OCR
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Cambridge **TECHNICALS LEVEL 3**

ENGINEERING

Cambridge TECHNICALS 2016

Combined feedback on the June 2017 exam paper (including selected exemplar candidate answers and commentary)

Unit 3 – Principles of mechanical engineering

Version 1

ocr.org.uk/engineering

CONTENTS

INTRODUCTION

This resource brings together the questions from the June 2017 examined unit (Unit 3), the marking guidance, the examiners comments and the exemplar answers into one place for easy reference.

We have also included exemplar candidate answers with commentary for Questions 2c (i-iv), 5b (i), (ii), (iii) and 6b.

The marking guidance and the examiner's comments are taken from the Report to Centre for this question paper.

The Question Paper, Mark Scheme and the Report to Centre are available from:

https://interchange.ocr.org.uk/Modules/PastPapers/Pages/PastPapers.aspx?menuindex=97&menuid=250

GENERAL EXAMINER COMMENTS ON THE PAPER

Many candidates show room for improvement in their presentation of answers to calculation questions. Such candidates would benefit from showing evidence of; the equation (or principle) used; rearranging; substituting; stating clearly their answer to an appropriate number of significant figures; including appropriate units. There were a number of missing or incorrect units being used for numerical answers and candidates need to ensure that they convert values to consistent powers of ten before carrying out any calculation.

Candidates' responses to questions 5(b) and 6(b) indicate that understanding of learning objective 4 is relatively weak.

Resources which might help address the examiner comments:

From the link below, you'll find 'The OCR guide to examinations' (along with many other skills guides)
http://www.ocr.org.uk/i-want-to/skills-guides/

Command verbs definitions
http://www.ocr.org.uk/Images/273311-command-verbs-definitions.pdf

Question 1(a)

Answer **all** questions.

1 **(a)** Fig. 1 shows a steel plate aligned within a Cartesian coordinate system, (x, y), with the origin at point O. Dimensions are shown in millimetres.
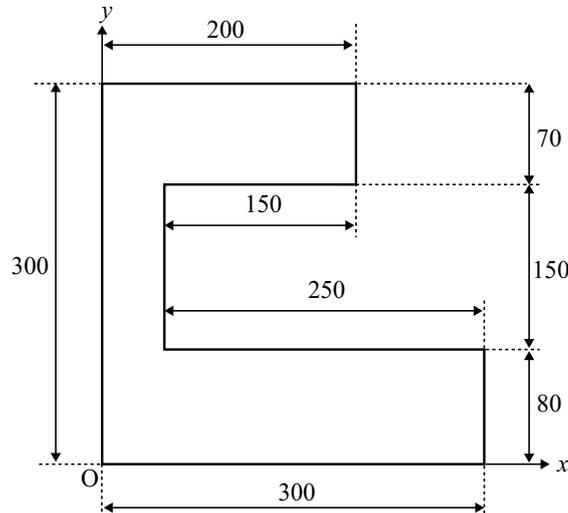
Fig. 1

Calculate the coordinates, $\bar{x}$ and $\bar{y}$, of the centroid of the plate.

Total area = 45500

Application of second moment of area

$$45500 \begin{pmatrix} \bar{x} \\ \bar{y} \end{pmatrix} = 15000 \begin{pmatrix} 25 \\ 150 \end{pmatrix} + 10500 \begin{pmatrix} 125 \\ 265 \end{pmatrix} + 20000 \begin{pmatrix} 175 \\ 40 \end{pmatrix}$$

$$45500 \begin{pmatrix} \bar{x} \\ \bar{y} \end{pmatrix} = \begin{matrix} 5187500 \\ 5832500 \end{matrix}$$

$\bar{x} = 114.0 (mm)$
$\bar{y} = 128.19 (mm)$

[5]

Question 1(b)

(b) (i) A steel component operates at a working axial stress of 110 MPa. The ultimate stress of the material is 240 MPa. Calculate the Factor of Safety of this component.

(FOS = 240 ÷ 110 =) 2.2 (2.18)   **[1]**

(ii) Explain the implications for the behavior of this component if the operational stress level were to exceed the elastic limit of the material.

There would be permanent / plastic deformation (owtte).   ......

[1]

(iii) The component is a circular metal bar with diameter 45 mm and is subjected to a shear force of 120 N. Calculate the shear stress in the component. You must give appropriate units with your answer.

Area = π × 22.5^2 = 1590.4...mm^2 (or 0.00159 m^2)

(Shear stress =) 120/1590.4

= 0.07545 N/mm^2 (or MPa) UNIT REQUIRED
(OR 75451 N/m^2 or Pa)

[3]

Mark scheme guidance

Question 1(a):

Correct substitution seen or implied for second moment of area method. Allow ecf for area.

1 compensation mark available for $\bar{x}$ and 1 compensation mark available for $\bar{y}$.

Candidates may have split shape up differently and so areas and centroid values will need checking.

Allow ecf for incorrect area only.

Allow ecf for incorrect area only.

Question 1(b)(iii):

Calculation of area.

Allow ecf for incorrect area.

Allow ecf for incorrect area.

Allow 0.076N/mm^2.

