OCR
Oxford Cambridge and RSA

Cambridge **TECHNICALS LEVEL 3**

ENGINEERING

Cambridge TECHNICALS 2016

Feedback on the June 2018 exam paper
(including selected exemplar candidate answers
and commentary)

Unit 2 – Science for engineering

Version 1

ocr.org.uk/engineering

CONTENTS

INTRODUCTION

This resource brings together the questions from the June 2018 examined unit (Unit 2), 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 4(a), 4(b), 6(i), 6(ii), 6(iii) and 6(iv).

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

This Erratum Notice is relevant to question 3(b).

The notice can be found on Interchange.

GENERAL EXAMINER COMMENTS ON THE PAPER

In general candidates are making good use of the answer space available to show working for calculation questions and are more often including correct units in numerical answers. Candidates need to make sure that they read the question properly and make better use of scientific terminology to improve their overall performance in this paper. There seemed little evidence of candidates running out of time. Question 6 proved to be challenging for many candidates as it had a synoptic nature.

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

Answer **all** the questions.

1 (a) Which of the following units is a correct unit of force? Put a ring around the correct response.

$kg\ m\ s^{-1}$ $kg\ m\ s^{-2}$ $kg\ m^2\ s^{-2}$ $kg\ m^2\ s^{-1}$

[1]

(b) Convert the following measurements to the given units.

- $5\,m = $ ……….......………. µm
- $10\,cm^2 = $ ………………… m^2
- 100 litre = ………………... mm^3

5 m = 5 × 106 µm [5,000,000]

100 cm² = 10⁻³ m² [0.001]

100 litre = 108 mm³ [100,000,000]

[3]

(c) For a standard deviation of σ = 0.45 and sample size $N = 15$ calculate the standard error of the mean. Use the equation standard error of the mean = σ/(√N).

(SE = σ ÷ (N)⁰·⁵ = 0.45 ÷ (15)⁰·⁵ =) 0.12

Standard error of the mean = ……………………… **[1]**

(d) Explain what is meant by the term 'calibration' and why it is important in measuring.

One mark for each of the following – up to a max of 3 marks.
- Checking/adjusting instrument
- Comparing measurements (from one instrument with those from a more accurate instrument) to a standard (method/procedure)
- Use of predefined interval or marker
- Ensures instrument measures correctly/accurately
- Need to make all measurements repeatable/consistent
- Errors can be accounted for/corrected/removed.

[3]

(e) If the true length of a beam is 150 mm and the measured value is 151 mm calculate the relative error and absolute correction.

Relative error (151 – 150) ÷ 150 = 0.0067
(Absolute correction: 150 – 151 =) -1(mm)

Relative error = ………………………………..… **[1]**

Absolute correction = ………………… mm **[1]**

© OCR 2018

Mark scheme guidance

Question 1(a):

Second one is ringed.

Accept other clear methods to indicate choice.

Question 1(c):

Answer is 0.116.

Question 1(d):

ALLOW set to zero.

Question 1(e):

ALLOW $\frac{1}{150}$ (soi) and 0.006.

ALLOW 0.67%. Ignore any units given.

Correction must have negative sign.

Examiner comments

Question 1(a) – was generally well answered, with many candidates showing good understanding of base SI units in this context.

Question 1(b) – very few candidates gained all three marks, despite the first two conversions being relatively straightforward. A common error in the first example was to suggest that 5 m is 5×10^{-6} μm instead of 5×10^{6} μm. Common misconceptions in converting 10 cm^2 included forgetting the squared factor or thinking that 10 cm^2 is a square 10 cm × 10 cm. Converting units is a skill needed throughout the paper and in engineering in general.

Question 1(c) – was generally well answered.

Question 1(d) – most candidates were able to write some relevant comments about calibration and were able to gain some marks here.

Question 1(e) – many candidates were able to calculate both relative error and absolute correction, but some omitted the negative sign on the correction.

Question 2(a)

2   (a)   A 75 kg driver is travelling in a car with mass 1300 kg.

Fig. 1 shows how the velocity of the car changes as it stops at traffic lights.
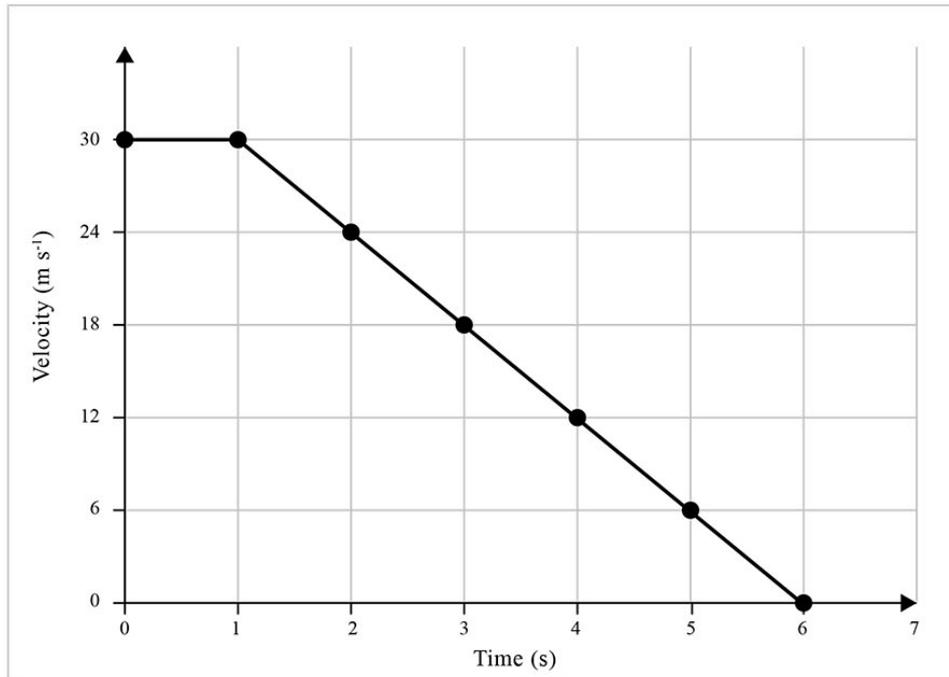
Fig. 1

Calculate

(i)   the deceleration of the vehicle whilst it is braking. Indicate the units used in your answer.

a = ΔV ÷ Δt / a = gradient of the graph / a = (30 ÷ 5)
= 6 m s^{-2}

Deceleration = ………………………………… **[2]**

(ii)   the force acting on the driver due to the deceleration in part (i).

