3.10 Physics: Fields (Gravitational, Electric, Magnetic): Test Pack

Total Marks

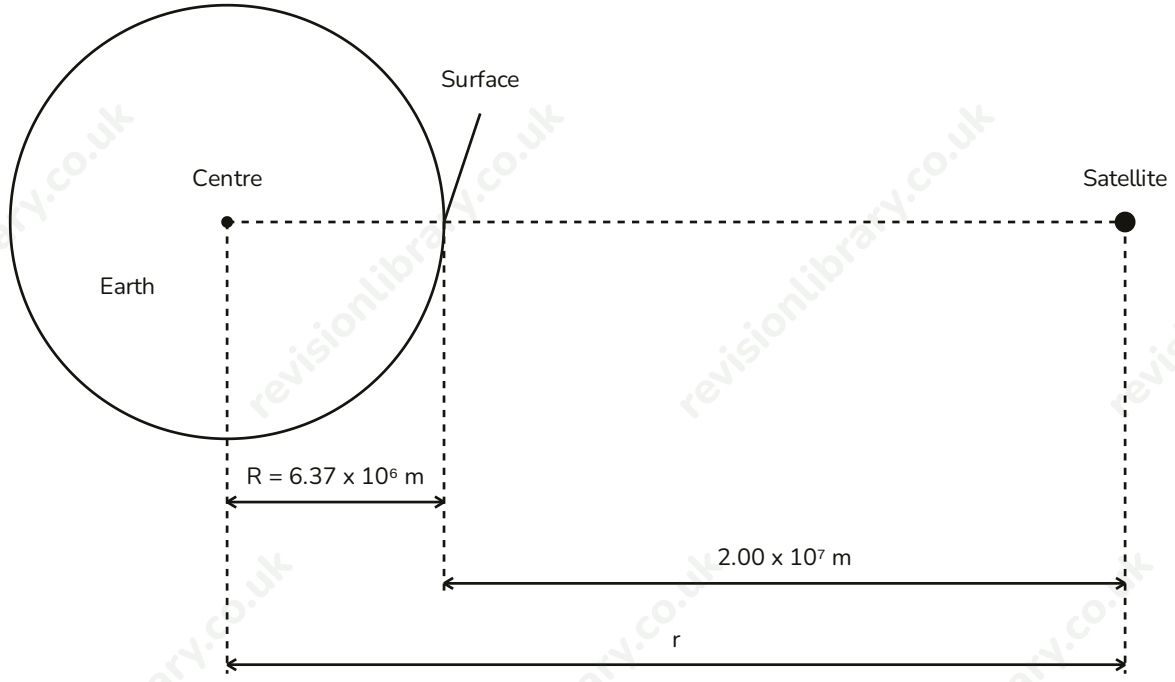
AQA 7408 · Calculator allowed · about 30 minutes

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 A navigation satellite of mass 640 kg moves in a circular orbit around the Earth at constant speed, held in orbit entirely by the Earth's gravitational attraction. Treat the Earth as a uniform sphere of mass $M = 5.97 \times 10^{24}$ kg and radius $R = 6.37 \times 10^{6}$ m, and take $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}. You are given Newton's law of gravitation, $F = GMm/r^2$, and the definition of gravitational field strength, $g = F/m$, where m is the mass placed in the field.

Diagram NOT accurately drawn



(a) Show that the gravitational field strength at a distance r from the centre of the Earth is given by $g = GM/r^2$. **(2)**

(b) The satellite orbits at a height of 2.00×10^7 m above the Earth's surface. Calculate the gravitational field strength at the position of the satellite. **(3)**

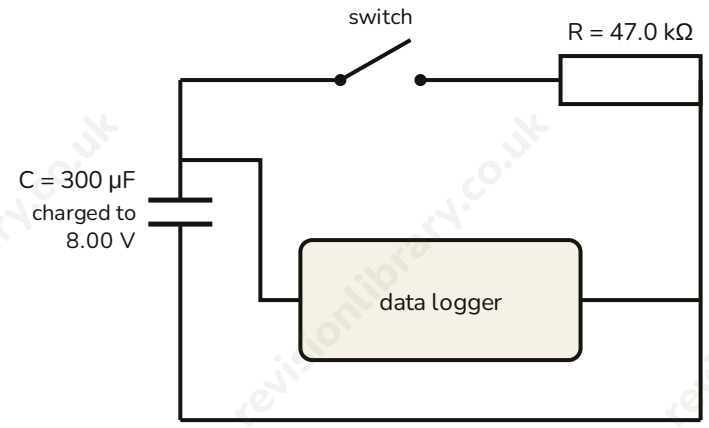
(c) By equating the gravitational force on the satellite to the centripetal force needed for circular motion, and using $v = 2*\pi*r/T$, show that the orbital period T of the satellite is given by $T = 2*\pi*\sqrt{r^3/(GM)}$. **(3)**