Examiners comments

Question 1(a) – Most Centres had clearly given candidates good preparation in how to determine the coordinates of the centroid of a flat plate. Candidates lost marks mainly due to careless errors. Many candidates used a tabular approach to show workings for the individual parts that the plate is broken down into and this good practice. The best candidates also included summary equations before clearly stating their computed coordinates.

Question 1(b) – It is worth noting that Factor of Safety is dimensionless. Many candidates made good use of the terms "plastic deformation" and/or "permanent deformation" in explaining what happens when the elastic limit is exceeded. Many candidates failed to score full marks for calculating shear stress because they omitted to include appropriate units. In this case this was explicitly required in the question, but it is good practice always to include appropriate units even when not explicitly required; sometimes candidates may "get away" without losing marks by not including units, but sometimes they will not – so it is strongly recommend that appropriate units are always included.

Questions 2(a), (b) and (c)

2 **(a)** Give one reason for selecting a wormgear and wormwheel arrangement for an application.

........| • Non-reversible direction of transmission wanted
       • Much smaller than using spur gears or equivalents
       • Input and output axes at 90 degrees | **[1]**

(b) Give one example of a mechanism that uses a Class one lever.

........| E.g. pliers, crowbar, jack for a car | **[1]**

(c) A Class 2 lever has a mechanical advantage (MA) of 1.95. The maximum load the lever can lift is 392 N.

   (i) Calculate the effort required to lift this load.

(Effort = 392/1.95 =) 201(N) **[1]**

   (ii) The effort is applied at a distance of 1.2 m away from the fulcrum of the lever. Calculate the distance between the load and the fulcrum.

(B = 1.2 ÷ 1.95 =) 0.615 (m)

.... **[1]**

   (iii) The 392 N load lifted by the lever is a circular metal bar of uniform density 7000 kg m^{-3}. Calculate the volume of the bar.

(Mass = weight/g = 392/9.8 =) 40(kg)
(Volume = mass/density = 40/7000
=) $5.714... \times 10^{-3}$ (m^3) **[2]**

   (iv) The length of the bar is 0.35 m. Using your answer from part (c)(iii) calculate the diameter of the bar.

Area = volume/length = 0.01632...

Radius = $\sqrt{\dfrac{Area}{\pi}}$

= 0.0721.. m
(Diameter =) 0.1441 (m) **[2]**

Question 2(d)

(d) (i) Two spur gears, A and C, are meshed together. A is the input gear and has 24 teeth. Calculate the number of teeth required on gear C such that it rotates at 1.5 times the speed of gear A.

> (VR = (teeth in)/(teeth out) = 1.5)
> (teeth out = 24/1.5 =) 16

... **[1]**

(ii) The application for the gears A and C in part (d) (i) requires gear C to rotate in the same direction as gear A. An alternative gear train is proposed, with gear B inserted between gears A and C. The gears are represented as circles in Fig. 2.

Gear A: 24 teeth

Gear B: 48 teeth
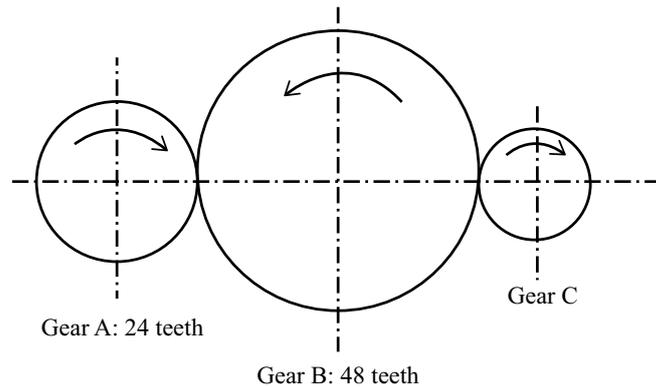
Gear C

Fig. 2

State the name for gear B as used in this application.

> Idler gear

... **[1]**

(iii) Gear B has 48 teeth. It is still required that gear C rotates at 1.5 times the speed of gear A. Calculate the number of teeth required on gear C for this alternative gear train.

> VR = (24/48)(48/TC)
> = 1.5
> (TC = 24/1.5 =) 16

... **[2]**

(iv) An alternative system to transfer rotary motion between two shafts would be a belt and pulley system. Give **one** advantage to using a gear system such as the one shown in Fig. 2 rather than a belt and pulley system.

> One mark from e.g.:
> • Less maintenance
> • No slipping (if compared with non-toothed belts)
> • Greater maximum torque transmission

... **[1]**

Mark scheme guidance

Question 2(a):

Accept any valid reason

Reason must be specific to this type of gear arrangement.

Question 2(b):

Accept any valid application.

Accept see saw balance.

Question 2(c)(iii):

Method mark for calculation of mass.

Award 1 if volume calculated correctly using weight instead of mass (Answer of 0.056 seen) and previous mark not already awarded.

Question 2(c)(iv):

Allow ecf part (iii).

Accept answers between 0.07208 and 0.07211. Allow ecf part (iii) only.

Question 2(d)(iv):

Accept suitable alternative answers.

Accept higher efficiency or higher accuracy.

Advantage must be specific to this gear arrangement.

Examiners comments

Question 2(a) – Correct answers gave specific reasons for selecting "wormgear and wormwheels" rather than other types of gear arrangement. For example, "high gear ratio" was not credited as it is too general (and can be achieved by many alternative arrangements).