(F = m a = F = 75 × 6 =) 450 (N)

Force = ……………………………….. N **[1]**

Mark scheme guidance

Question 2(a)(i):

CHECK ANSWER LINE; If answer = 6 m s^{-2} award 2 marks.

Correct answer must include unit.

Ignore sign.

Max 1 mark if 6 seen with no unit.

Question 2(a)(ii):

Ignore sign.

Allow ecf of a from part (i).

Examiner comments

Most candidates were able to correctly calculate the acceleration in part (i) from the information given in the graph, and it was good to see the majority including the correct units. Some candidates used the total time period rather than just the 5 seconds when the velocity was changing. However, in part (ii), many candidates did not use the mass of the driver to calculate the force acting on the driver.

Question 2(b)

(b) The same car and driver travel along a straight road at 100 km h⁻¹. The driver applies the brakes and comes to a stop in 38 m.

Calculate

(i) the initial kinetic energy,

> Conversion of speed into ms-1
> (v = 100 × 103 ÷ 3600 =) 27.8 (ms⁻¹)
> (Kinetic energy = mv² ÷ 2 = (1375 × (27.8)²) ÷ 2 =) 5.3 × 10⁵ (J)

Kinetic energy = ... J **[2]**

(ii) the average total braking force.

Average braking force = ... N **[2]**

> Either (using energy = force × distance):
> ΔEk / 5.3 × 10⁵ = F s or F = 5.3 × 10⁵ / 38
> F = 14 × 10³ (N)
>
> $a = \dfrac{v^2}{2s}$ and F = *ma* (seen or implied) or F = *ma* $\dfrac{mv^2}{2s} = \dfrac{13785 \times 27.8^2}{2 \times 38}$
>
> F = 14 × 10³ (N)

Mark scheme guidance

Question 2(b)(i):

CHECK ANSWER LINE; If answer = 5.3×10^5 J award 2 marks.

Use of m = 1300 kg is incorrect

– MAX 1 mark.

If no conversion; energy = 6.9×10^6 (or 10^8); award 1mark.

Question 2(b)(ii):

CHECK ANSWER LINE; If answer = 1.4×10^3 N award 2 marks.

Use of correct relationship.

Allow ecf incorrect energy from (ii).

Use of correct relationships.

Allow ecf incorrect speed and/or mass from (i).

Examiner comments

Most candidates used the correct equation from the formula booklet to calculate kinetic energy in part (i), but there were still a large proportion of candidates who did not attempt to convert the velocity of 100 km h^{-1} to m s^{-1}, or made an error in their conversion. Some then forgot to square the velocity or used the incorrect mass. In part (ii) many candidates did not choose the equation power = force × velocity from the formula booklet, which would then have needed some rearrangement to calculate the force. Many candidates attempted to use the SUVAT equations to find acceleration and hence force, which could have gained them full marks but was a two-step process, so gave more opportunity for errors to occur. Again, some candidates used the wrong mass, and some used the acceleration calculated in part (a)(i).

Question 2(c)

(c) Fig. 2 shows an aerial view of the horizontal forces acting on the car as it goes around a bend.

Determine the value of the resultant horizontal force acting on the car and its direction relative to F_1.
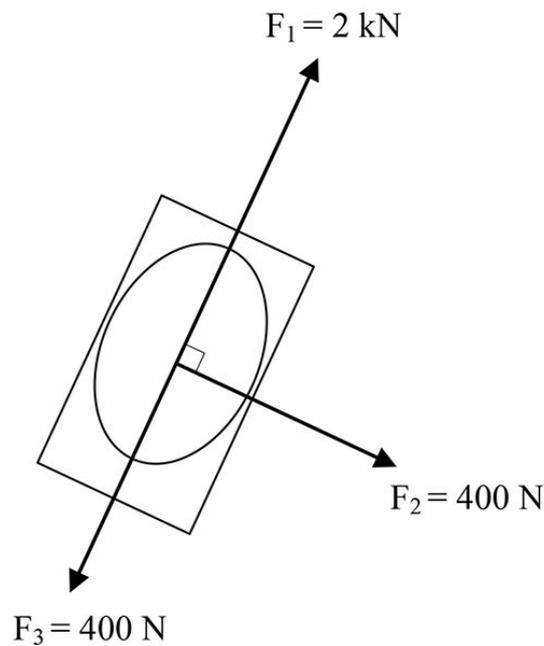
Fig. 2

Either using pythagorus:
Resultant force = $\sqrt{((2000 - 400)2 + 4002)}$ (= $\sqrt{(2.72 \times 106)}$)
= 1650 (N) (tan θ = 400 ÷ 1600 = 0.25 so) θ = 14(°)
or by using a scale diagram:
force diagram or force triangle drawn to scale
Resultant force in range 1600 N ≤ F ≤ 1700 N
angle in range 12° ≤ θ ≤ 16(°)

Resultant force = ... N

Direction = ...

[3]

Mark scheme guidance

ACCEPT 1600 or 1700 with correct working.

ACCEPT 0.24 (radian).

BOD 76° if accompanied by a clearly labelled diagram showing/stating angle relative to F_2.

Examiner comments

2(c) was not particularly well answered. Most candidates attempted to calculate rather than use a scale drawing, but often made mistakes in finding the magnitude of the resultant force. Finding the angle seemed to be the hardest mark to achieve in this question. Some candidates used cosine instead of sine, but the majority showed little understanding of how to find an angle.

Question 3(a)(i)

3 (a) A resistor is connected to a charged capacitor. Initial current flowing through the resistor is 5 mA and it drops to 0.68 mA after 2 seconds.

   (i) On the axes shown in Fig. 3 sketch the graph to show how the current through the resistor changes with time over the first 3 seconds.

