Q1

Convert the units in the following statements into S.I. units.

(i) A hot air balloon descends at 5.94×10^5 cm h^{-2}.
(ii) The density of oil is about 0.95 g cm^{-3}.
(iii) The average spike ball player can hit the ball at a velocity of 43.5 km h^{-1}.

[3]

DERIVED/COMPOUND SI UNITS

ANY COMBINATION OF

SECONDS, METERS, KILOGRAMS
s m kg

i) $cm\ h^{-2} \longrightarrow m\ s^{-2}$

cm → m ÷100 $h^{-2} \rightarrow s^{-2}$ $\div(60\times60)^2$

$594000 \div 100 \div (3600)^2 = 0.0004583...$

$4.58 \times 10^{-4}\ ms^{-2}$

ii) $g\ cm^{-3} \longrightarrow kg\ m^{-3}$

g → kg ÷1000 $cm^{-3} \rightarrow m^{-3}$ $\times 100^3$

$0.95 \div 1000 \times 100^3 = 950$

$950\ kg\ m^{-3}$

iii) $km\ h^{-1} \longrightarrow m\ s^{-1}$

km → m ×1000 $h^{-1} \rightarrow s^{-1}$ $\div(60\times60)$

$43.5 \times 1000 \div 3600 = 12.08333...$

$12.08\ m\ s^{-1}$

Q2

2

By converting to S.I. units compare which of the following accelerates quickest.

A: A motorbike accelerates at 0.0035 km s^{-2}.
B: A cheetah accelerates at 28.8 km min^{-2}.
C: A race car accelerates at 108 m per square min.

[4]

SI UNIT FOR ACCELERATION = ms^{-2}

A: MOTORBIKE

$0.0035\ km\ s^{-2} \times 1000 = 3.5\ ms^{-2}$

B: CHEETAH

$28.8\ Km\ min^{-2} \times 1000 \div 60^2 = 8\ ms^{-2}$

C: RACECAR

$108\ m\ min^{-2} \div 60^2 = 0.03\ ms^{-2}$

CHEETAH ACCELERATES QUICKEST FOLLOWED BY MOTOR CYCLE THEN RACECAR

(THIS IS ACTUALLY TRUE!!)

Q3a

Define each of the following and give an example of how they could be used in a mathematical model, include any related assumptions which can be made.

(a) A lamina and a non-uniform rod.

[3]

(b) A bead and wire.

[3]

a)

A LAMINA IS AN OBJECT WITH AREA BUT NEGLIGIBLE THICKNESS AND EVENLY DISTRIBUTED MASS

e.g. A PIECE OF PAPER OR SHEET OF METAL

A NON UNIFORM ROD IS A RIGID OBJECT WHICH DIFFERS IN MASS AT SOME POINT MEANING ITS CENTRE OF MASS IS NOT CONCENTRATED ALONG THE LINE OF THE ROD

e.g. A SHARPENED PENCIL OR WOODEN STAKE

ANY MODEL DESCRIBING A PENCIL INTERACTING WITH A PIECE OF PAPER OR EQUIVALENT

e.g A PENCIL ROLLING OVER A PIECE OF PAPER OR A WOODEN STAKE PIERCING A SHEET OF METAL

Q3b

3b

Define each of the following and give an example of how they could be used in a mathematical model, include any related assumptions which can be made.

(a) A lamina and a non-uniform rod.

(b) A bead and wire.

[3]

[3]

b)

A BEAD IS A PARTICLE THAT CAN MOVE FREELY ALONG A WIRE

e.g. A SHOWER CURTAIN HOOP OR A ROLLERCOASTER CAR

A WIRE IS A RIGID LENGTH OF METAL WHICH CAN BE TREATED AS ONE DIMENSIONAL

e.g. A SHOWER RAIL OR ROLLER COASTER TRACK

ANY MODEL INVOLVING A BEAD MOVING ALONG A WIRE

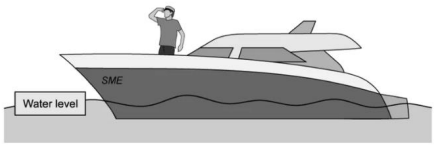
e.g. A SHOWER CURTAIN BEING OPENED OR A ROLLER COASTER MOVING ALONG THE TRACK

Q4a

4a

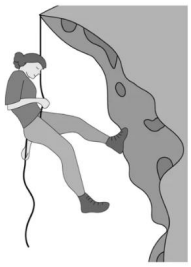
Label the following diagrams with the appropriate forces.