Question 2(b) – Most candidates correctly identified a class 1 lever.

Question 2(c) – The best responses clearly stated the relevant basic formula used, showed rearrangement and substituted values, and then stated the calculated answer to an appropriate number of significant figures together with the appropriate unit. It would benefit all candidates to follow this approach.

Question 2(d) – Most candidates were able to successfully apply their knowledge of gears to the situation involving 2 spur gears although most were unable to deal with calculations when an idler gear was introduced. It was pleasing though that most used the correct technical term for this 3rd gear.

Exemplar Candidate Work

Question 2(c) – low level answer

(i) Calculate the effort required to lift this load.

$$1.95 \times 392 = 764.4 \text{ N} \quad [1]$$

(ii) The effort is applied at a distance of 1.2 m away from the fulcrum of the lever. Calculate the distance between the load and the fulcrum.

$$\frac{392}{201.0} = \frac{d}{1.2} \qquad d = \frac{392}{201.0} \times 1.2 = 2.34 \text{ m} \quad [1]$$

(iii) The 392 N load lifted by the lever is a circular metal bar of uniform density 7000 kg m⁻³. Calculate the volume of the bar.

$$\frac{392}{9.8} = 40 \qquad \frac{7000}{40} = 175 \text{ m}^3 \quad [2]$$

(iv) The length of the bar is 0.35 m. Using your answer from part (c)(iii) calculate the diameter of the bar.

$$D \times L = V$$
$$\frac{V}{L} = D \qquad D = 0.016 \text{ m} \quad [2]$$

Commentary

In 2ci calculation is incorrect. Only 1 mark is available and to score this, candidate should use the relationship "Load/effort = MA" (with correct substitution and calculation). The recommended approach for calculations is to state clearly the relevant basic formulae used, rearrange and substitute values, and then state the calculated answer to an appropriate number of significant figures together with the appropriate unit.

In 2cii the calculation is incorrect. Only 1 mark is available and to score this, the candidate should use:

EITHER "(sum of) clockwise moment(s) = (sum of) anticlockwise moment(s)" together with the relationship "Moment of Force = Force × (perpendicular) distance" (with correct substitution and calculation)

OR Distance between Effort and Fulcrum/Distance between Load and fulcrum = MA (with correct substitution and calculation.

The recommended approach for calculations is to state clearly the relevant basic formulae used, rearrange and substitute values, and then state the calculated answer to an appropriate number of significant figures together with the appropriate unit.

In 2ciii the calculation is not correct, and no compensation mark is awarded. 2 marks are available and to score both marks candidate should use the relationships "density = mass/volume" and "Weight = mass × gravitational field strength" (with correct substitution and calculation). It is possible to score 1 compensation mark by correctly calculating the mass. A clear statement of the formula used (e.g. W = mg) is recommended.

The recommended approach for calculations is to state clearly the relevant basic formulae used, rearrange and substitute values, and then state the calculated answer to an appropriate number of significant figures together with the appropriate unit.

In 2civ the calculation is not correct, and no compensation mark is awarded. 2 marks are available and to score both marks candidate should use the relationships "volume (of cylinder) = cross sectional area × length" and "Area (of circle) = pi r^{2}" (with correct substitution and calculation). It is possible to score 1 compensation mark by using "Area = volume/length" (or if candidate's answer to 2ciii divided by 0.35 is seen or calculated).

The recommended approach for calculations is to state clearly the relevant basic formulae used, rearrange and substitute values, and then state the calculated answer to an appropriate number of significant figures together with the appropriate unit.

Exemplar Candidate Work

Question 2(c) – high level answer

(i) Calculate the effort required to lift this load.

MA $\quad \dfrac{392}{1.95} = 201N$ [1]

(ii) The effort is applied at a distance of 1.2 m away from the fulcrum of the lever. Calculate the distance between the load and the fulcrum.

$\dfrac{Fo}{Fi} = \dfrac{a}{b} \qquad \dfrac{7644}{392} = \dfrac{1.2}{b} \qquad 1.95 = \dfrac{1.2}{b} \qquad b = \dfrac{1.2}{1.95} = 0.615m$ [1]

(iii) The 392 N load lifted by the lever is a circular metal bar of uniform density 7000 kg m^{-3}. Calculate the volume of the bar.

$p = mv \quad \dfrac{m}{p} \quad \dfrac{\left(\dfrac{392}{9.8}\right)}{7000} = 5.7 \times 10^{-3} m^3$ [2]

(iv) The length of the bar is 0.35 m. Using your answer from part (c)(iii) calculate the diameter of the bar.

$V = \pi r^2 l$

$0.5488 = \pi r^2 \times 0.35$ [2]

$r^2 = \dfrac{0.5488}{0.35\pi}$

Ci. $1.95 = \dfrac{392}{in}$

force in $= 201.03 N$

$r^2 = 0.4991$

$r = 0.7065$

$d = 1.413m$

Commentary

In 2ci the calculation and answer are correct.

The recommended approach for calculations is to state clearly the relevant basic formulae used, rearrange and substitute values, and then state the calculated answer to an appropriate number of significant figures together with the appropriate unit.

In 2cii the calculation and answer are correct.