Line passes through (0,5) and (2,0.68) (within half a small square), smooth curve, with negative but becoming shallower gradient, across width of graph grid (i.e. 3 seconds).
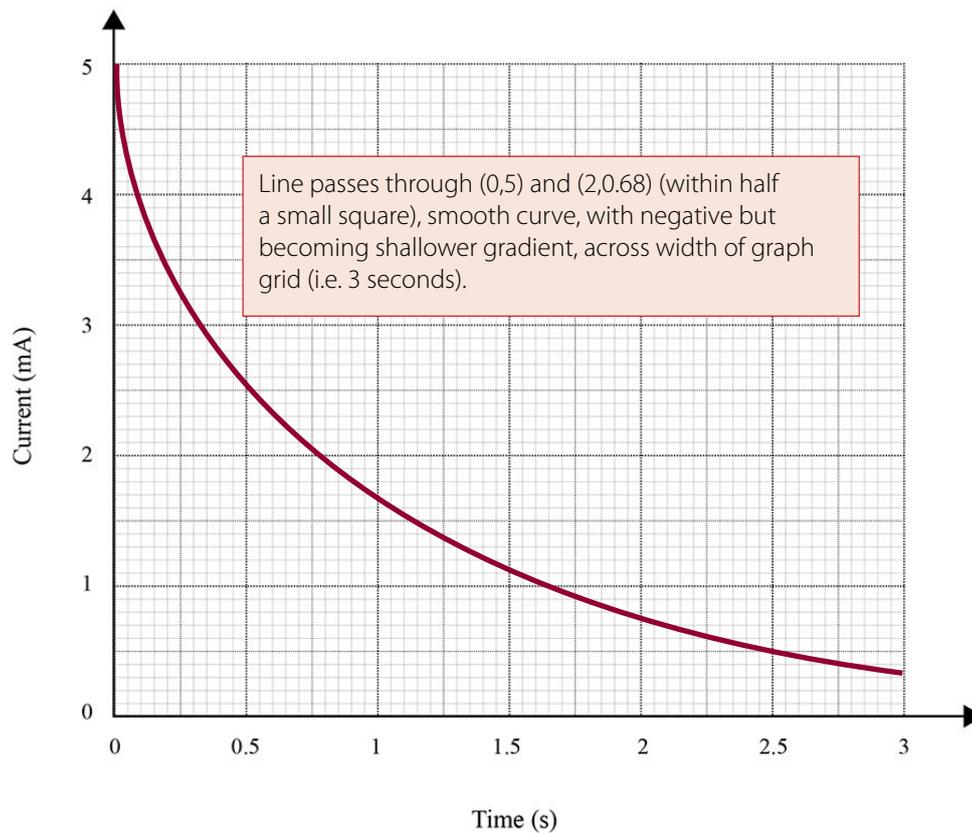
Fig. 3

[2]

Examiner comments

In 3(a) a significant number of candidates did not draw a decay curve to show the discharge of a capacitor. Most drew a straight line between the points stated in the question. Most candidates showed a limited understanding of the concept of the time constant for a capacitor. Many suggested that it was the gradient or the area under the graph.

Question 3(a)(ii)

(ii) Explain how the graph drawn in Fig. 3 could be used to find an approximate value of the time constant for the discharge of the capacitor.

Either:
Line tangent is drawn from the initial part of discharge curve
to intersect the time X axis at the point denoting the time constant (approx 1 s in this case)
Or:
Time constant is the time taken for initial value to fall to 1/e or 37% of original value.
Find the time taken for the current to fall to 1.84 mA (this gives value of 1 s)
Or:
Extrapolating curve until it (almost) reaches x axis.
The time it takes to discharge is approximately 5 × time constant.
Or:
Find half life/time taken for current to halve.
Time constant = half life ÷ 1n2/ = half life × 1.44 Or:
Use data point value for I and value for t.
Substitute into $I = I_o e^{\frac{-t}{RC}}$, (where $I_o = 5$) and time constant = RC.

[2]

© OCR 2018

Mark scheme guidance

These methods can be shown by annotating the graph.

Questions 3(b) and (c)

(b) A partially charged capacitor is additionally charged with 2 mA for 5 seconds. The internal resistance of the capacitor is 200 MΩ. The final voltage over the capacitor is 40 V.

Calculate

(i) how much charge has been added to the capacitor,

$(Q = It = (2 \times 10^{-3})\ (5) =)\ 0.01\ (C)$

Charge added = …………………………..C **[1]**

(ii) the electrical energy added to the capacitor.

Indicate the units used in your answer.

$(W =)\ ½VQ\ \text{or}\ (W =)\ ½VIt\ \text{or}\ (W =)\ ½\ (40)\ (10 \times 10^{-3})$
$E = 0.20\ J$

Energy = ………………………………. **[2]**

(c) A DC electric motor draws a 2 A current from a 300 V supply. The efficiency of the motor is 80%.

Calculate

(i) the output power of the motor,

(Input power $(= IV = 2 \times 300 =)$ 600 W
(Output power = Input Power × efficiency = 600 × 0.8 =) 480 (W)

Output power = ………………………….. W **[2]**

(ii) the energy supplied to the motor during 1 minute.

(Energy supplied = Input Power × time = 600 × 60 =) 36000 (J)

Energy supplied = ………………………..J **[1]**

Mark scheme guidance

Question 3(b)(ii):

CHECK ANSWER LINE; If E = 0.20 J award 2 marks.

Use of correct equation.

Correct value and **unit** with consistent

POT. Max 1 mark for 0.2 without unit.

Allow ecf of Q from part (i).

Question 3(c)(i):

CHECK ANSWER LINE; If Output power = 480 W award 2 marks.

Calculation of power.

Correct calculation of output power.

Question 3(c)(ii):

Use of output power is incorrect but allow ecf of input power from part (i) if clearly stated.

Examiner comments

Question 3(b) – It was good to see that many candidates converted the current given in mA to a current in A before calculating the amount of charge in part (i). In part (ii) many candidates chose the incorrect equation $W = QV$ from the formula booklet, not realising that for a capacitor the potential difference is not constantly at 40 V so $W = \frac{1}{2}QV$ is the correct equation to use.

Question 3(c) – Part (i) involved a two-step calculation. Many candidates only did the first step of calculating the input power of 600 W, and then not using the efficiency to find the output power. In part (ii) candidates needed to realise that the input power should be used to find the energy supplied in a minute, but most were able to choose the correct equation from the formula booklet.

