Engineering Studies ATAR

(Mechanical)

2022

Unit 1 exam

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: **Core content**					
Part A: Multiple-choice	10	10	10	10 9	10 9
Part B: Extended answer	3	3	50	45 36	30 24
Section Two: **Mechanical**					
Part A: Multiple-choice	10	10	10	10 9	10 9
Part B: Extended answer	4	4	80	88 77	50 43.75
Total				153	100 85.75

Instructions to candidates

1. Answer the questions according to the following instructions.

Sections One and Two, Part A: (Multiple Choice)

Answer all questions in this Question /Answer Booklet. For each question circle the letter to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that circle, do not erase or use correction fluid, and circle your new answer. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

All other components of Exam:

Write answers in space provided in this Question/Answer Booklet. **All questions must be answered.**

2. You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.

3. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.

- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e., give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Section one: Core content
This section has **two (2)** parts **40% (55 marks)**

Part A: Multiple choice	Answer **all** questions	10	10%
Part B: Extended answer	Answer **all** questions	45	30%

Suggested working time: 70 minutes

1. Which best describes the Engineering Design Process you have been asked to follow?

a) Investigating, Devising, Producing, Evaluating ✓
b) Design, Make and Appraise
c) Draw it, make it, Sell it
d) Research, Development, Production, Evaluate

2. At what part of the process would you be creating a materials and parts list?

a) Evaluate
b) Producing ✓
c) Research
d) The End

3. You are asked to design a child's toy, what consideration would be most important?

a) Cost
b) Appearance
c) Safe Operation ✓
d) Colour

4. In an orthogonal drawing, what do Regular Dashed Lines represent?

a) Outlines ——————
b) Centre Lines —·——·—
c) Hidden Detail ✓
d) Cut Lines

NO CUT LINES IN ORTHOGONAL

5. When selecting a type of steel, what do you recognise as "Mild Steel" as referring to?

a) Colour of bar
b) Low carbon content
c) High carbon content
d) Weight

6. What is an Alloy?

a) Pure Ore
b) A combination of materials ← COMPOSITE
c) Two or more metals melted together
d) Type of Aluminium

7. If you were setting up formwork to pour a concrete slab next to an existing wall, how could you quickly and accurately check that the end of the formwork is 90 degrees to the wall?

a) Make a large try square NOT QUICK USE ONE?
b) ~~Trust your judgement~~ NOT ACCURATE
c) Measure both diagonals to see if they are equal
d) Measure the length of end, diagonal and wall edge and test using Pythagoras NOT QUICK

8. An 80kg Toolbox accidently rolled off the edge of the fifth story (20m high) of a building site. Ignoring wind resistance etc calculate the Kinetic energy of the Toolbox just before impact with the ground.