The recommended approach for calculations is to state clearly the relevant basic formulae used, rearrange and substitute values, and then state the calculated answer to an appropriate number of significant figures together with the appropriate unit.

In 2ciii the calculation and answer are correct.

The recommended approach for calculations is to state clearly the relevant basic formulae used, rearrange and substitute values, and then state the calculated answer to an appropriate number of significant figures together with the appropriate unit.

In 2civ the calculation and answer are correct.

The recommended approach for calculations is to state clearly the relevant basic formulae used, rearrange and substitute values, and then state the calculated answer to an appropriate number of significant figures together with the appropriate unit.

Question 3

3 **(a)** **(i)** In a game of curling a player is using a force of 20 N to propel a curling stone to a speed of 5 m s^{-1}. Calculate the instantaneous power of the stone.

$(P = Fv = 20 \times 5 =)$ 100 (W) .. **[1]**

(ii) The curling stone has a mass of 19.5 kg and after it has been released by the player it travels along the ice until its speed has reduced to 3 m s^{-1}. Calculate the kinetic energy of the stone at this time.

$(E_k = (19.5 \times 3^2)/2 =)$ 87.75 (J) .. **[1]**

(iii) At this time the curling stone hits another stationary stone of mass 17.5 kg. After the collision the stationary stone is pushed forward at a speed of 1 m s^{-1}. Assuming conservation of momentum calculate the speed of the 19.5 kg stone immediately after the collision.

$19.5 \times 3 + 17.5 \times 0 = 19.5v + 17.5 \times 1$ ....
$(v = (58.5 - 17.5)/19.5 =)$ 2.1026 (m s^{-1}) .. **[2]**

(b) At a particular time while a ball is travelling through the air it is acted upon by three forces as shown in Fig. 3.
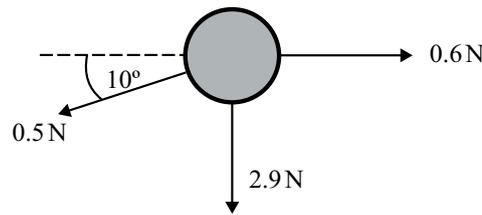

Fig. 3

(i) State what the 2.9 N force shown in the diagram represents.

. Weight (of the ball) .. **[1]**

(ii) Calculate the magnitude of the resultant force acting on the ball.

(Net) horizontal force = 0.6-0.5cos10 / 0.1076 ....
(Net) vertical force = 0.5sin10 + 2.9 / 2.9896 ....
Res = $\sqrt{0.1076^2 + 2.9868^2}$ ....
Res = 2.99 (N)

[4]

(iii) Calculate the acceleration of the ball in the direction of this resultant force.

. $(A=\Sigma F/m = 2.99/0.3 =)$ 9.96 (m s^{-2}) .. **[1]**

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Mark scheme guidance

Question 3(b)(i):

NOT mass of the ball. NOT gravity.

Accept other reasonable answers.

e.g. mass of ball × g OR mg if seen.

force acting on the ball due to gravity etc.

Question 3(b)(ii):

Accept reasonable rounding (expect answers between 2.95 and 3.2).

Question 3(b)(iii):

Allow ecf part (ii).

Accept reasonable rounding [9.8,…. 10.2].

Examiners comments

Question 3(a) – Most candidates were able to apply basic formulae to calculate power and kinetic energy. However very few candidates were able to deal with a simple conservation of energy calculation involving a collision between a moving and a stationary object.

Question 3(b) – It was disappointing that so many candidates use the term "gravity" when they mean "weight" or "force due to gravity". There was good evidence that Centres had given candidates good preparation in the calculation a resultant forces by resolving into vertical and horizontal components. In most cases where marks were lost, this was due to careless mistakes by candidates. Most candidates were able to calculate acceleration using their calculated resultant force and the mass of the object.

Question 4

4   A lorry of mass 4000 kg travels along a rough horizontal road.

   (i)   The lorry starts from rest and accelerates uniformly for 14 seconds until it reaches a speed of 24.5 m s^{-1}. Calculate the acceleration of the lorry.

   $v = u + at$
   $24.5 = 0 + 14a$
   $(a =) 1.75 \text{ (ms}^{-2})$ **[2]**

   (ii)   The coefficient of friction between the road surface and the tyres of the lorry is 0.22. Calculate the frictional force acting on the lorry.

   $R = 4000 \times 9.8 / R = 39200$
   $(F_{max} = \mu R = 0.22 \times 39200 =) 8624 \text{ (N)}$ **[2]**

   (iii)   The engine of the lorry produces a driving force F N. Calculate the value of the driving force required to achieve the acceleration as calculated in part (i). You may assume that no other forces are acting on the lorry except for the friction force calculated in part (ii).

   $\Sigma F = ma = 4000 \times 1.75$
   $F - 8624 = 4000 \times 1.75$
   $(F =) 15624 \text{ (N)}$ **[3]**

Mark scheme guidance

Question 4(i):

Correct equation and correct substitution.

Question 4(iii):

Attempt to apply N2L with at least 'ma' calculation shown.

All elements of calculation correct including signs.

Allow ecf from part (i) and (ii).

