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WORKSHEETS
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OCR A A Level Gravitational Fields 2 worksheet

35–40 minutes independent practice + 15–20 minutes review | 37 marks

Specification points covered

- 5.4.3(a) State Kepler's three laws of planetary motion.
- 5.4.3(b) Explain that the gravitational force provides the centripetal force for planetary motion.
- 5.4.3(c) Derive and use $T^2 = (4\pi^2/GM)r^3$ for circular orbits.
- 5.4.3(d) Apply Kepler's third law, $T^2 \propto r^3$, to systems beyond the Solar System.
- 5.4.3(e) Define geostationary orbit and describe uses of geostationary satellites.

StormWatch satellite network

The StormWatch team is developing a satellite network to monitor the formation and movement of Atlantic cyclones. Aurora is a low-orbit prototype; Horizon is intended to observe the same longitude continuously.
Model all stated satellite paths as circular. Take $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}, Earth's mass as 5.97×10^{24} kg and Earth's radius as 6.37×10^6 m.
Earth rotates west to east once every 23.93 h. Unless stated otherwise, orbital radius is measured from Earth's centre.

1. Building the circular-orbit model

1. State Kepler's three laws of planetary motion. [3 marks]

2. For a satellite of mass m in a circular orbit of radius r around Earth, show that v = √(GM/r). Start by equating gravitational force to centripetal force. [2 marks]

3. Figure 1 is a section through Earth's equatorial plane. On the satellite, draw (i) one possible instantaneous velocity vector and (ii) the gravitational force vector. State what provides the centripetal force for the circular orbit. [3 marks]

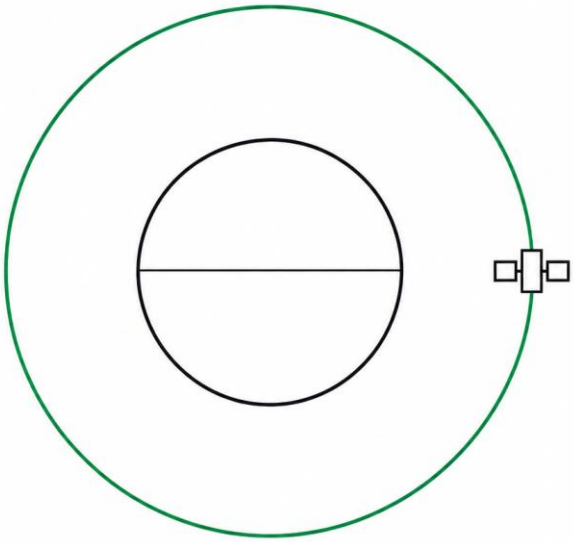

Figure 1: a section through Earth's equatorial plane with the satellite at the right of its circular path

2. The low-orbit prototype

4. The low-orbit StormWatch prototype Aurora is 630 km above Earth's surface. Calculate (a) its orbital speed and (b) its orbital period in minutes. [4 marks]

5. Explain why Aurora is not suitable for providing an uninterrupted image sequence of the same tropical storm. [2 marks]

3. Applying Kepler's third law

6. A second circular-orbit satellite has an orbital radius of 1.40×10^7 m. Aurora has orbital radius 7.00×10^6 m and a period of 97.2 min. Use Kepler's third law to calculate the period of the second satellite in minutes. [3 marks]

7. Horizon has a circular orbit of radius 4.22×10^7 m. Use $T^2 = (4\pi^2/GM)r^3$ to calculate its orbital period in hours. Earth rotates once every 23.93 h. State whether Horizon has the required period for geostationary orbit. [3 marks]

4. Designing a geostationary weather satellite

8. State four conditions that a satellite must satisfy in order to be geostationary. [4 marks]

9. Calculate Horizon's altitude above Earth's surface in kilometres. [2 marks]

5. Beyond Earth’s weather network

10. A data-analysis algorithm is tested using two planets orbiting the distant star Nysa. Planet P has a period of 48.0 Earth days. Planet Q has an orbital radius 2.25 times that of P. Calculate the period of Q in Earth days. State the assumption that permits this ratio calculation. [4 marks]

11. The StormWatch team needs continuous images of cyclones near 20° W longitude. Use Table 1 to select the only suitable satellite. Justify your choice using the orbital data and explain why each rejected option fails at least one geostationary condition. [4 marks]

Table 1: candidate StormWatch satellite designs

Satellite	Orbit / plane	Direction	Period
Aurora	7.00×10^{6} m / polar	varies with polar path	97.2 min
Horizon	4.22×10^{7} m / equatorial	west to east	23.98 h
Drift	4.22×10^{7} m / equatorial	east to west	23.98 h

12. State one use of a geostationary satellite other than weather observation. Explain why placing several geostationary weather satellites at different longitudes improves coverage, but does not give equally good coverage at the poles. [3 marks]