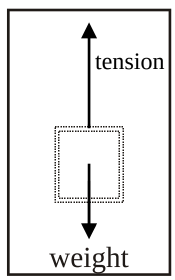
From 14 to 24 s, its acceleration is …**zero**……………………………………………………….. [1]

Since the total resistive force is (**smaller than/greater than/<u>equal to</u>**) the forward driving force, the net force acting on the car is …**zero**……………………………………………………….. [1]

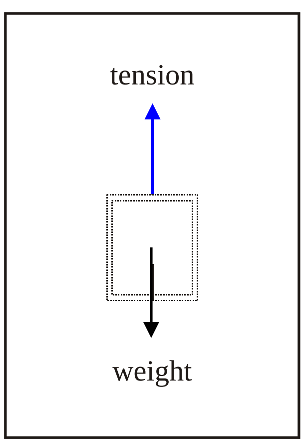
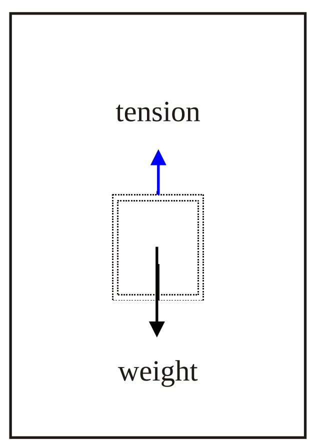
4. An elevator (lift) starts from rest on the ground floor and comes to rest at a higher floor. Its motion is controlled by an electric motor. A simplified graph of the variation of the elevator's velocity with time is shown below.



The elevator is supported by a cable. The diagram below is a free-body force diagram for when the elevator is moving upwards during the first 0.5 s.



(a) In the space below, draw the tension acting on the elevator during the following time intervals.[2]

(i) 0.5 s to 11.5 s	(ii) 11.5 s to 12.0 s
	
[1]: Tension must be equal to weight.	[1]: Tension must be less than weight.

Note: Point of application (POA) from top of elevator as given in the diagram.

(b) A person is standing on weighing scales in the elevator. Before the elevator rises, the reading on the scales is *W*.

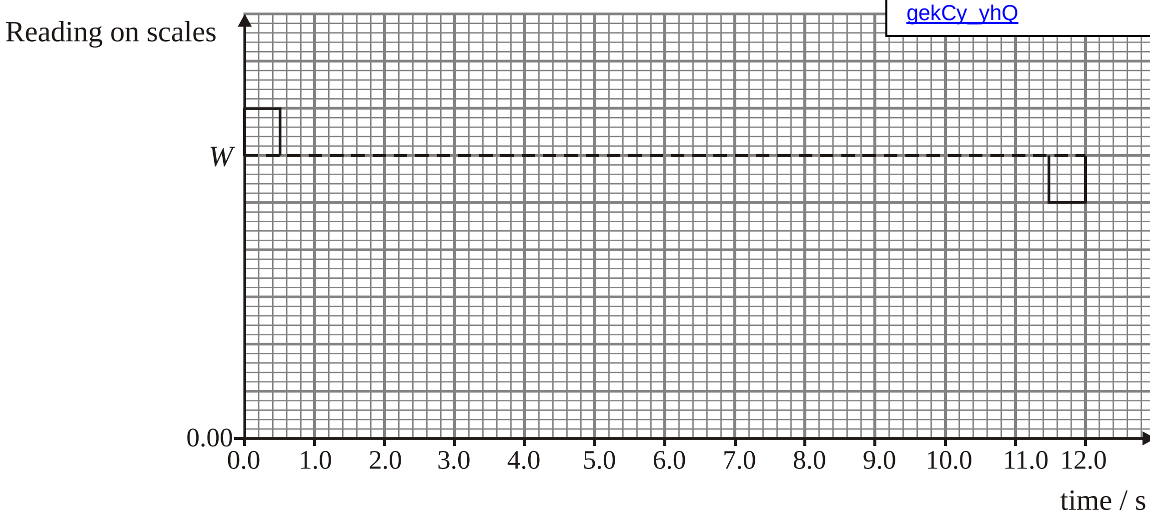
On the axes below, sketch a graph to show how the reading on the scales varies during the whole 12.0 s upward journey of the elevator. (*Note that this is a sketch graph – you do not need to add any values*.) [3]

[1]: a value **greater** than W before 0.5 s and **smaller** than W after 11.5 s.