a) 3.85 kJ
b) 38.5kJ
c) 50 kJ
d) 200 j

$E_K = \frac{1}{2} mv^2$ 3841.6J

$= \frac{1}{2} 80$

$E_P = mgh = 80 \times 9.8 \times 20 = 15680\,J$

9. Just before it rolled over the edge, what was the potential energy of the Toolbox?

a) 15.7 KJ
b) 12 KJ
c) 900 KJ
d) 9.5 KJ

10. Which of these is a NON-RENEWABLE Source of Energy?

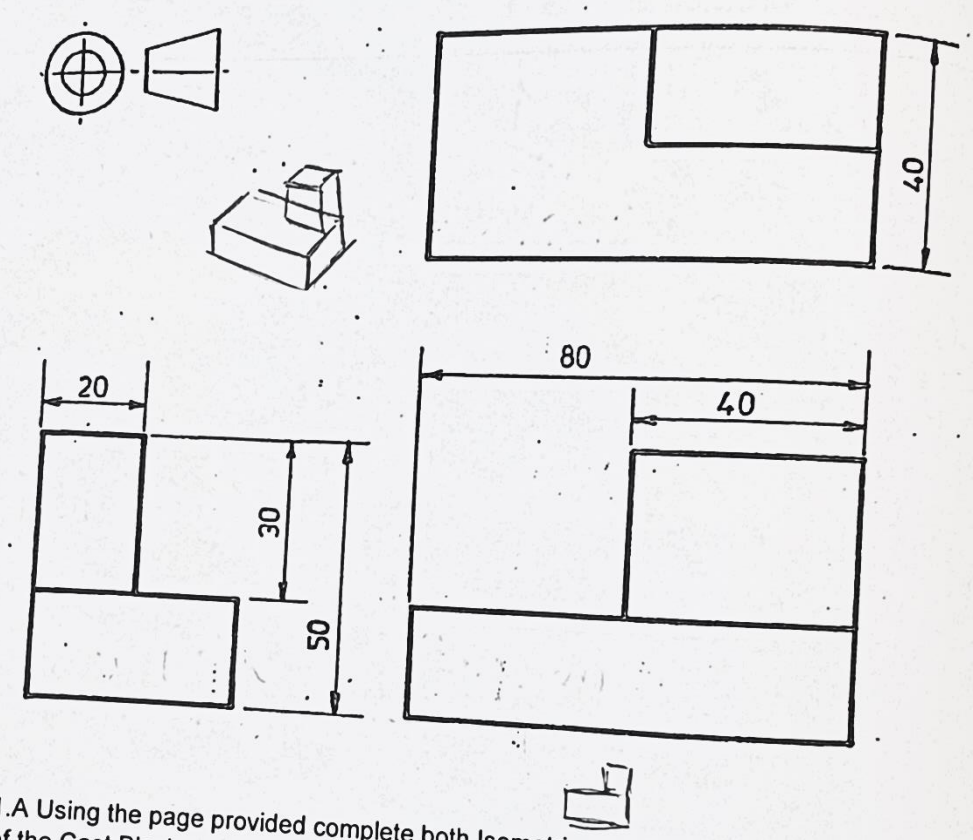
a) Solar
b) Wind
c) Tidal
d) Gas

9

Section one: Core content
Part B: Extended answer Answer **all** questions

14.
(24 Marks)

Q.1
All parts of this question refer to the simple Cast Block shown in the Orthogonal drawing below.



1.A Using the page provided complete both Isometric and Oblique simple sketches of the Cast Block.

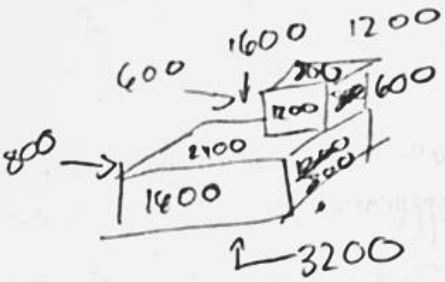
- To present the most ideal 3D representation
- Use a ruler to help keep lines reasonably straight
- Draw to scale
- Outline finished sketches but do not dimension

NB: Line angles can be estimated as long as they are consistent. Additional paper at end of exam booklet if required.

6

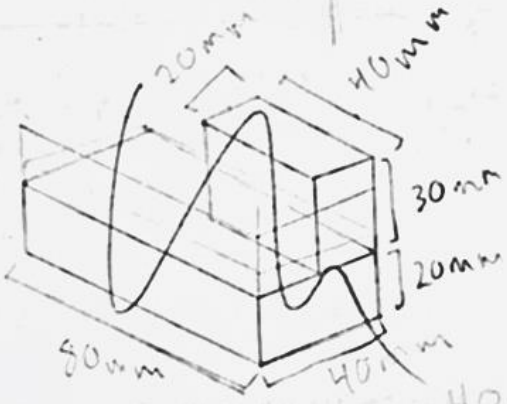
8 marks

ISOMETRIC



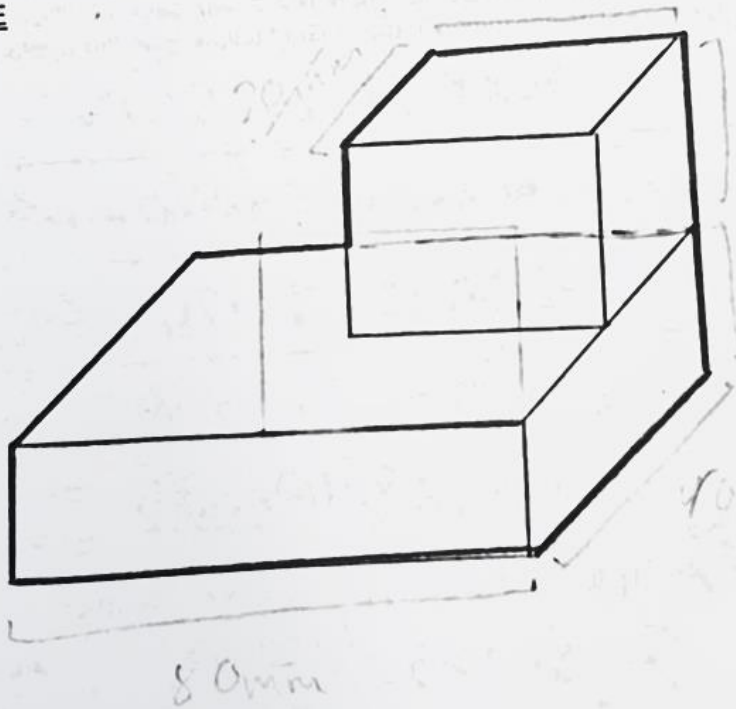
SEE BACK

$\frac{1}{2}$ SCALE



1 SCALE

OBLIQUE



1.B Using the drawings as a guide, calculate the total surface area of the Cast Block

BOTTOM $80 \times 40 = 3200 mm^2$

TOP 1 $3200 - (20 \times 40) = 2400 mm^2$

TOP 2 $20 \times 40 = 800 mm^2$

FRONT+B $80 \times 20 = 1600 mm^2$

$30 \times 40 = 1200 mm^2$

SIDES $= 40 \times 20 = 800 mm^2$

$30 \times 20 = 600 mm^2$

$3200 + 2400 + 800 + 1600 + 1200 + 1600 + 1200 + 800 + 600 + 800 + 600 + 800$

$= 14800 mm^2$

4

SEE WORKING ON LAST PAGE

4 marks

1.C. You have been asked to use the 3D printer to manufacture 12 of these cast blocks. Assuming they will be solid plastic (not hollow at all), calculate the total volume of plastic that will be consumed in their manufacture, ignoring wastage.