Question 4(a)

4 (a) Fig. 4 shows the stress-strain graphs for two materials.
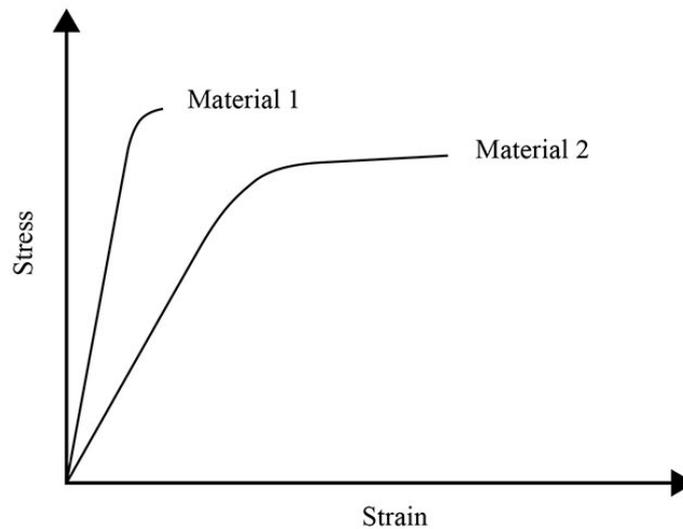
Fig. 4

State and explain which material, 1 or 2, is

(i) stiffer,

Material 1.
because there is a higher gradient (of the stress-strain curve in the elastic region)/higher value of Young's Modulus/less strain at the same stress.

[2]

(ii) stronger,

Material 1.
because there is a higher stress value before failure/higher maximum stress/higher UTS value.

[2]

(iii) tougher.

Material 1.
because there is a larger area under the curve/more energy stored within the material before failure/work done before failure.

[2]

Mark scheme guidance

Question 4(a)(i):

Not just lower strain.

Question 4(a)(ii):

Not just higher stress.

Do not allow higher force before failure, unless reference to area of samples.

Examiner comments

In 4(a), although many candidates were able to identify which material was stiffer and which was stronger, they were unable to explain the reason clearly. There were several vague comments such as "is stiffer because it takes more stress over strain", which doesn't mean anything. Some candidates referred to the amount of force, but as the graph was a stress-strain graph there is no indication of the dimensions of the materials. Part (iii) seemed much more difficult as very few candidates were able to identify that material 2 was tougher and that toughness relates to the energy absorbed by the material or the area under the stress-strain graph.

Exemplar Candidate Work

Question 4(a) – High level answers

4 (a) Fig. 4 shows the stress-strain graphs for two materials.
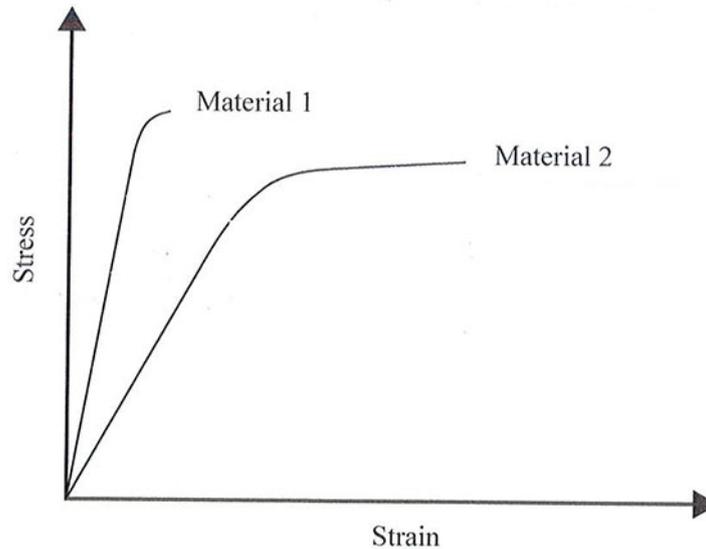
Fig. 4

State and explain which material, 1 or 2, is

(i) stiffer,

Material 1 as the gradient is higher. It experiences less strain for the same stress than material 2 so it bends less. [2]

(ii) stronger,

Material Material 1 as it has a higher ultimate tensile strength than material 2. It can bear more force without breaking than material 2 [2]

(iii) tougher.

Material 2 as it can take more strain than material 1. It stretches more than material 1. [2]

Commentary

This candidate correctly identifies each of the specified materials and the explanations for the first two are correct. In part (i) the candidate correctly refers to the gradient of the straight-line section as a measure of stiffness. A stiffer material will give a steeper line. In part (ii) there is good use of scientific terminology as the candidate states that a stronger material has a higher ultimate tensile strength, which is shown by the peak of the curve being at a higher stress level. In part (iii) the candidate has correctly stated that material 2 is tougher, but the explanation should show some understanding of the term 'toughness'. Toughness of a material is a measure of the amount of energy absorbed when a material fails, and this is represented by the area under the curve. In order to make this a full mark high level answer the candidate needs to state that material 2 absorbs more energy before failure or that there is a larger area under the graph.

Question 4(b)

(b) The table below shows some material properties for steel and an aluminium alloy.

Material property	Steel	Aluminium alloy
Young's Modulus E (GPa)	201	69
Yield Strength (MPa)	450	260

A tie bar of length 1 m and cross section area 40 mm^2 needs to support a 10 kN load without elongating by more than 2 mm.

Explain which material is more suitable. Support your choice with calculation.

Steel is more suitable because e.g., its yield strength is greater than the maximum stress level and/its extension is less than required or it has a high enough Youngs modulus.

Either:
Max stress = F/A = 10 /40 = 250(MPa)
Max strain = e/l = 2×10^{-3} or 1/500
Calculating strain of each material.
Strain for steel at 250 MPa (= $250 \times 10^6 \div 201 \times 10^9$ =) 1.2×10^{-3} and
Strain for aluminium at 250 MPa (= $250 \times 106 \div 69 \times 109$ =) 3.6×10^{-3}.

Or:
Max Stress = 250 (MPa)
Attempt to calculate extension = length x σ /E (soi)
steel extension (= $1 \times (250 \times 10^6)/(201 \times 10^9)$ =) 1.2×10^{-3} m and
aluminium extension (= $1 \times (250 \times 10^6)/(69 \times 10^9)$ =) 3.6×10^{-3} m.

Or:
Max stress = F/A = 10/40 = 250(MPa)
Max strain = e/l = 2×10^{-3} or 1/500
Minimum Youngs Modulus (= $250 \times 10^6 \div 2 \times 10^{-3}$ =) 1.25×10^{11} Pa.