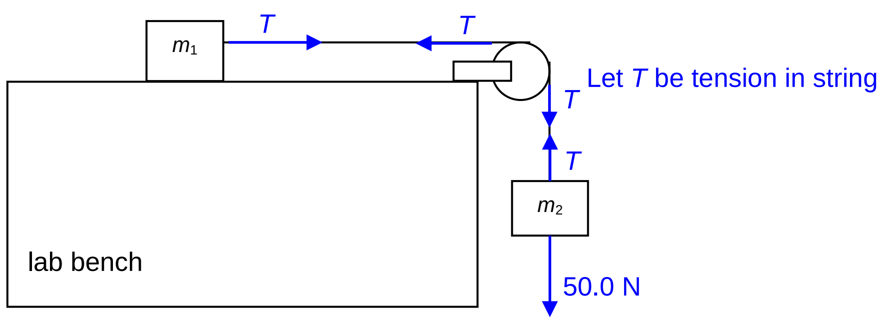
[1]: a constant value **equal** to W from 0.5 to 11.5 s

[1]: constant value of W from 0 s to 0.5 s and from 11.5 s to 12.0 s.

Can we experience weightlessness on Earth?
https://www.youtube.com/watch?v=yd8_FNSAEgM
https://www.gozerog.com/reservations/ (Cost of zero-g flight)
https://www.youtube.com/watch?v=44gekCy_yhQ



5. An inextensible string, connecting the objects m_1 and m_2 over a frictionless pulley, is shown in the diagram below.



The 3.00 kg mass, m_1, moves on a frictionless surface while the 5.00 kg mass, m_2, moves vertically when it is released from rest. Take the acceleration due to gravity to be 10 m s^{-2}.

Assume the string is taut throughout the time when the two masses are moving.

(a) Calculate

(i) the acceleration *a* of the whole system, [2]

By considering both masses as one system, since $F_{net} = ma$,

5.00 X 10 N = (3.00 kg + 5.00 kg) *a* [1]

a = <u>6.25 m s^{-2}</u> (to 3 s.f.) [1]

(Note: Net force, which pulls both masses, is weight of mass m_2.)

(ii) the tension T in the string. [2]

To find tension in the string, consider only one free body, i.e. either m_1 or m_2.

Consider only 3.00 kg mass.	Consider only 5.00 kg mass.
$T = F_{net} = ma$	$F_{net} = ma$
$= (3.00\ \text{kg})(6.25\ \text{m s}^{-2})$ [1]	$50.0\ \text{N} - T = (5.00\ \text{kg})(6.25\ \text{m s}^{-2})$ [1]
$= 18.75$ N = <u>18.8 N</u> (to 3 s.f.) [1]	$T = 18.75$ N = <u>18.8 N</u> (to 3 s.f.) [1]

(b) A rough wooden surface was placed on the lab bench and the whole experiment was repeated with the mass m_1 moving across the wooden surface when the mass m_2 was released from rest.

Given the constant kinetic friction acting on the mass m_1 is 9.00 N, calculate its acceleration. [2]

$50.0\ \text{N} - 9.00\ \text{N} = (3.00\ \text{kg} + 5.00\ \text{kg})\ a$ [1]

a = <u>$5.13\ \text{m s}^{-2}$</u> (to 3 s.f.) [1]

6. This question is about equilibrium.

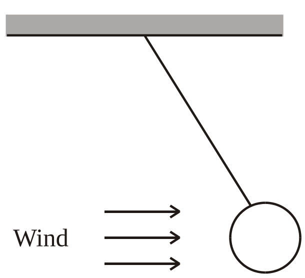
Explain whether each of the following is **in equilibrium** (i.e. net force on object is zero).

(a) A satellite in orbit at constant speed round the Earth.

[1]: Not in equilibrium. [1]: As it orbits round the Earth, its direction is constantly changing. Since there is a <u>change in velocity</u>, it is <u>accelerating</u>.
OR The net (or centripetal) <u>force</u> acting <u>perpendicularly to</u> the <u>direction of motion</u> (or towards the centre of the orbit) causes the satellite to <u>accelerate</u>.
……………………………………………………………………………………………………..

……………………………………………………………………………………………………..[2]

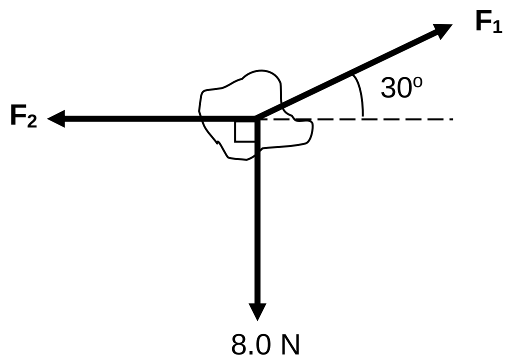
(b) A small sphere suspended on a string and blown to one side by a wind so that the string makes a constant angle with the vertical, as shown below.



[1]: In equilibrium. [1]: <u>Forces</u> acting on sphere <u>are balanced</u>. Hence, the sphere is <u>at rest</u> (or has zero velocity or no acceleration), thus there is no net force.
……………………………………………………………………………………………………..