$V = b \times w \times h$ BLOCK P1 $= 80 \times 40 \times 20$

$= 64000 mm^3$

BLOCK P2 $= 40 \times 20 \times 30$

$= 24000 mm^3$

$64000 + 24000 = 88000 mm^3$

$88000 \times 12 = 1056000 mm^3$ 4

12 BLOCKS

4 marks

1.D

i) If the 12 Cast Blocks were made with Acrylic, what would be their total mass?

ACRYLIC → 1190 kg m^{-3} (DENSITY) 88000 mm^3 = 8800 cm^3

↳ 88 mm^3

88 × 12 = 1056 m^3

~~1056 ÷ 1190 = 0.887 kg~~

~~= 887 g~~

1190 ÷ 1056

= 1.13 kg

2 marks

ii) A second order of the same quantity was made, but to be cast in Aluminium. For packaging purposes what would be the difference in weight between the two orders?

ALUMINIUM DENSITY → 2710 kgm^3

2710 ÷ 1056 = 2.57 kg TOTAL OF 12 ~~CUB~~ BLOCKS

3 marks

iii)

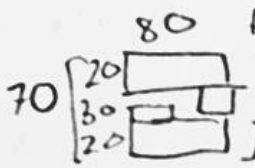
You have been asked to package the 12 items for delivery by parcel post and need to order a specific sized cardboard box.

Suggest the minimal internal dimensions required for this box, assuming that the components stack neatly together without issue.

Length 160 mm

Width 120 mm.

Height 70mm



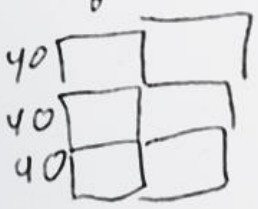
AREA OF 2

3

160 70 × 80 × 40

=

3 marks



(5 Marks) 4

Q2
The College is looking to save money on power usage by installing some form of renewable energy source.

A. Can you suggest two sources of renewable energy that could possibly utilized in this case?

SOLAR POWER → SOLAR ENERGY

HYDROKINETIC ENERGY FROM DAM → tidal

WIND ENERGY FROM TURBINE 2

2 marks

B. Consider that it would take an investment of $40,000 to set up and $500 maintenance each year for a renewable energy system. If the College power bill was reduced $5,000 each year, how many years would it take to pay for the cost of the system alone?

cost ↓

$y = 500x$ (x: year) $+ 40\,000$

8 years just for $40 000

↳ $+500 \times 8 = \$4\,000$ TOTAL OVER 8 years IS $44

extra 4000 = 1 year $500 $4400

9 years $4500

2

3 marks

Q3 13 **(16 Marks)**

A Large wind turbine was set up in the Southeast corner of the College grounds. The turbine <u>without</u> the 3 metre blades was 1.5 tonnes on a 35 metre stand or tower.

A. A delegation from the neighbouring Estate complained about the Wind Turbine. Can you suggest two concerns the neighbours may have with this installation?

SAFETY OF CONSTRUCTION, SAFETY OF STRUCTURE
NOISE/SOUND FROM INSTALLING, IT SOMEHOW
VIOLATES BUILDING/SAFETY RESTRICTIONS
NOT ALLOWED TO BUILD TURBINE
THERE

2 marks

2.

B. During the construction period, when a crane was used to lower the turbine into place on the tower (without its blades), two Engineering students were admiring the progress. One turned to the other and said "What if the Turbine broke its mountings and fell from the Tower? "
Can you suggest the Potential Energy of the Turbine in the scenario described?

$E_p = m \times g \times h$

$= 1500 \times 9.8 \times 35$

$= 514500\ J$

$\hookrightarrow 514.5kJ$ 4

4 marks

C. Alas, just as the students were watching, for some reason the crane slings holding the Turbine in place on the tower snapped and the Turbine fell to the ground. Fortunately, nobody was injured.
But the students could not help themselves as they quickly took out their calculators and worked out what the Kinetic energy of the Turbine was just before it hit the ground.

What would you calculate as the Kinetic Energy?

$E_K = \frac{1}{2} mv^2$ ~~ASSUM~~

$m = 1500kg \times 9.8^2/2 \rightarrow 72030\ J$

$= 144060\ J$ $= 72.03kJ$

~~$\hookrightarrow 144.06kJ$~~

4

4 marks

DISTANCE MOVED

D. Assuming that the Turbine was setup correctly with its blades intact and was operational. If it is considered the force of the wind 1.24N acts on the middle of the blade which is 1.5 metres from the centre shaft.

MIDDLE OF BLADE = 0.75m

i). In one full revolution, what is the work done by each blade?

WORK = FS = 1.24 x 0.75 = 0.93 Nm^2

F = 1.24N

S = 0.75m

1

3 marks

ii). If the blades took 3 seconds to complete a revolution what is the power generated?