(a) A speed boat travelling through water.



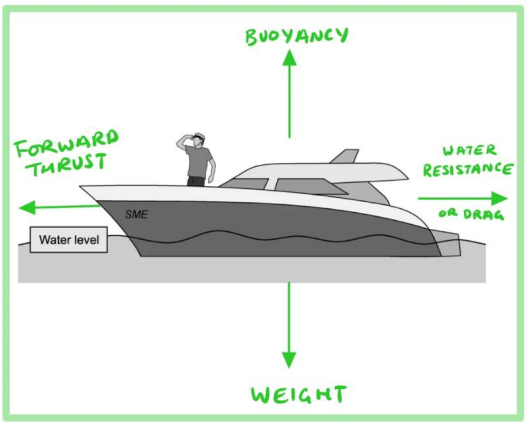
[2]

(b) A climber abseiling down a cliff.



[2]

a)

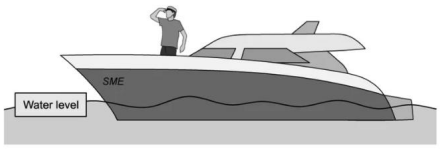


Q4b

4b

Label the following diagrams with the appropriate forces.

(a) A speed boat travelling through water.

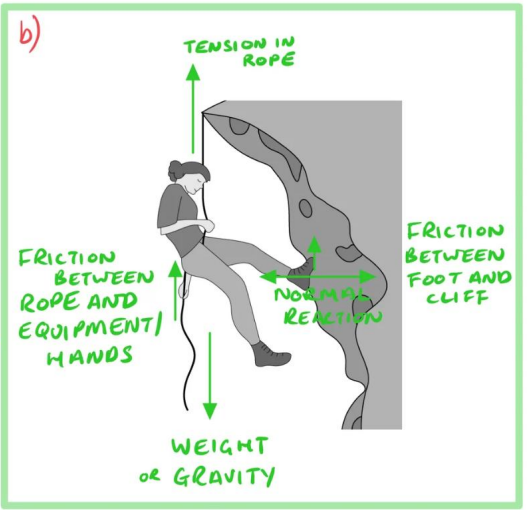


[2]

(b) A climber abseiling down a cliff.

[2]

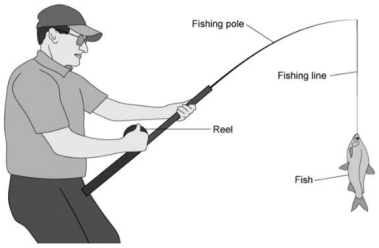
b)



FRICTION LABELS ARE NOT ESSENTIAL

Q5

Fishing company, Fin-tastic Rods, are designing a new fishing pole. They set up a model as shown in the diagram below to consider the forces involved in catching a fish.



Explain what effect the following assumptions would have on the model described above and whether or not they are suitable.

(i) The fishing line is inextensible and light.
(ii) The fishing pole is a light rod.
(iii) The fish is modelled as a particle.

[6]

i) FISHING LINE HAS ZERO MASS AND DOES NOT STRETCH WHICH IS SUITABLE

ii) ROD IMPLIES ZERO MASS AND RIGID WHICH IS UNSUITABLE

(ROD MUST BEND AND HAVE MASS TO PULL AGAINST FISH!)

iii) MODELLED AS SINGLE POINT, DIMENSIONS DON'T MATTER WHICH IS SUITABLE TO BEGIN SIMPLE MODEL, ROTATIONAL FORCES (MOVEMENT) AND AIR RESISTANCE CAN BE IGNORED

MAY NEED TO CONSIDER DIFFERENT ASSUMPTIONS LATER FOR MORE COMPLICATED CALCULATIONS/MODEL

Q6

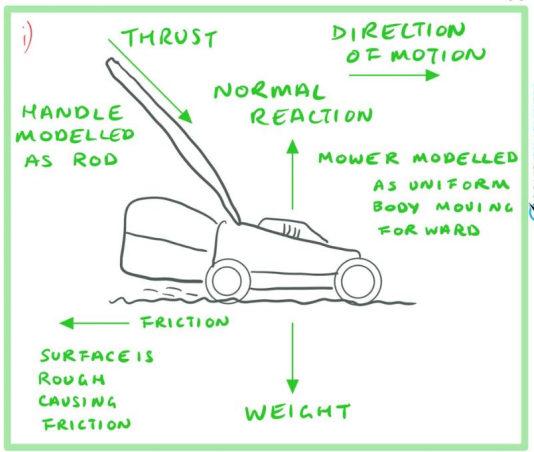
6

Draw a simple diagram to represent each of the following models. Label your diagrams with the appropriate forces involved and detail any assumptions you make about your model.