(d) Hence calculate the orbital period of the satellite, giving your answer in hours. **(3)**

(Total for Question 1 is 11 marks)

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2 REQUIRED PRACTICAL. A student carries out the required practical to investigate how the potential difference across a discharging capacitor varies with time. A capacitor of capacitance 300 uF is charged to 8.00 V then discharged through a resistor of resistance 47.0 kOhm, with a data logger recording the potential difference V across the capacitor at regular time intervals. You are given: V = V0 * exp(-t/(RC)), where V0 is the potential difference at t = 0.



(a) Calculate the time constant of this circuit, stating an appropriate unit. **(2)**

(b) Calculate the initial charge stored on the capacitor. **(2)**

(c) Calculate the potential difference across the capacitor 20.0 s after the discharge begins. **(3)**

(d) Describe how the student could use their V against t data to determine the time constant RC graphically, without directly reading a value from the decay curve itself. **(3)**

(e) State one precaution the student should take to improve the accuracy of the reading taken at t = 0. **(1)**

(Total for Question 2 is 11 marks)

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Mark scheme · 3.10 Physics: Fields (Gravitational, Electric, Magnetic): Test Pack

Question 1

(a) states g = F/m (or equivalent definition of field strength as force per unit mass) **B1**

(a) substitutes $F = GMm/r^2$ and cancels m correctly to reach $g = GM/r^2$ (cao) **B1**

(a) Answer: $g = GM/r^2$

(b) correctly finds $r = h + R = 2.00 \times 10^7 + 6.37 \times 10^6 = 2.637 \times 10^7$ m **M1**

(b) substitutes $GM = 3.982 \times 10^{14}$ and their r into $g = GM/r^2$ **M1**

(b) $g = 0.573$ N kg^{-1} (awrt 3 sf), allow ecf from their r **A1**

(b) Answer: $g = 0.573$ N kg^{-1}

(c) equates gravitational force to centripetal force: $GMm/r^2 = m*v^2/r$ (or $m*\omega^2*r$) **B1**

(c) substitutes $v = 2*\pi*r/T$ and rearranges to $GM/r^2 = 4*\pi^2*r/T^2$ **B1**

(c) correctly rearranges to $T^2 = 4*\pi^2*r^3/(GM)$, hence $T = 2*\pi*\sqrt{r^3/(GM)}$ (cao) **B1**

(c) Answer: $T = 2*\pi*\sqrt{r^3/(GM)}$

(d) substitutes $r = 2.637 \times 10^7$ m and $GM = 3.982 \times 10^{14}$ into $T = 2*\pi*\sqrt{r^3/(GM)}$ **M1**

(d) correctly evaluates $r^3/(GM) = 4.61 \times 10^7$ (or equivalent intermediate value), giving $T = 4.26 \times 10^4$ s **A1**

(d) converts to T = 11.8 hours (awrt 3 sf), allow ecf **A1**

(d) Answer: $T = 4.26 \times 10^4$ s = 11.8 hours

Question 2

(a) uses time constant = R*C **M1**

(a) tau = 14.1 s (awrt), correct unit s **A1**

(a) Answer: tau = 14.1 s

(b) uses Q0 = C*V0 **M1**

(b) $Q0 = 2.40 \times 10^{-3}$ C (awrt, allow 2.40 mC) **A1**

(b) Answer: $Q0 = 2.40 \times 10^{-3}$ C

(c) uses V = V0*exp(-t/(RC)) with their tau from part (a) **M1**

(c) correctly substitutes t = 20.0 s and tau = 14.1 s **A1**

(c) V = 1.94 V (awrt, allow ecf) **A1**

(c) Answer: V = 1.94 V

(d) plots ln(V) on the y-axis against t on the x-axis **B1**

(d) recognises that ln(V) = ln(V0) - t/(RC), so a straight line is obtained (of gradient -1/(RC)) **B1**

(d) states that RC is found from RC = -1/gradient (i.e. the negative reciprocal of the gradient of the line of best fit) **B1**

(d) Answer: Plot ln(V) against t; the gradient of the resulting straight line equals -1/(RC), so RC = -1/gradient.

(e) e.g. start the timer/data logger at the exact instant the discharge begins (using a switch synchronised with the logger), or ensure the capacitor is fully charged to V0 before starting the discharge **B1**

(e) Answer: Synchronise the start of timing precisely with the instant the switch is used to begin the discharge (or ensure the capacitor is fully charged to V0 first).

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