P = E/t OR Fs/t

Fs = 0.93 NM^2 → 930 NMM

t = 3 seconds

0.930 ÷ 3 = 0.31 W (N.M)

2

3 marks

Section two: Mechanical **60% (98 marks)**

This section has **two (2)** parts

Part A: Multiple choice	Answer **all** questions	10	10%
Part B: Extended answer	Answer **all** questions	88	50%

Suggested working time: 90 minutes

1. A temporary strut holding a damaged roof is subject to a compressive force of 1.5 kn. What is the stress in the strut if the Cross-sectional area is 18mm²?

$\sigma = \frac{F}{A}$ ✓

a) 400 Nmm²
b) 83.3 Nmm²
c) 27 Nmm²
d) 12 Nmm²

2. Why can mild steel not be hardened and tempered?

a) ~~It's too soft~~ → HARD
b) ~~Can't see colour changes~~
c) Insufficient carbon content ✓
d) ~~Cheap~~

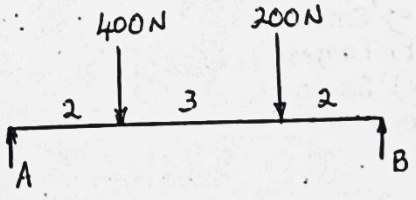
3. How many Pascals in a Megapascal?

10^6
1000 000 ✓

a) ~~10~~
b) ~~1000~~
c) 1000,000
d) ~~1000,000,000~~

4. If it was calculated that reaction force B= 257.14 What must A =

a) 154 N
b) 1.54 KN
c) 342.86 N
d) 2 KN



✓

$Fy = 0: A + B = 400N + 200N$ $400 \times 2 + 200 \times 5$

$= 600N$ $800 + 1000$

$A = 342324.86$

1. HEAT IT TO CRITICAL TEMP

2.

5. Annealing is the process of:

a) The heating and cooling of a metal to produce the softest state.
b) ~~The forming of metal by compressive forces~~
c) The heating of hardened steel below critical temperature
d) ~~Work hardening~~

ANNEALING SOFTENS METAL ✓

~~HARDENING~~ TEMPERING

6. Strain in a bar under tension is best described as:

$\frac{L}{\Delta L}$ $\frac{\Delta L}{L}$ ✓

a) The compression in the bar
b) The change in length divided by the original length of the bar
c) The elongation of the bar
d) The load applied to the bar

EFFORT

7. If a 200 N force is applied to a simple lever system, resulting in a 400N Load being lifted, what is the mechanical advantage of the system?

a) 3
b) 2
c) 4
d) 1

$MA = F_{out}/F_{IN}$ LOAD/EFFORT

$= 400/200$

$= 2$ ✓

8. For the system in Q7. The 200 N input pushed the lever down 1.2 m and raised the 400 N load 600mm. What is the movement or velocity ratio of the system?

a) 4
b) 3
c) 2
d) 1

$\frac{d\text{effort}}{d\text{load}}$ $\frac{1200}{600} =$ ✓

A

9. A six speed geared bicycle is ridden up hill in the lowest gear selection. Which sprocket is the chain engaged on the rear wheel?

a) Smallest
b) Largest
c) Second
d) Fourth

10. A 6m long snatch strap used to pull a bogged 4-wheel drive vehicle, stretched 12mm during the event, what was the strain in the strap?

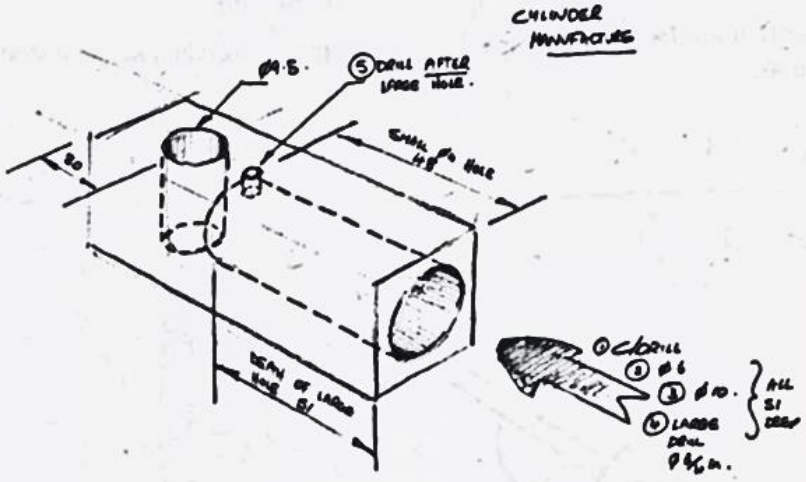
a) 0.002
b) 0.0002
c) 0.004
d) 0.00012

$$\varepsilon = \frac{\Delta L}{L} = \frac{12}{6000}$$

9

NB

- Material for Cylinder Block 25 x 25mm Mild steel
- Bore and Piston Ø 19mm



1A. If the air compressor was set to deliver a pressure of 50kpa when the air was connected at the inlet port at the top of the cylinder (5), calculate the force with which the piston out stroked. When P=F/A

For reference 100 kpa is equivalent to 0.1Nmm

Pa → Nm^2

$P = F/A = 50$ ~~$0.05 \cdot 283.53$~~ ✓

$P = 50\ kpa = 0.05\ N_{mm}$ ~~pa~~ N_{mm} ✓

$A = \pi r^2 = \pi \times 9.5^2 = 283.53\ mm^2$ ✓

↳ $28.353\ cm^2$.