Examiners comments

Most candidates were able to use suvat equations (or just the definition of acceleration) to calculate acceleration. Most were also able to calculate frictional force from the mass and coefficient of friction – although a significant minority omitted "g" from their calculations. Not quite as many candidates – although still a majority – were able to calculate the force required to achieve the acceleration. Learners may find it useful to draw a simple free body diagram in order to better understand situations like this one. Note also that the earlier comments on presentation and units are relevant here too.

Question 5

5 **(a)** Give an example of what could cause the following types of load on a structure.

(i) Uniformly Distributed Load (UDL)

E.g. wind loading on wall, cars bumper to bumper on a bridge, snow load on a roof. **[1]**

(ii) Point Load

E.g. individual car or truck on a bridge, main load carried by a crane. **[1]**

(b) Fig. 4 shows a simply-supported beam with supports A and B. The beam is subjected to three forces, 2000 N, 4000 N and 1500 N in the directions shown.
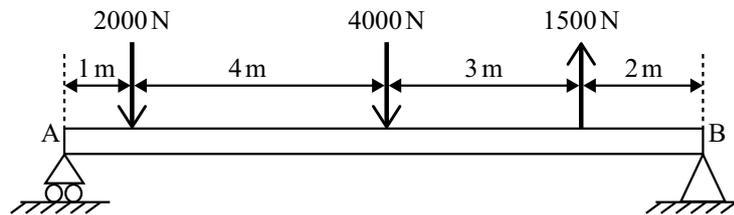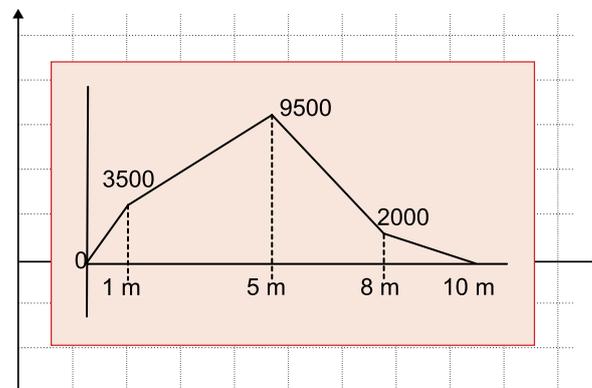

Fig. 4

(i) Calculate the vertical reaction forces at supports A and B.

$2000 \times 1 + 4000 \times 5 = 1500 \times 8 + 10R_b$
OR $10R_a + 1500 \times 2 = 4000 \times 5 + 2000 \times 9$
OR $R_a + R_b = 4500$
$R_b = 1000 (N)$
$R_a = 3500 (N)$ **[3]**

(ii) Calculate the bending moment at the centre of the beam.

$1000 \times 5 + 1500 \times 3 = 9500$ Nm
Or $3500 \times 5 - 2000 \times 4 = 9500$ Nm **[1]**

(iii) Draw a labelled bending moment diagram for the beam on the grid below.

[4]

Mark scheme guidance

Question 5(a)(i):

Accept any sensible answer – must state what structure loading is acting upon (e.g. wall, bridge roof etc).

Question 5(a)(ii):

Accept any sensible answer – must state what structure the load is acting upon.

Question 5(b)(ii):

Allow -9500.

Question 5(b)(iii):

Values of 0 (Nm) at 0m and 10m (or A and B shown) – only award for a BENDING MOMENT diagram.

Value of 9500 (or ecf) seen at correct point on diagram (may be negative).

Values of 3500 and 2000 shown at correct points on diagram (must have same sign as 9500).

Diagram drawn and labelled correctly as shown.

Examiners comments

Question 5(a) – The most pleasing responses avoided examples that were simply too vague by making clear what structure the load specified was acting upon.

Question 5(b) – With some notable exceptions, the vast majority of candidates scored very low – often zero – marks for this question. Question 5(b) is essentially a GCSE level science question although the context may be a slightly unfamiliar one. It seems clear that candidates need more practice and instruction in dealing with these simple moments questions. The parts of the question on bending moments and bending moment diagrams are different in that they would not appear on either GCSE science or A level physics specifications so this clearly represents a greater challenge for learners and Centres alike. However, the principles involved are relatively simple so again this is an area for more time spent in instruction by Centres and practice by learners.

Exemplar Candidate Work

Question 5(b) – low level answer

(i) Calculate the vertical reaction forces at supports A and B.

$$-(1500 \times 2) + (4000 \times \frac{8}{5}) + (2000 \times 9)$$
$$= A = 35000 N$$
$$B = 10,000 N \qquad [3]$$

(i) Calculate the vertical reaction forces at supports A and B.

$\Omega = \zeta$

$$R_A + R_B + 1500 = 2000 + 4000 \qquad R_A + R_B = 4500 N$$

resolve @ A $= (2000 \times 1) + (4000 \times \frac{5}{4}) = (1500 \times 8) + (R_B \times 10)$

$$2000 + 20,000 = 12,000 + 10R_B$$

$$\frac{22,000 - 12,000}{10} = R_B \qquad R_B = 1000N \qquad [3]$$

R_A is found on extra paper. $R_A = 3500N$

(iii) Draw a labelled bending moment diagram for the beam on the grid below.