Or:
Max stress = F/A = 10/40 = 250(MPa)
Max strain = e/l = 2×10^{-3} or 1/500
Calculating stress of each material at that strain.
Stress for steel (= $2 \times 10^{-3} \times 201 \times 10^9$ =) 4.0×10^8 Pa / 400 MPa and
Stress for aluminium (= $2 \times 10^{-3} \times 69 \times 10^9$ =) 1.4×10^8 / 140 MPa.

....

....

....

.... **[4]**

Mark scheme guidance

Must include reason.

ACCEPT steel is more suitable because it is stronger/stiffer/(than Aluminium).

Any POT errors, max 2 marks for correct methods.

Accepted for any of the four answers included in answer on page 21.

Examiner comments

4(b) was a more open question with several alternative acceptable approaches. Some candidates were able to set out their calculations well as the evidence for selecting the material. Some candidates used inconsistent powers of ten, or did not show their working very well, but most were able to identify steel as the more suitable choice, even if the reasoning was not well presented.

Exemplar Candidate Work

Question 4(b) – High level answers

(b) The table below shows some material properties for steel and an aluminium alloy.

Material property	Steel	Aluminium alloy
Young's Modulus E (GPa)	201	69
Yield Strength (MPa)	450	260

A tie bar of length 1 m and cross section area 40 mm² needs to support a 10 kN load without elongating by more than 2 mm.

Explain which material is more suitable. Support your choice with calculation.

$$Strain = \frac{0.002}{1} = 0.002$$

10 kg
N
load

1m
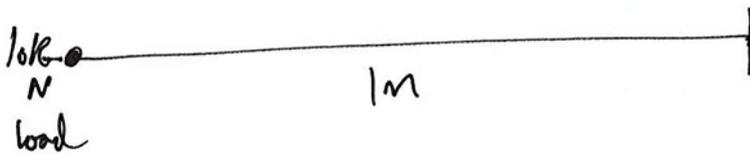
$$Strain = \frac{0.002}{1} = 0.002$$
$$= 0.002$$

The strain at most would be 0.002

Stress for steel : $201 \times 0.002 = 0.402$ $201 \times 0.002 = 0.402$

Stress for Aluminium alloy : $69 \times 0.002 = 0.138$

I would use steel as it has a higher yield strength meaning it is less likely to break. It also is more stiffer so it would not deform for than 2mm   [4]

Commentary

This candidate starts by calculating the maximum permissible strain, and then finds the stress for each material at that strain. Then the mores suitable material is identified as steel with reasoning. This is a valid method, but is incomplete as there is no comparison of the calculated values of stress for each material to the stress experienced by the tie bar described in the question. In order for this to achieve full marks the maximum stress should be calculated with consistent units to the stress values for each material.

Question 5(a)

5 (a) Fig. 5 shows a hydraulic lift designed to displace a 700 N load by 15 cm on a 350×10^{-4} m^2 plate.
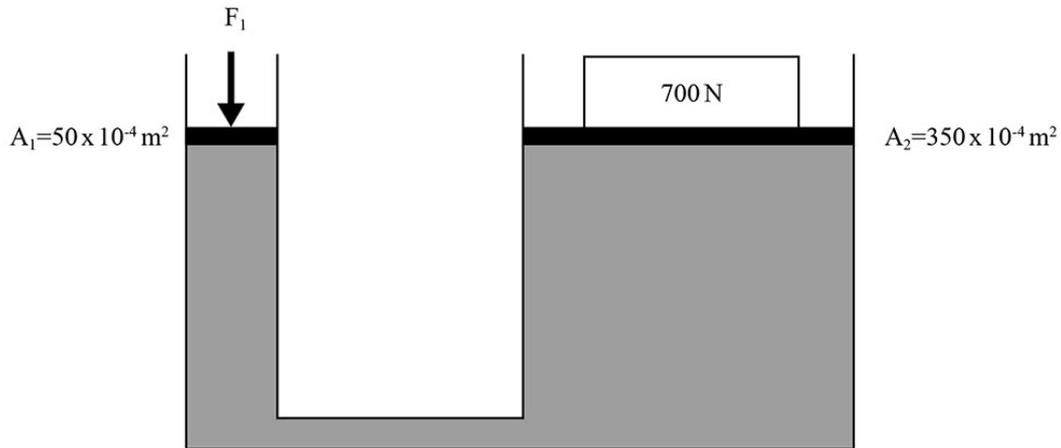
Fig. 5

Calculate

(i) the pressure exerted by the working fluid on plate A_2,

> $P = F/A = 700 \div A$
> $(P = 700 / 350 \times 10^4 =) 2.0 \times 10^4$ (Pa)

Pressure = ... Pa **[2]**

(ii) the force F_1 exerted on a 50×10^{-4} m^2 plate A_1 required to elevate the 700 N load,

> $(P_1 = P_2$, so $P_2 = F_1/A_1$ so $F_1 = (2.0 \times 10^4) (50 \times 10^{-4}) =)$ 100 (N)

Force = ... N **[1]**

(iii) the vertical displacement of plate A_1 required to achieve a 15 cm displacement of the 700 N load.

> Displaced volume of fluid is the same on both sides/$V_1 = V_2$ (because liquids are incompressible)/displacement is inversely proportional to area/$\frac{d_1}{d_2} = \frac{A_2}{A_1}$
> ($d_1 = (350 \div 50) \times 15$, so h =) 105 (cm).

Vertical displacement = ... cm **[2]**

Mark scheme guidance

Question 5(a)(i):

CHECK ANSWER LINE; If E = 2.0 × 10⁴ Pa award 2 marks.

Dividing 700N by either area.

Correct calculation.

Question 5(a)(ii):

Allow ecf of incorrect area from (i).

Question 5(a)(iii):

CHECK ANSWER LINE; If h = 105 cm award 2 marks.

Examiner comments

In 5(a) most candidates were able to use the correct equations to work out the pressure and force appropriately in parts (i) and (ii). Part (iii) proved slightly more challenging as it required more application of ideas rather than directly using an equation from the formula booklet.