↳ $0.28353\ m^2$

$0.05_{Nmm} = F * 283.53\ mm^2$

$0.05 = 283.53F$

$F = \frac{0.05}{283.53} = 14.18\ N$

5 marks 5

1B. Suggest a change or addition to this design that could make the engine more efficient and how?

INCREASE THE BORE AND PISTON DIAMETER AS IT WILL HAVE A LARGER SURFACE AREA OF FORCE, CREATING MORE AIR PRESSURE TO PUSH MORE PRESSURE

1

2 marks

1C. Name an alternative material that could be used to make the piston. Describe two characteristics of that material.

BRASS → MALLEABLE + DUCTILE + PLASTIC
↳ ANOTHER METAL W/ PROPERTIES LIKE MILD STEEL OR ALUMINIUM WHICH HAS SIMILAR PROPERTIES

3

COULD USE ABS AND 3D PRINT IT, BUT IS BRITTLE, UNELASTIC NOT MALLEABLE OR DUCTILE

3 marks

$25 \times 25 = 625\,mm$ → 45.4%.

A = 283.53 mm IS HOLE

1D. It was decided to make a smaller version of the engine, using **20mm square** mild steel instead of 25mm.

45.4% OF $20 \times 20 = 181.6$

i) If you had to choose between 19, 16, 14, and 10mm diameter round bar for the piston, which would you use and why?

→ 45.4% OF BLOCK WAS DRILLED

LAST PISTON HAD 6mm LEEWAY, TO MATCH THIS IN 20mm SQUARE, 16mm WOULD APPROX SCALE DOWN TO SIZE (SEE WORKING OUT)

2. **2 marks**

16mmØ

ii) If the same pressure was applied to this newly constructed engine, what would the out-stroking force be in this case?

$P = F/A$ 16mmØ

$F = ?$ $P = 0.05 N mm^2$ $A = \pi r^2 = \pi \times 8^2 = 201.06\,mm$

$0.05 = F \div 201.06$

$F = 0.05 \times 201.06$

$= 10.053N$

4 **4 marks**

$D = 2\sqrt{\frac{A}{\pi}}$

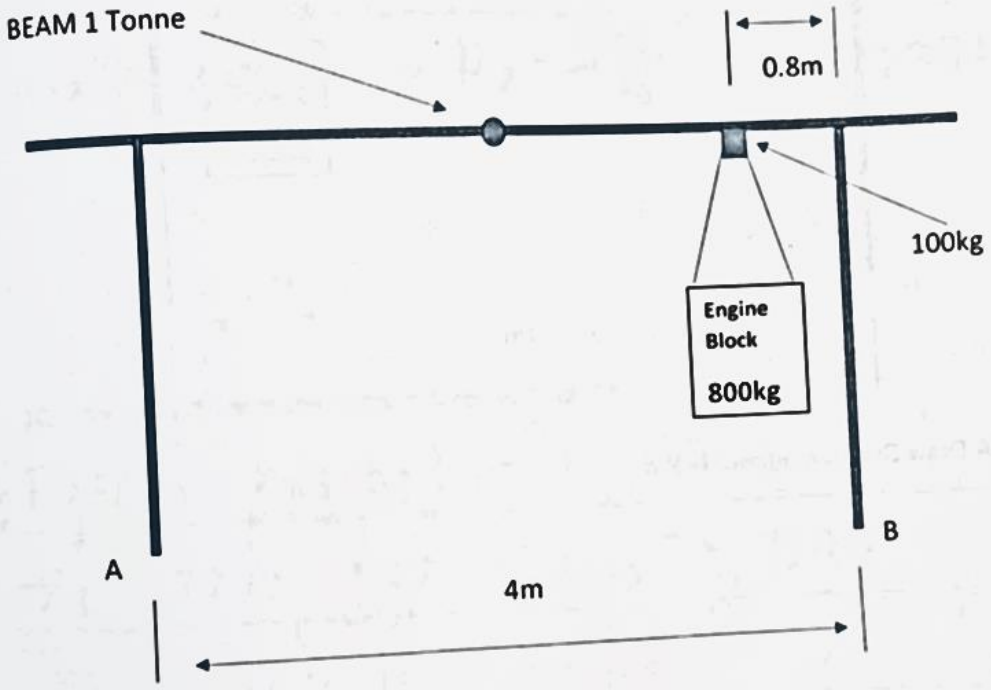
$= 2\sqrt{\frac{181.6}{\pi}}$

$= 15.2 mm$

Q2. 35
(42 Marks)

It was decided to build a Gantry system in the shed at the back of E block. This was to enable the raising and moving of heavy items such as Engine Blocks.

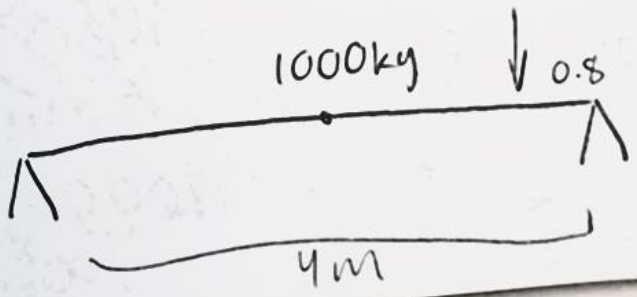
The Gantry consisted of a Large I beam (RSJ) that spanned the width of the shed and protruded through the external walls a short distance. The beam was supported by two large struts of the same material.