[4]
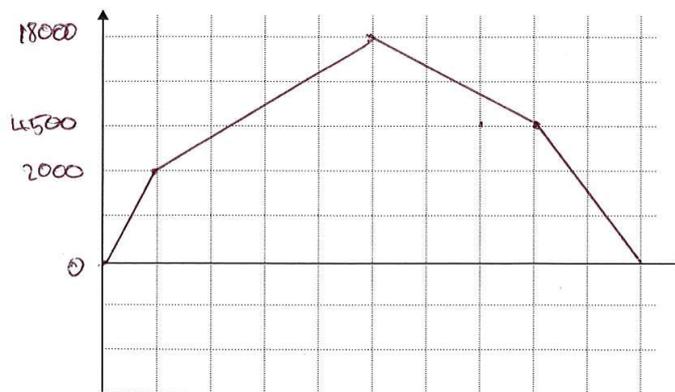
Commentary

In 5bi the candidate does not correctly calculate either vertical reaction force and does not score a compensation mark. A compensation mark can be scored EITHER by a correct statement of rotational equilibrium about A or B (e.g. 2000 × 1 + 4000 × 5 = 1500 × 8 +10RB) OR by a correct statement of vertical equilibrium (i.e. RA + RB = 4500).

The recommended approach for calculations is to state clearly the relevant basic formulae used, rearrange and substitute values, and then state the calculated answer to an appropriate number of significant figures together with the appropriate unit.

In 5bii the calculation is incorrect. Only 1 mark is available and to score this, candidate should apply the relationship "Moment of Force = Force × (perpendicular) distance" (with correct substitution and calculation). The recommended approach for calculations is to state clearly the relevant basic formulae used, rearrange and substitute values, and then state the calculated answer to an appropriate number of significant figures together with the appropriate unit.

In 5biii credit is given for showing values of 0Nm at BOTH 0m and 10m. Correct value of BM at 5m would score a 2nd compensation mark and correct values of BM at BOTH 1m and 8m would score a 3rd compensation mark. In order to score all 4 marks the diagram needs to be drawn and labelled correctly as shown in mark scheme.

Exemplar Candidate Work

Question 5(b) – high level answer

(i) Calculate the vertical reaction forces at supports A and B.

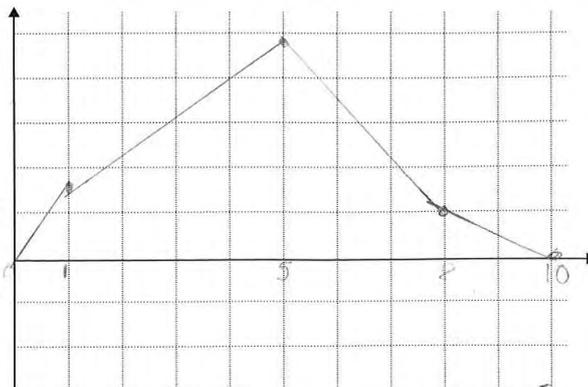$A + B = 4500$ $A = (2000) + (5 \times 4000) - (8 \times 1500) + B \times 16$

$B = 1000$ $A = 3500$

[3]

(ii) Calculate the bending moment at the centre of the beam.

$(3500 \times 5) - (2000 \times 4) = 9500 NM$ [1]

(iii) Draw a labelled bending moment diagram for the beam on the grid below.

A $3500 \times 0 = 0$
B $3500 \times 1 = 3500$

C $3500 \times 5 - 2000 \times 4$
$= 9500$

D $3500 \times 8 - 2000 \times 7$
$- 4000 \times 3 = 2000$

$3500 \times 9 - 2000 \times 8$
$- 4000 \times 4 + 1500 \times 2$
2000

[4]

Commentary

In 5bi, candidate shows correct statements of rotational and vertical equilibrium leading to correct values of RA and RB so this is a high level answer.

In 5bii the candidate applies the appropriate relationship to calculate the bending moment at the centre of the beam leading to correct value.

In 5biii the candidate's diagram is drawn and labelled correctly (i.e. as shown in mark scheme) so this is a high level answer.

Questions 6(a)

6 (a) Fig. 5 shows a particle suspended in equilibrium. The particle is subjected to a vertical downward force of 210 N, a horizontal force of P N and a force of Q N acting at an upward angle of 35° to the horizontal.
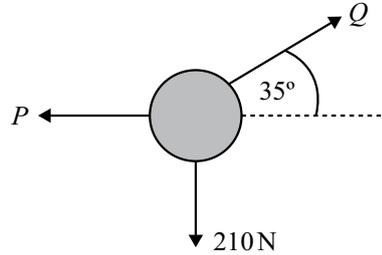

Fig. 5

Calculate the magnitudes of P and Q such that the particle remains suspended in equilibrium.