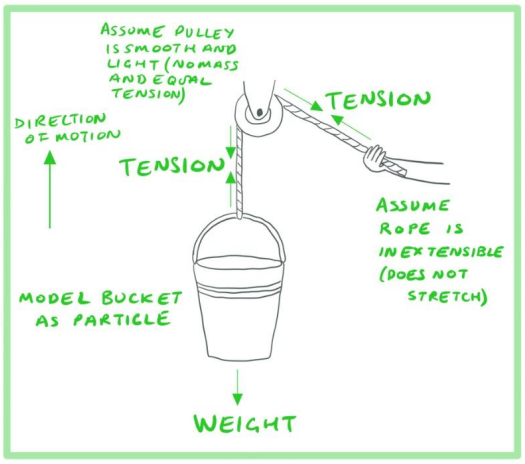
(i) A lawnmower being pushed along to mow an uneven lawn.
(ii) A bucket on a rope being raised using a pulley.

[8]

i)



ii)



Q7

7

List any assumptions you could make in order to create a simple model for each of the following.

(i) The motion of a pencil rolling along a table.
(ii) The motion of a ball being hit by a bat.

[6]

i) THE PENCIL IS A LIGHT SMOOTH UNIFORM ROD SO RIGID WITH NO MASS OR THICKNESS
THE TABLE SURFACE IS FLAT

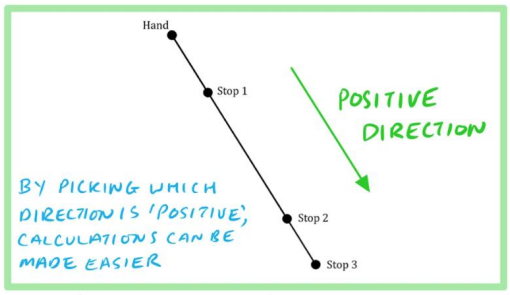
CANNOT HAVE BOTH TABLE AND PENCIL BEING SMOOTH OTHERWISE PENCIL WOULD SLIDE RATHER THAN ROLL, IF TABLE IS SMOOTH PENCIL MUST NOT BE

ii) BALL MODELLED AS A PARTICLE SO ROTATIONAL EFFECTS AND AIR RESISTANCE CAN BE IGNORED
BAT MODELLED AS SMOOTH ROD THEREFORE RIGID AND FRICTIONLESS

Q8

8

A yo-yo moves in a straight line up and down a 1 m string. As it travels down the string it has a velocity of 0.15 m s^{-1} and a velocity of 0.12 m s^{-1} when returning towards the hand. In order to do certain tricks, the yo-yo stops at different places along the string as shown in the diagram below. The stops of one particular trick, 'The Mechanic', are as follows: Hand-2-1-3-1-Hand



Stop 1 is $\frac{1}{4}$ of the way along the string, Stop 2 is $\frac{4}{5}$ of the way along the string. When the yo-yo reaches Stop 3 the string is fully extended.

By indicating your chosen positive direction clearly on the diagram above, state the following in relation to the yo-yo:

(i) the displacement from the hand once Stop 2 is reached
(ii) the velocity when travelling between Stop 2 and Stop 1
(iii) the velocity when travelling between Stop 1 and Stop 3
(iv) the maximum displacement from the hand
(v) the displacement from Stop 3 to Stop 1.

[4]

i) 0.8m OR 80cm
ii) -0.12 m s^{-1}
iii) 0.15 m s^{-1}
iv) 1m OR 100cm
v) -0.75 m OR -75cm

ANSWERS WOULD BE ACCEPTABLE WITH POSITIVE DIRECTION LABELLED GOING UP THE STRING AND SIGNS ADJUSTED ACCORDINGLY

i) -0.8m OR -80cm ii) 0.12 m s^{-1}
iii) -0.15 m s^{-1} iv) -1m OR -100cm
v) 0.75 m OR 75cm