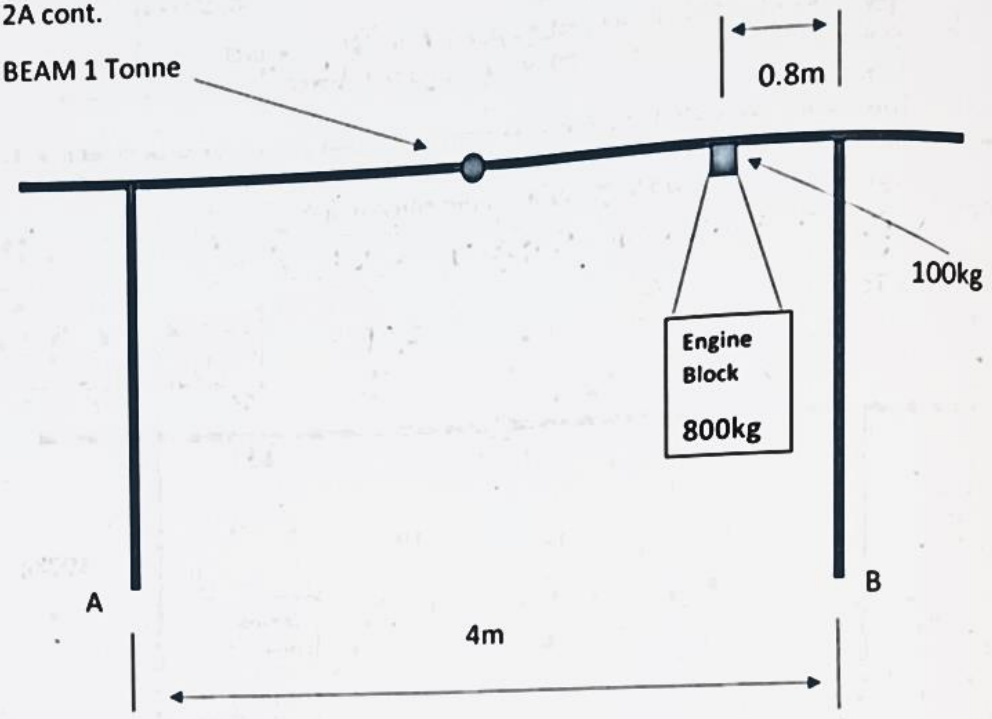
2A. Draw a Force Diagram of the Gantry System (on the next Page), when:

- The I beam constitutes a Uniformly distributed load of 1 Tonne which is considered to be acting in the middle of the beam
- The block and tackle apparatus is located 800mm from the centre of the strut B and has a mass of 100kg
- An 800kg engine block is suspended from the block and tackle.

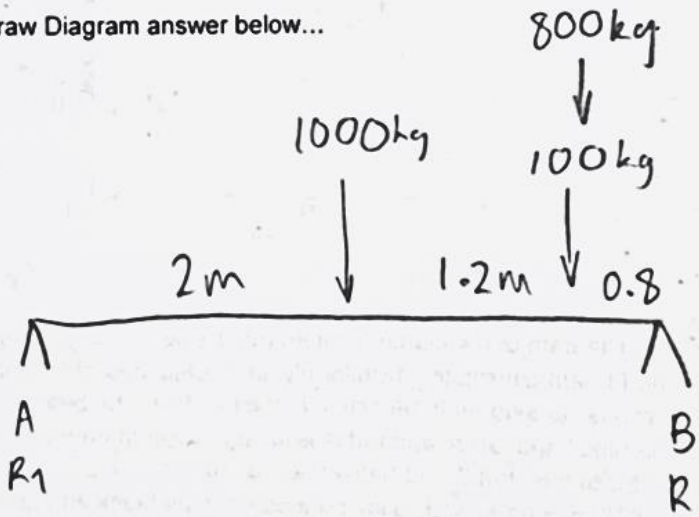
800 | 100



2A cont.



2A Draw Diagram answer below...



3/

$F = mg$

=

$100N = 1kg$

$2000N = 200kg$

$1000kg = 100000N$

$100kg = 10000N$

kg = ~~N~~

3 marks

2B. Calculate the reaction force in strut B

★ 1kg = 10N

$M_{R1} = 0 \therefore \Sigma CWM = \Sigma ACWM$

$= R_2 \times$ DISTANCE TO = F x D ... = 1000kg x 2 + 800kg x 3.2 x 32m

$= R_2 \times D_T = 20000N \; 28800N = 48800$

$R_2 \times 4 = 4880000 \rightarrow R_2 = \frac{48800}{4} = 12200N$ N

B

4

6 marks

2C. Therefore, what is the reaction force in Strut A?

