OCR
RECOGNISING ACHIEVEMENT

LEVEL 3 CERTIFICATE

MATHEMATICS FOR ENGINEERING

H860/02

Paper 2

Candidates answer on the answer booklet.

OCR supplied materials:
- 8 page answer booklet (sent with general stationery)
- Insert (inserted)
- List of Formulae (MF1)

Other materials required:
- Scientific or graphical calculator

Thursday 26 May 2011
Morning

Duration: 1 hour 30 minutes

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INSTRUCTIONS TO CANDIDATES

- The insert will be found in the centre of this document.
- Write your name, centre number and candidate number in the spaces provided on the answer booklet. Please write clearly and in capital letters.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Final answers should be given to a degree of accuracy appropriate to the context.
- The acceleration due to gravity is denoted by $g\,\text{m}\,\text{s}^{-2}$. Unless otherwise instructed, when a numerical value is needed, use $g = 9.8$.
- You are permitted to use a scientific or graphical calculator in this paper.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- **You are reminded of the need for clear presentation in your answers.**
- You are advised that an answer may receive **no marks** unless you show sufficient detail of the working to indicate that a correct method is being used.
- The total number of marks for this paper is **40**.
- This document consists of **4** pages. Any blank pages are indicated.

The symbols used in these questions are defined in the pre-release document.

1 An electric vehicle with a streamlined profile has the following properties.

Mass in kg: $M = 1500$
Wheel radius in m: $r = 0.3$
Rolling resistance coefficient: $C_r = 0.01$
Drag coefficient: $C_d = 0$

The vehicle travels along a straight uniform road.

(a) Calculate the following.

(i) The driving force required to maintain the vehicle at a constant speed on a level part of the road. **[1]**

(ii) The driving force required to accelerate the vehicle uniformly from rest to $20\,\text{m s}^{-1}$ in 12 s on a level part of the road. **[2]**

(iii) The driving force required to maintain the vehicle at a constant speed up a part of the road that has a uniform slope with a gradient of 1 in 20. **[3]**

(b) The vehicle travels along a level part of the road with a constant acceleration of $1.5\,\text{m s}^{-2}$ in the direction of travel. The vehicle has a speed of $20\,\text{m s}^{-1}$ when it passes a particular point on the road.

What is its speed when it passes another point 300 m further along the road? **[2]**

(c) A driving force of 2000 N is applied to the vehicle when it is travelling up a part of the road that has a uniform slope with a gradient of 1 in 20. Calculate the acceleration of the vehicle. **[2]**

2 An electric vehicle, fitted with an electric motor similar to the one described in the pre-release document, has the following properties.

Electrical-to-mechanical power efficiency coefficient: $\eta = 0.9$
Mass in kg: $M = 1500$
Drag coefficient: $C_d = 0.4$
Rolling resistance coefficient: $C_r = 0.01$
Wheel radius in m: $r = 0.3$
Gear ratio: $k{:}1 = 4.5{:}1$
Area of the front of the vehicle in m^2: $A = 2.5$

The density of air should be taken as $1.2\,kg\,m^{-3}$.

(a) The vehicle travels at a constant speed of $24\,m\,s^{-1}$ on a straight level road.

Calculate the following.

(i) The torque required from the motor. **[4]**

(ii) The rotational speed of the motor. **[2]**

(iii) The approximate current required, assuming that the voltage remains constant at 120 volts. **[1]**

(b) With a driving force of 250 N, the vehicle travels at a constant speed along a straight level road. The vehicle reaches a slope of 5° and the driving force is increased to 1600 N. The vehicle then continues to travel up the slope.

Calculate the following.

(i) The speed of the vehicle on the level part of the road. **[2]**

(ii) The maximum speed that the vehicle could reach on the slope. **[3]**

3 The time, t minutes, that a particular type of 120 volt battery bank can provide useful power when drained at a constant current of i amperes is given by

$$t = \frac{10\,000}{i}.$$

A vehicle with a fully-charged battery bank of this type is driven 100 km at a constant speed around a level test circuit. You should assume that the battery voltage remains constant at 120 volts and that all the electrical power is converted into mechanical power to propel the vehicle.

It is known that the aerodynamic drag, F_d N, is given by $F_d = v^2$, where $v\,m\,s^{-1}$ is the speed of the vehicle. The rolling resistance, F_r N, is given by $F_r = 150$.

By comparing expressions, in terms of v, for the journey time and the time for which the battery bank can provide useful power, calculate the maximum speed at which the vehicle can travel for the entire 100 km test distance without the battery bank needing recharging. **[6]**

[Question 4 is printed overleaf.]

4 An electric vehicle has the following properties.

Mass in kg: $M = 1200$
Drag coefficient: $C_d = \frac{5}{9}$
Rolling resistance coefficient: $C_r = 0.012755$
Area of the front of the vehicle in m^2: $A = 3$

The vehicle is stationary on a straight level road. At time $t = 0$, a constant driving force of 550 N is applied.

(a) Using the equations for drag force, F_d, and rolling resistance, F_r, given in the pre-release document, show that the motion of the vehicle may be described by the differential equation

$$1200\frac{\mathrm{d}v}{\mathrm{d}t} + v^2 = 400,$$

where
v m s^{-1} is the speed of the vehicle,
t s is the time after the driving force is first applied. **[4]**

(b) Show that the differential equation may be solved by separation of variables to give

$$\int \frac{1200}{v^2 - 400}\,\mathrm{d}v = c - t$$

where c is a constant. **[3]**

(c) By performing the integration shown in part **(b)** and rearranging the result, find an expression for v in terms of t.

You may use a result from page 5 of the list of formulae and statistical tables (list MF1). **[5]**