Question 5(b)(i)

(b) Fig. 6 shows a communicating vessel which is initially separated by a baffle.
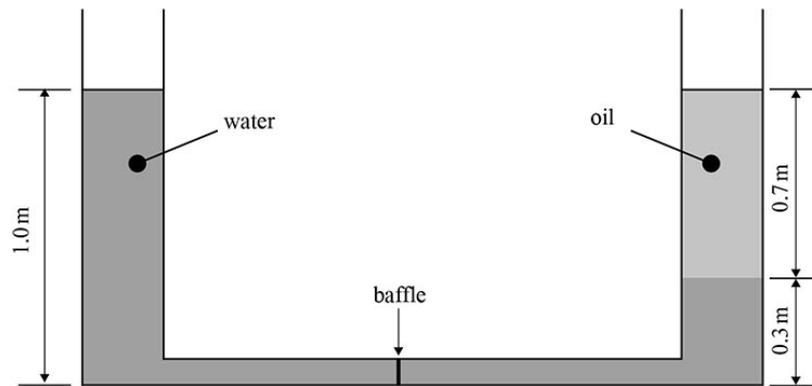
Fig. 6

The column on the left contains water with height $h_1 = 1$ m.

The column on the right contains water and oil.

The height of the water column $h_2 = 0.3$ m and the height of the oil column $h_3 = 0.7$ m.

Density of water $\rho_w = 1000$ kg m^{-3}

Density of oil $\rho_o = 800$ kg m^{-3}

Calculate

(i) the hydrostatic pressure at the bottom of the left side of the vessel,

(Pressure = ρ g h = (1000) (9.8) (1) =) 9.8×10^3 (Pa)

Pressure = ... Pa **[1]**

Examiner comments

Part (i) was generally well answered.

Question 5(b)(ii)

(ii) the height of the water column on the left side of the vessel once the baffle has been removed. Indicate the units used in your answer.

Height = ... [5]

© OCR 2018   **Turn over**

Either:
Pressure on both sides will be equal once baffle is removed /PL = PR.
$\rho_w h_L g = (\rho_w h_R + \rho_o h_3) g$ so $\rho_w (h_L - h_R) = \rho_o h_3$ so $h_L - h_R = (\rho_o h_3) / \rho_w$
$h_L - h_R = (800 \times 0.7) \div 1000 = 0.56$ m
(Total volume of water columns will not change, so providing area of columns equal.) $h_1 + h_2 + h_3 = h_L + h_R + h_3 = 2m$ **OR** $h_1 + h_2 = h_L + h_R = 1.3$ m
Using simultaneous equations:
$h_L = 0.93$ **m** (and $h_R = 0.37$ m)
Or:
original pressure on right hand column = sum of oil pressure + water pressure
$P_R = (\rho_w h_2 + \rho_o h_3) g = ((1000 \times 0.3) + (800 \times 0.7)) \times 9.8 = 8428$ Pa
Difference in pressure between the two columns $\Delta P = 9800 - 8428 = 1372$ Pa
Giving rise to a height difference = $\Delta P \div (\rho_w \times g) = 1372 \div (1000 \times 9.8) = 0.14m$
Providing area of columns equal.
Water on left moves down by $0.14 \div 2 = 0.07$ m so height = 0.93 **m**.

Mark scheme guidance

CHECK ANSWER LINE; If $h_L = 93$ cm award 5 marks.

Stated either in words or symbols correct rearrangement of formula.

Final value with **unit**.

Accepted for either of the two answers included in answer on page 27.

Examiner comments

Part (ii) was challenging too many candidates, but some were able to gain some of the marks for performing relevant calculations even if they did not manage to get the correct final answer. This is a good reason for ensuring that working is shown clearly.

Question 6(i)

6   Fig. 7 shows a hydraulic turbine-generator unit installed in a water dam which is used to generate electricity.

Water enters and leaves the turbine at $2.5\,\text{m s}^{-1}$ through pipes of constant diameter $d = 2\,\text{m}$.

This content has been removed due to third party copyright restrictions.
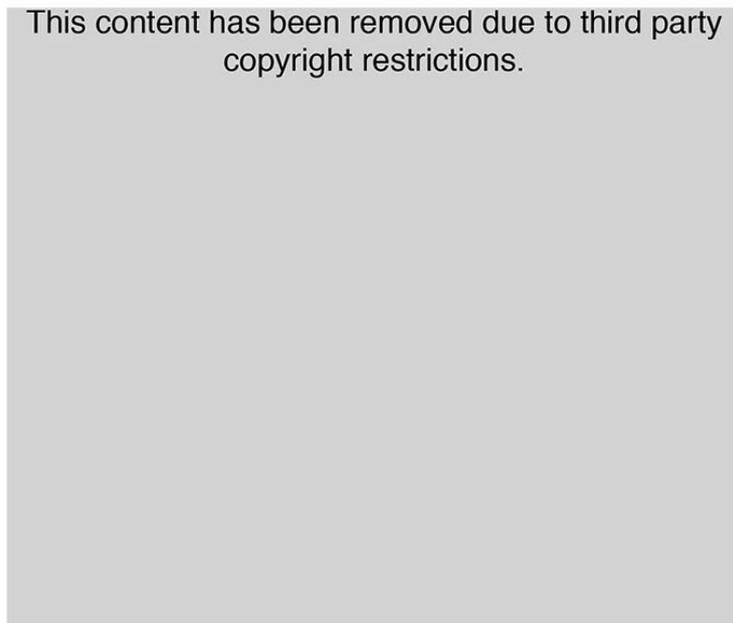
Fig. 7

The height at the surface of the upper reservoir (point 1) is $50\,\text{m}$ above the surface of water in the lower reservoir (point 2).

The efficiency of the generator $= 95\%$ and it supplies $3300\,\text{kW}$.

Density of water $\rho_w = 1000\,\text{kg m}^{-3}$

The mass of water entering the turbine each second is known as the mass flow rate.

Calculate

(i)   the mass flow rate of water,

> (Mass of water per second =) volume <u>per second</u> × density or velocity × pipe cross section × density or ρ v A or $1000 \times 2.5 \times (\pi(1)^2 =$
> $= 7.85 \times 10^3$ (kg s^{-1})

Mass flow rate = ………………………….. kg s^{-1} **[2]**

Mark scheme guidance

CHECK ANSWER LINE; If mass = 7850 (kg s⁻¹) award 2 marks.

Accept 7800 and 7900 here.