$\Sigma F_y = 0 \; R_1 + R_2 = F_T \downarrow = A + B = F \downarrow$

A $R_1 + 1220 = 1000 + 800 + 100 = 1900$

$R_1 = 19000 - 1220 = 680$

$A = 6800$

3

4 marks

2D. If the engine was suspended from the block and tackle by two straps (Ø 8.5mm each) which carried the load equally?

i) Calculate the stress in each strap.

$\sigma = F/A =$

$F = mg = 800 \times 9.8 = 7840\,N$

$A = \pi r^2 = \pi \times 4.25^2 = 56.75\,mm^2$

$\sigma = 7840/56.75 = 138.15\,N\,mm^2$

6

7 marks

ii) Each strap was found to stretch under load 1.4mm. Calculate the strain if the straps were 1 metre long.

$\varepsilon = \frac{\Delta L}{L} = \frac{1.4\,mm}{1000\,mm} = 0.0014\,\varepsilon$

$\Delta L = 1.4\,mm$

$L = 1000\,mm$

3

3 marks

iii) Using your calculations determine what the Youngs modulus of the strap material must be.

$E = \frac{\sigma}{\varepsilon} = \frac{138.15}{0.0014} = 98678.57\,N\,mm^2$

$\sigma = 138.15$

$\varepsilon = 0.0014$

$E = \frac{FL}{\Delta L A} = \frac{7840 \times 1000}{56.75 \times 1.4}$

2

3 marks

$= \frac{7840000}{79.45}$

$= 98678.57\,N\,mm^2$

$$L = \frac{\Delta L}{\varepsilon}$$

2E) Assuming the straps had to be replaced with a material that could only be worked to a safe working stress of 50 Nmm².

What minimum diameter strap of this material could be used if the set up was otherwise exactly the same? (If unsure of load refer to information at start of question 2)

$d = 2\sqrt{\frac{A}{\pi}}$ $A = \frac{7840}{50}$ ✓

$\sigma = 50 Nmm^2$ ✓ $= 156.8 mm^2$

$\sigma = \frac{F}{A} \therefore A = \frac{F}{\sigma}$ $d = 2\sqrt{\frac{156.8}{\pi}}$

$F = 7840 N$ $= 14.13 mm$ ✓

4

7 marks

2F. What would the extension in the strap be under load if the Young's Modulus of this material was 60kN/mm²?

$60\,000 = \frac{FL}{A\Delta L} = \frac{\sigma}{\varepsilon}$ $= \frac{7840000}{156.8\Delta L}$

$= \frac{7840 \times 1000mm}{156.8 \times \Delta L}$ ✓

$9408000\Delta L = 7840000$ ✓

$\Delta L = 7840000 \div 9408000 = 0.8\overline{3} mm$

4 marks

4

2G. The two struts that support the beam, and subsequent loads are constantly under compression. These are made from Structural Steel square hollow section 100mm with a 5mm wall thickness.

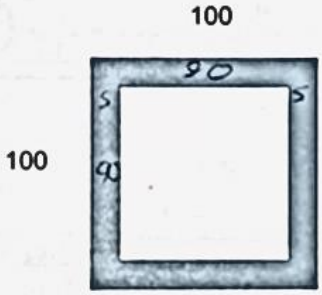
Calculate the compressive stress in member "B" using the resistant force calculated for that member in the previous question 2B.

Nb. Use 12 kN as the resistant force if you did not complete the question.

RES FORCE = 12200N

$\sigma = \frac{F}{A}$ $A = 100\,mm \times 100\,mm - (90 \times 90)$ ✓ cross area

$= 1900\,mm^2$ **5 marks**

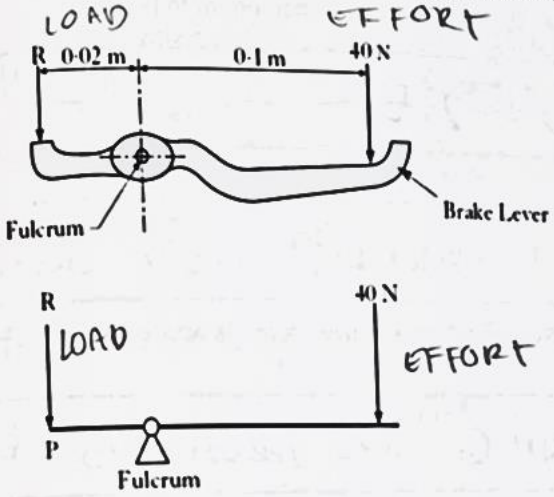


$\sigma = \frac{12200N}{1900mm^2}$

$= 6.421N/mm^2$

Q3. 15 **(18 Marks)**

The diagram below is that of a Bicycle Brake lever.



A. i) Label the diagram where load and effort would be applied 2

2 marks

ii) If the system is in Equilibrium show that the force at R= 200N

$R = 200\,N \rightarrow \Sigma CWM = \Sigma ACWM$ $\quad R = \frac{4}{0.02} = 200\,N$

$\Sigma CWM = 0.1 \times 40 = 4 \therefore \Sigma ACWM = 4$ $\quad R \times 0.02 = 4$

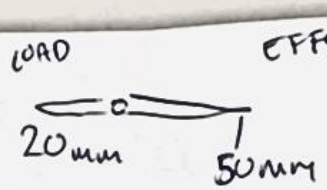
4

4 marks

B. i) Determine the Mechanical Advantage of the system assuming no loss of efficiency due to friction etc.

$$MA = \frac{F_{OUT}}{F_{IN}} = \frac{LOAD}{EFFORT} = \frac{200}{40} = 5$$ 2

2 marks



ii) If the brake lever was engaged and in fact the end of the handle was pulled 50 mm in distance. The opposite end R moved 20mm, what is the movement or velocity ratio?