Horizontal equilibrium: Qsin35 = 210
Q = 366.1(N)
Vertical equilibrium: P = Qcos35
P = 299.9 (N)

[4]

Questions 6(b)

(b) Fig. 6 shows a rectangular plate ABCD subjected to five forces acting perpendicular to its sides. Force F acts at a distance of x m to the right of corner A.
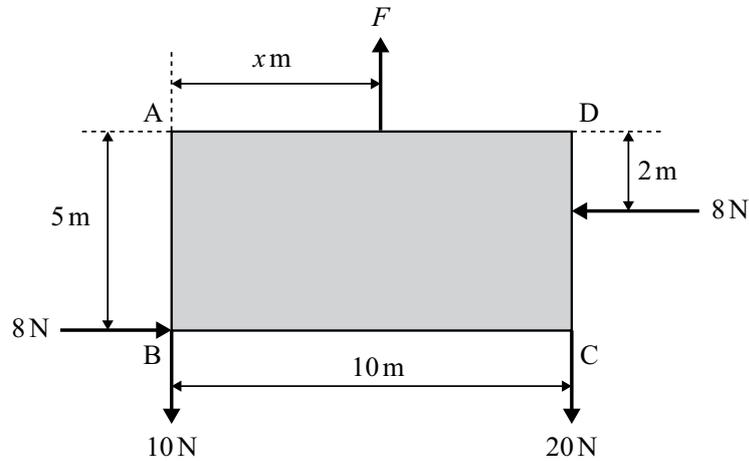

Fig. 6

Calculate the force F and the distance x required to maintain the plate in vertical, horizontal and rotational equilibrium.

(For vertical equilibrium) F = 10 + 20

F = 30 (N)

Correct moments equation (e.g. F x + 8 × 3 − 20 × 10 = 0)
(x = 276/30 =) 5.87 (m)

[6]

Mark scheme guidance

Question 6(b):

Award 1 mark for correct equation.

Award 3 marks for correct moments equation about any corner. Deduct 1 mark for each mistake.

Examiners comments

Question 6(a) – This question provided more evidence that most Centres had prepared their learners well for questions involving resolution of forces; most learners applied this knowledge successfully in this situation involving static equilibrium.

Question 6(b) – This question provided further evidence that the majority of learners were not comfortable dealing with simple moments questions for a body in equilibrium. Candidates where low marks were scored in 5(b)(i) unsurprisingly tended to score low (or no) marks for 6(b).

Exemplar Candidate Work

Question 6(b) – low level answer

(b) Fig. 6 shows a rectangular plate ABCD subjected to five forces acting perpendicular to its sides. Force F acts at a distance of x m to the right of corner A.
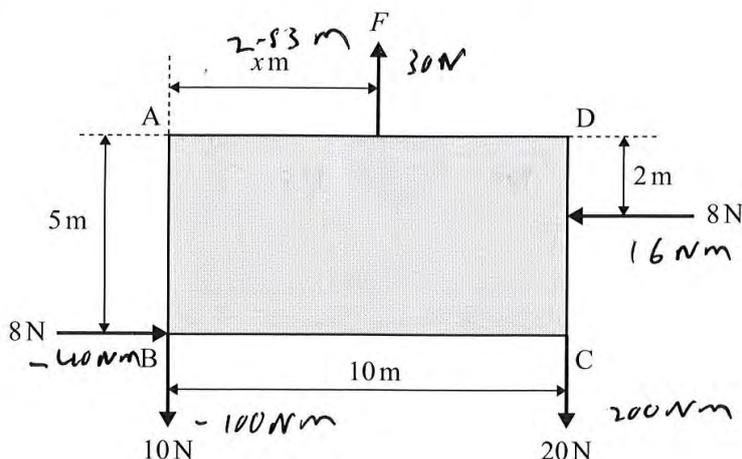

Fig. 6

Calculate the force F and the distance x required to maintain the plate in vertical, horizontal and rotational equilibrium.

$-5 \times 8 = -40 \, Nm$ $2 \times f = 16 \, Nm$

$10 \times 20 = 200 \, Nm$ $-10 \times 10 = -100 \, Nm$

H   V $-40 + 16 + 200 - 100 = 76$

$76 \, Nm$ clockwise

$8 - 8$ flat $-10 - 20 = -30 \, N$ down   [6]

$30 \times d = 76$ $76 \div 30 = 2.53 \, m$

$F = 30N$ $x = 2.53 m$

Commentary

In 6b, candidate correctly states the value of F as 30N and has therefore implicitly applied the principle of vertical equilibrium.

However, the candidate does not calculate the value of x correctly and does not apply the principle of rotational equilibrium correctly and so does not score any additional marks.

Compensation mark(s) could have been scored by writing down a correct (or partially correct) equation using the relationships "sum of clockwise moments = sum of anti-clockwise moments" and the relationship "Moment (of force) = Force × (perpendicular) distance". These improvements would have made this a medium level answer.

Exemplar Candidate Work

Question 6(b) – medium level answer

(b) Fig. 6 shows a rectangular plate ABCD subjected to five forces acting perpendicular to its sides. Force F acts at a distance of x m to the right of corner A.
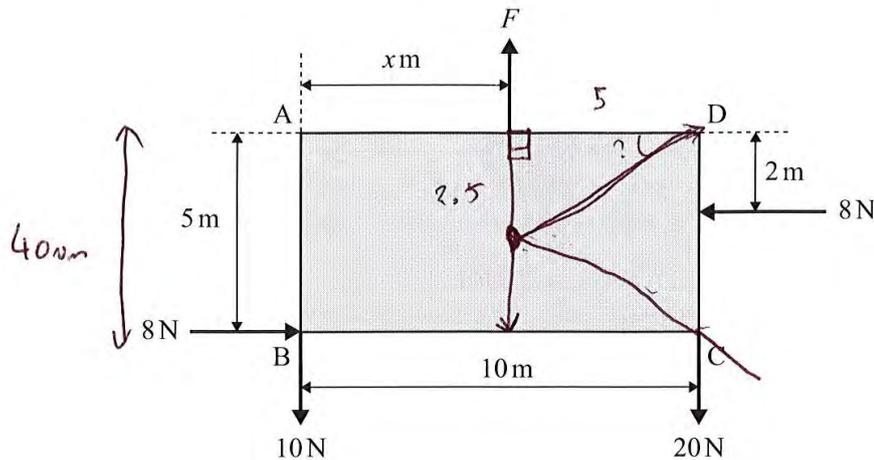