Examiner comments

This question was not well answered as candidates found it difficult to apply scientific knowledge to new situations, which is a useful skill for all engineers. The text in the question gave them the information needed to find the mass flow rate in part (i), but they also needed to find the equation for the volume of a cylinder from the formula booklet and recall the relationship between mass, density and volume.

Exemplar Candidate Work

Question 6(i) – High level answers

6   Fig. 7 shows a hydraulic turbine-generator unit installed in a water dam which is used to generate electricity.

Water enters and leaves the turbine at 2.5 m s⁻¹ through pipes of constant diameter d = 2 m.

This content has been removed due to third party copyright restrictions
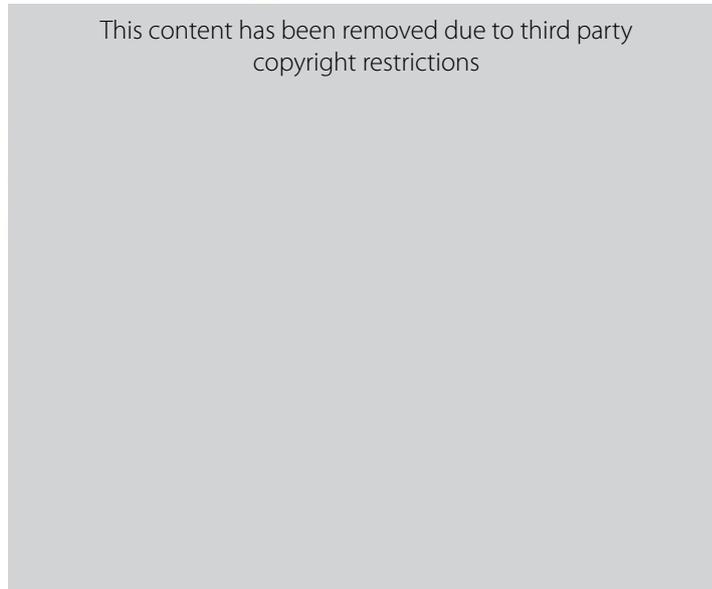
Fig. 7

The height at the surface of the upper reservoir (point 1) is 50 m above the surface of water in the lower reservoir (point 2).

The efficiency of the generator = 95% and it supplies 3300 kW.

Density of water ρ_w = 1000 kg m⁻³

The mass of water entering the turbine each second is known as the mass flow rate.

(handwritten)
$\times 10^3$
3300×10^3
$\times 0.95 =$
$3135000 W$

Calculate

(i)   the mass flow rate of water,

(handwritten)
πr^2
$\pi 1^2 = 9.869 \ m^2$

$2.5 \times 9.869 \times 1000$

Mass flow rate = ...24650...... kg s⁻¹ **[2]**

Commentary

This response shows the correct method to calculate the mass flow rate. The candidate has attempted to find the area of the pipe = $\pi 1^2$. However, there is a calculation error as this should be equal to 3.14 m². The candidate has then multiplied the incorrect value for area (9.669) by the velocity (2.5) and the density (1000). Had there been no mathematical error in the calculation of area, this candidate would gain full marks.

Questions 6(ii), (iii) and (iv)

(ii) the change in gravitational potential energy per unit mass of water between points 1 and 2,

> Use of $\Delta E_p = m\, g\, (\Delta h)$
> (For unit mass, m = 1, so $\Delta E_m/m = 9.8 \times 50 =$) 490 (J kg^{-1})

Change in energy per unit mass = ………………………….…………….. J kg^{-1} **[2]**

(iii) the power supplied to the turbine by the fluid,

> Power input = energy per second = $\Delta E_m/m \times$ mass flow rate (soi)
> ($P_s = (\dot{m}/t)\,(\Delta E_m/m) = (7.9 \times 10^3) \times 490 =$) 3.85×10^6 (W)

Power supplied = …………………………….. W **[2]**

(iv) the efficiency of the turbine.

Efficiency of turbine = ……………………………… **[3]**

> For generator: Power input = power output ÷ efficiency = 3300 ÷ 0.95 = 3470
> Power input for generator is power output of turbine.
> turbine efficiency = power output ÷ power input = 3470 ÷ 3850 = 0.90 / 90%)
> OR:
> Combined efficiency = power output ÷ power input = 3300 ÷ 3850 = 0.86 / 86%
> Combined efficiency is the product of efficiencies / = $\eta_g \times \eta_t$
> Turbine efficiency = 0.86 ÷ 0.95 = 0.90 / 90%

Mark scheme guidance

Question 6(ii):

CHECK ANSWER LINE; If energy = 490 (J kg^{-1}) award 2 marks.

Use of E = mgh with any mass, not just quoting equation.

Question 6(iii):

CHECK ANSWER LINE; If power = 3850 kW award 2 marks.

Accept 3.8×10^6 and 3.9×10^6 here.

Allow ecf of calculated values in (i) and (ii) multiplied together.

Question 6(iv):

CHECK ANSWER LINE; If efficiency = 90% award 3 marks.

Allow ecf of incorrect value of power input from part (iii).

Examiner comments

In part (ii) many candidates missed the point about being asked for the "energy per unit mass", and used the equation to calculate the potential energy of some mass of water instead.

Part (iii) should have just entailed multiplying the potential energy per unit mass, by the mass per second (or mass flow rate) to give energy per second or power supplied to the turbine, but many candidates used the information about the efficiency of the generator instead.

In part (iv) some candidates were able to gain one mark for correctly calculating the energy input for the generator by dividing the power output (3300 kW) by the efficiency of 95%. However, a large number of candidates multiplied instead. This question clearly had complicated multi-stage calculations and highlights that candidates do need to read the questions very carefully.

Exemplar Candidate Work

Question 6(ii) – High level answers

(ii) the change in gravitational potential energy per unit mass of water between points 1 and 2.

$$GPE = mgh \qquad 7\,853.98 \times 9.8 \times 50 = 3{,}848{,}450.2$$

Change in energy per unit mass = ...~~38~~ ~~3,789~~ .3.848.450.2 J kg⁻¹ [2]

Commentary

This candidate has correctly used the equation for gravitational potential energy (mgh) but used the mass flow rate calculated in the previous part (i) for the mass. The question asks for the change in gravitational potential energy per **unit** mass. This would have been a full mark high level answer if the candidate had used mass = 1 kg instead of 7854 kg.