VR = d effort ÷ d load

= 50 ÷ 20 = 2.5

2 marks 2

C. What is the Torque in the System when the given force is applied?

WHEELS TURNING AND BREAK IS APPLIED

ACTION OF BREAKS .

2 marks -

D. Levers like this are quite often made by casting them using Aluminium or Al. alloys.

i) Suggest why a company would produce items such as Brake levers by this method?

COST EFFICIENT, DOES NOT REQUIRE MUCH TIME + LABOUR AND IS DONE BY PART MACHINE 2

2 marks

ii) Castings like these have been known to crack or break. Can you suggest reasons why they may break?

INCORRECTLY CAST, DOES NOT WITHSTAND MOLTEN ALUMINIUM OVER TIME, EXPANDS 2

2 marks

NOT ENOUGH

AND CONTRACTS TOO QUICKLY FROM HEAT,

↳ ALUMINIUM POURED

iii) If you had all the facilities available and cost was not a factor, suggest a method of manufacture you could use to make a stronger lever or handle, state why it would be stronger.

Al YIELD STRENGTH = ~~470~~ 415 NMM2 TENSILE = 150 NMM²

ONE WITH HIGHER YIELD + UTS IS MILD STEEL. YIELD STRENGTH IS HOW MUCH FORCE IS NEED UNTIL METAL DEFORMS

UTS IS WHEN METAL STARTS TO NECK

2 marks

MILD STEEL YIELD STRENGTH = 250 NMM²

UTS = 470 NMM²

↑ HENCE MORE DURABLE

12
Q4 **(12 Marks)**

Select **Two only** from these images.

Identify the basic mechanism. Give another example, then describe the principle involved. I.e., How it is used to gain Mechanical advantage and adjust the Velocity ratio.

A B C D

i)

Image B

Mechanism PULLEY (LEVER)

Other Example FULCRUM → CRANE

2 marks

How can it provide mechanical advantage?

THE EFFORT PUT IN IS LESSENED BUT YOU HAVE TO MOVE MORE FOR LOAD TO MOVE A SHORTER DISTANCE YOU PULL LESS WEIGHT THAN ACTUAL WEIGHT

2 marks

How can you change the Velocity ratio?

VR = d EFFORT / d LOAD

BY CHANGING THE DISTANCE OF THE EFFORT OR LOAD → CHANGE WEIGHT OR CHANGE PULLY

2 marks

il)

Image A

Mechanism WHEEL

Other Example MECHANICAL SHARPENER

TOWER FAN

2 marks 2

How can it provide mechanical advantage? (SPOKES)

GIVES MORE SPACE TO TURN OVER AN AREA

WHICH PULLS HEAVY WEIGHT (BUCKET)

2

2 marks

How can you change the Velocity ratio?

CREATE A LARGER OUTER WHEEL TO INNER

WHEEL RATIO, CHANGE WEIGHT OF BUCKET

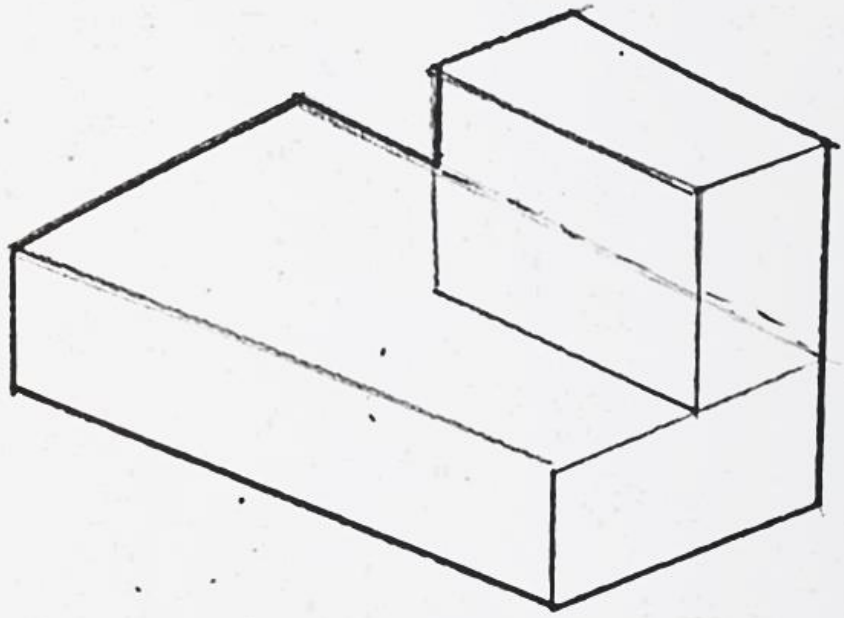
2 marks

2

End of Exam

Additional Working Paper

ISOMETRIC



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