Fig. 6

Calculate the force F and the distance x required to maintain the plate in vertical, horizontal and rotational equilibrium.

$$8 \times 5 = 40 \text{ Nm} \quad \times 2 = 80 \text{ Nm} \qquad 10 \div 2 = 5 \qquad x = 5 \text{ m}$$

$$10 \quad 10$$

$$20 - 10 = 10 \text{ N} \qquad F = 20 + 10 = 30$$

$$20 + 10 = 30 \text{ N} \qquad F = 30 \text{ N}$$

$$30 \times 10 = 300 \text{ N.m}$$

[6]

Commentary

In addition to the 2 marks awarded in the low level answer above, an additional 2 marks with BOD (benefit of doubt) are awarded for an attempt to apply rotational equilibrium. In order to score these additional marks more securely, it should be clear that moments are being taken about a stated point, and an equation should be seen including the moments due to the relevant forces (allowing for some errors).

In order to make this a high level answer, a correct equation should be seen which uses the relationships "sum of clockwise moments = sum of anti-clockwise moments" and "Moment (of force) = Force × (perpendicular) distance". Values should then be substituted correctly and the correct value of "x" should be calculated and stated to an appropriate number of significant figures.

Exemplar Candidate Work

Question 5(b) – high level answer

(b) Fig. 6 shows a rectangular plate ABCD subjected to five forces acting perpendicular to its sides. Force F acts at a distance of x m to the right of corner A.
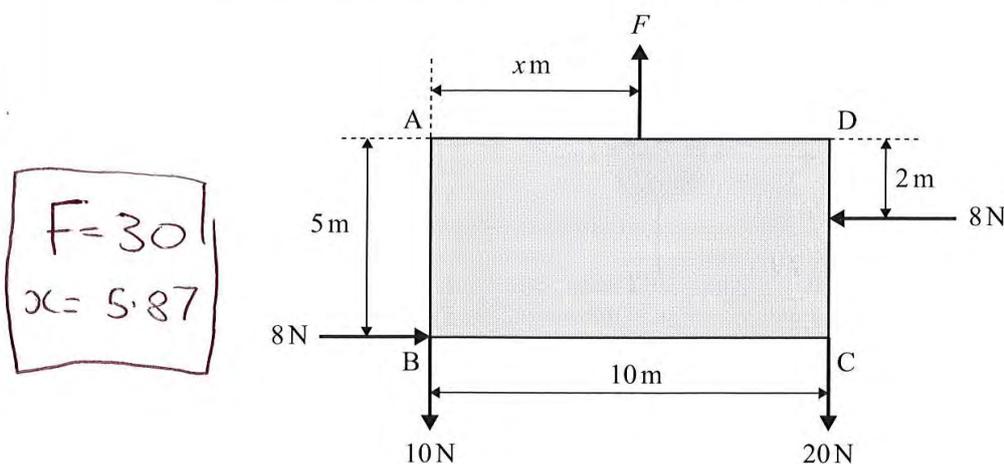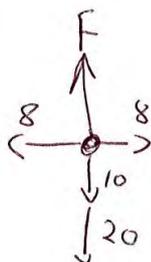
$F = 30$
$x = 5.87$

Calculate the force F and the distance x required to maintain the plate in vertical, horizontal and rotational equilibrium.

$R \uparrow \downarrow \quad F - 30N = 0 \quad \boxed{F = 30 N}$

$R \leftrightarrows = 0$
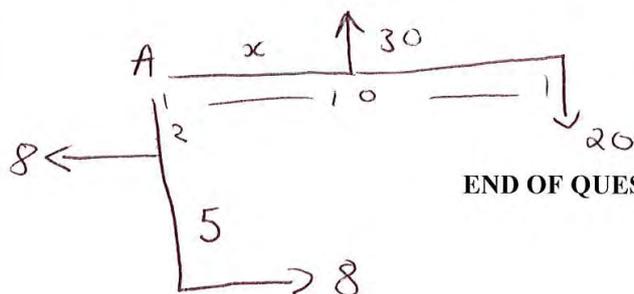
$R \circlearrowleft = 30x + (5 \times 8) = 30x + 40$

$R \circlearrowright = (10 \times 20) + (2 \times 8) = 216$

$216 = 30x + 40 \qquad 30x = 176$

$\boxed{x = 5.87m}$ [6]

END OF QUESTION PAPER

Commentary

This candidate has calculated correctly the values of F and x using the appropriate principles of vertical and rotational equilibrium. Candidate has resolved forces vertically to find "F" and has taken moments about point A to find "x".

Excellent responses to questions of this type frequently include the statement "(taking) moments about (point) A" or similar.

The small print

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