Exemplar Candidate Work

Question 6(iii) – High level answers

6 Fig. 7 shows a hydraulic turbine-generator unit installed in a water dam which is used to generate electricity.

Water enters and leaves the turbine at 2.5 m s⁻¹ through pipes of constant diameter $d = 2$ m.

This content has been removed due to third party copyright restrictions
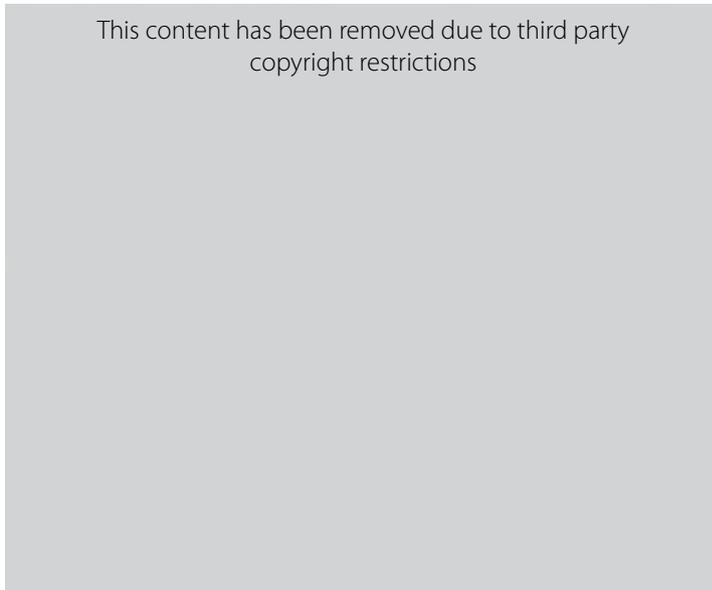
Fig. 7

The height at the surface of the upper reservoir (point 1) is 50 m above the surface of water in the lower reservoir (point 2).

The efficiency of the generator = 95% and it supplies 3300 kW.

Density of water $\rho_w = 1000$ kg m⁻³

The mass of water entering the turbine each second is known as the mass flow rate.

Calculate $\dfrac{3300 \times 10^3}{0.95}$ ~~4 = ~~ ~~3473684.211W~~   = 3473684.211W

(i) the mass flow rate of water,

2.5ms⁻¹ of water.

$\pi r^2 = area$

$\pi \times 1^2 = \pi n^2$

$\dfrac{2.5\pi n^3}{1\ second}$ of water.

Mass flow rate = ...127....... kg s⁻¹ [2]

$\dfrac{1000 kg}{1 m^3}$

mass = $\dfrac{1000}{2.5\pi}$ = 127.32 kg s⁻¹

per second

= 127 kg (3sf)

(iii) the power supplied to the turbine by the fluid,

(handwritten working)

Power supplied = ... 3.47×10⁶ .... W **[2]**

Commentary

This candidate has obtained a valid number for the power supplied but there is a power of ten error. There is an error carried forward from part 6i, where the candidate has calculated a value for the time per unit mass, instead of a value for mass per unit time. In part 6i the candidate has gained a mark for finding the volume per unit time; in order to get a mass per unit time, this number should have been multiplied by the density, not divided into the density. This candidate's calculation is dimensionally correct as the power is the energy per unit mass (490) divided by this value for time per unit mass (127) being equivalent to energy divided by time.

Exemplar Candidate Work

Question 6(iv) – High level answers

(iv) the efficiency of the turbine.

$$3300 = 95\%$$

$$\frac{3300}{95} \times 60 = 3873.68 \text{Kw out.}$$

Efficiency of turbine = 9.32% .... [3]

$$\frac{3873.68}{3.73 \times 10^6} = 9.32\%$$

Commentary

This is a 2-stage process, so both the generator and the turbine need to be considered as separate machines. The information provided states that the efficiency of the generator is 95% and this candidate starts off correctly by finding the power output of the generator as 3470kW. Unfortunately, the next stage of the calculation has inconsistent units for the power output and the power input for the generator. The efficiency of the generator is calculated by dividing useful power output just calculated by the power input calculated in the previous part (iii). In this example the power output is given in kW and the power input (error carried forward) is given in W, so full marks cannot be achieved.

The small print

We'd like to know your view on the resources we produce. By clicking on the 'Like' or 'Dislike' button you can help us to ensure that our resources work for you. When the email template pops up please add additional comments if you wish and then just click 'Send'. Thank you.

Whether you already offer OCR qualifications, are new to OCR, or are considering switching from your current provider/awarding organisation, you can request more information by completing the Expression of Interest form which can be found here: www.ocr.org.uk/expression-of-interest

OCR Resources: *the small print*
OCR's resources are provided to support the delivery of OCR qualifications, but in no way constitute an endorsed teaching method that is required by OCR. Whilst every effort is made to ensure the accuracy of the content, OCR cannot be held responsible for any errors or omissions within these resources. We update our resources on a regular basis, so please check the OCR website to ensure you have the most up to date version.

This resource may be freely copied and distributed, as long as the OCR logo and this small print remain intact and OCR is acknowledged as the originator of this work.

OCR acknowledges the use of the following content:
Square down and Square up: alexwhite/Shutterstock.com

Please get in touch if you want to discuss the accessibility of resources we offer to support delivery of our qualifications: resources.feedback@ocr.org.uk

Looking for a resource?

There is now a quick and easy search tool to help find **free** resources for your qualification:

www.ocr.org.uk/i-want-to/find-resources/

www.ocr.org.uk/engineering
OCR Customer Contact Centre

Vocational qualifications
Telephone 02476 851509
Facsimile   02476 851633
Email vocational.qualifications@ocr.org.uk

OCR is part of Cambridge Assessment, a department of the University of Cambridge. *For staff training purposes and as part of our quality assurance programme your call may be recorded or monitored.*

© **OCR 2018** Oxford Cambridge and RSA Examinations is a Company Limited by Guarantee. Registered in England. Registered office 1 Hills Road, Cambridge CB1 2EU. Registered company number 3484466. OCR is an exempt charity.

Cambridge Assessment

LLOYD'S REGISTER · LRQA
ISO 9001

UKAS
MANAGEMENT SYSTEMS
001