……………………………………………………………………………………………………..[2]

7. (a) The diagram shows the top view of a smooth rock, of mass 2.0 kg, being acted on by three forces. The rock is at rest on a frictionless surface. By using a suitable scale diagram or otherwise, determine the magnitude of the forces $\mathbf{F_1}$ and $\mathbf{F_2}$. [3]

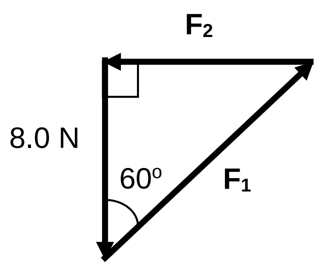


Answer for Question 7 (a):

Scaled drawing:

Minimum scale: 1.0 cm represents 2.0 N

Correct labelled vector diagram: [1]



F_2 = 7.0 X 2.0

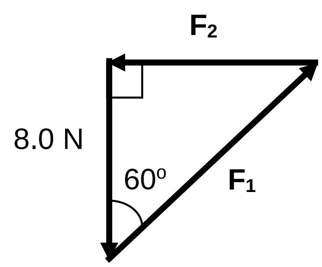
= <u>14.0 N</u> (Range: 13.6 N to 14.4 N) [1]

F_1 = 8.0 X 2.0

= <u>16.0 N</u> (Range: 15.6 N to 16.4 N) [1]

Mathematical method:

Correct labelled vector diagram: [1]



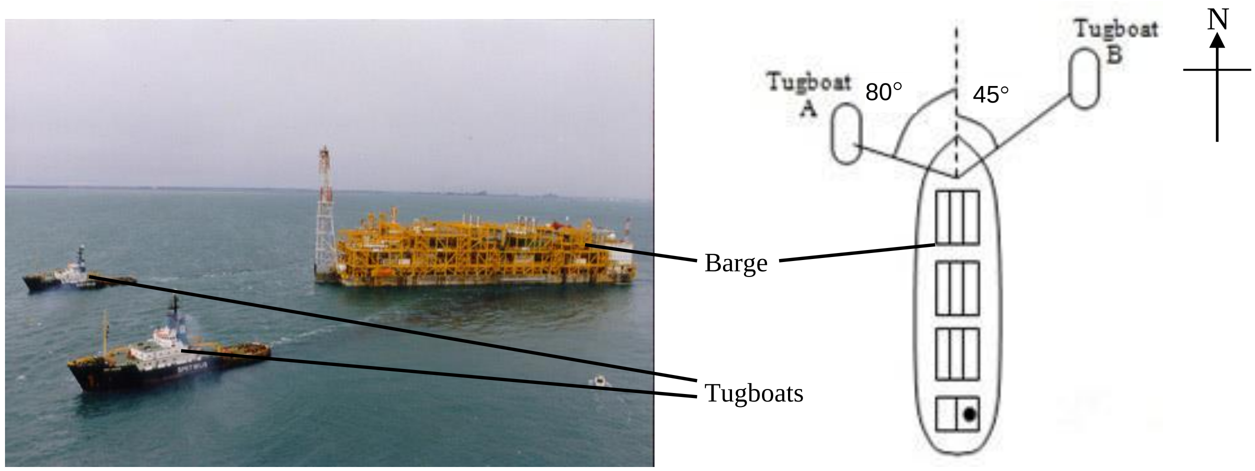
$$\left.\begin{array}{l} \tan 60° = F_2 / 8.0 \\ F_2 = \underline{14\text{ N}} \text{ (to 2 s.f.) [1]} \\ \\ \cos 60° = 8.0 / F_1 \\ F_1 = \underline{16\text{ N}} \text{ (to 2 s.f.) [1]} \end{array}\right\} \text{correct trigo working}$$

(b) If the 8.0 N force is increased to 10.0 N while the forces $\mathbf{F_1}$ and $\mathbf{F_2}$ remain constant, calculate the acceleration of the rock. [2]

(10.0 – 8.0) N = 2.0 kg (a) [1]

a = 1.0 m s^{-2} [1]

8. The diagram below, on the left, shows two tugboats towing a barge. The diagram below, on the right, shows the angles made by each tugboat with respect to the North direction. The resultant force of the forces in the two tugboats' cables, acting on the barge, is 94 kN in the North direction.



http://www.giantmarine.com/images/illustrations/02%20-%20Towage/towage_03_larger.jpg

(a) When the barge was towed by the two tugboats, **A** and **B**, it travelled at a constant velocity of 6.0 m s^{-1}.

State the magnitude and the direction of the force provided by the water resistance acting on the barge. [1]

Water resistance is 94 kN acting in the South direction. [1]

Explanation: Since the net force on the system is zero, the resultant of the forces by the two tugboats is equal in magnitude and opposite in direction to water resistance acting on barge.

(b) Using a scale of 1.0 cm to represent 10 kN, determine the magnitude of the forces exerted by tugboat **A,** F_A, and tugboat **B,** F_B, on the barge, through the cables. [3]

Correct labelled vector diagram: [1]

F_A = 8.1 x 10
= 81 kN [Range: 79 kN to 83 kN] [1]

F_B = 11.3 x 10
= 113 kN [Range: 111 kN to 115 kN] [1]

[Mathematically calculated to be correct]