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| 21: Fields ComparisonOrbits and Comparisons |
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| Paper 2 |  |
| 17: Thermal Physics 1Specific Heat Capacity and Latent Heat | 1. Orbital period and speed related to radius of circular orbit; derivation of $T^{2} ∝r^{3}$
2. Energy considerations for an orbiting satellite.
3. Total energy of an orbiting satellite.
4. Escape velocity.
5. Synchronous orbits.
6. Use of satellites in low orbits and geostationary orbits, to include plane and radius of geostationary orbit.
7. Concept of a force field as a region in which a body experiences a non-contact force.
8. Students should recognise that a force field can be represented as a vector, the direction of which must be determined by inspection.
9. Force fields arise from the interaction of mass, of static charge, and between moving charges.
10. Similarities and differences between gravitational and electrostatic forces:
11. Similarities: Both have inverse-square force laws that have many characteristics in common, eg use of field lines, use of potential concept, equipotential surfaces etc
12. Differences: masses always attract, but charges may attract or repel.

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| 18: Thermal Physics 2Gas Laws and the MKTM |
| 19: Gravitational FieldsField Strength and Potential |
| 20: Electric FieldsFields Strength and Potential |
| 21: Fields ComparisonsOrbits and Comparisons |
| 22: CapacitorsEnergy Stored and Exponential Decay |
| 23: Magnetic Fields 1Magnetic Forces and Flux |
| 24: Magnetic Fields 2Induction and Transformers |
| 25: Radioactivity 1Nuclear Radius and Types of Radiation |
| 26: Radioactivity 2Modes and Rate of Decay |
| 27: Nuclear Physics Binding Energy, Fission and Fusion |
| Paper 3 |
| 28: Electron DiscoverySpecific Charge and Millikan |
| 29: Wave-Particle DualityWaves, Quantum and Microscopes |
| 30: Special RelativityMichelson-Morley & Relativistic Speed |

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| **Monday: Orbits Notes**As we saw in Further Mechanics, gravity can provide the centripetal force required to keep an object orbiting a bigger object.Derive an equation that links the orbital speed to the radius of orbit.$$\frac{GMm}{r^{2}}=\frac{mv^{2}}{r}$$Show how the equation that links the orbital period and the radius is derived. $$T^{2}=\frac{4π^{2}}{GM}r^{3}$$Symbol $T$ Quantity …………………………………………………………………………………………… Units ………………………Symbol $M$ Quantity …………………………………………………………………………………………… Units ………………………Symbol $r$ Quantity …………………………………………………………………………………………… Units ………………………Complete these tables by calculating the missing values.

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| *T* | *r* | *M* |  | *T* | *r* | *M* |
|  | 1.50 × 1011 | 1.99 × 1030 |  |  | 3.8 × 108 | 6.0 × 1024 |
| 86400 |  | 6.0 × 1024 |  | 5.20 × 109 |  | 1.99 × 1030 |
| 2.08 × 107 | 11.2 × 109 |  |  | 2.18 × 105 | 192 × 106 |  |

What is meant by a geostationary orbit?………………………………………………………………….…………….……………………………………………………….………………..………………………………………………………………….…………….……………………………………………………….………………..……………………………………………………………………….……….……………………………….………………………………………..

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| Calculate the radius of a satellite in geostationary orbit of the Earth. | Calculate the speed of a satellite in geostationary orbit of the Earth. |

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|  | Low polar orbit satellites | Geostationary orbit satellites |
| Compare heights of orbit |  |  |
| Compare orbital periods |  |  |

What are the common uses of satellites in geostationary orbits? ......………………………………………………………………………….Explain why this type of orbit is most appropriate. ……….….………….……………………………………………………….……………….………………………………………………………………….…………….……………………………………………………….………………..………………………………………………………………….…………….……………………………………………………….………………..………………………………………………………………….…………….……………………………………………………….………………..What are the common uses of satellites in low polar orbits? ..………………………………………………………………………………….Explain why this type of orbit is most appropriate. ……….….………….……………………………………………………….……………….………………………………………………………………….…………….……………………………………………………….………………..………………………………………………………………….…………….……………………………………………………….………………..………………………………………………………………….…………….……………………………………………………….………………..Describe the orbit of a comet in terms of distance, speed, gravitational force and potential.………………………………………………………………….…………….……………………………………………………….………………..………………………………………………………………….…………….……………………………………………………….………………..………………………………………………………………….…………….……………………………………………………….………………..The energy of an orbiting satellite is sum of the gravitational potential energy and kinetic energy.Derivation1 Centripetal force = gravitational force2 Cancel r and rewrite in terms of KE3 GPE in a radial field4 Total energy = GPE + KE5 Tidy up the equationWhat is meant by the term ‘escape velocity’?………………………………………………………………….…………….……………………………………………………….………………..………………………………………………………………….…………….……………………………………………………….………………..………………………………………………………………….…………….……………………………………………………….………………..Derivation1 Work done (potential) = kinetic energy2 Cancel common terms3 Rearrange for velocity squared4 Rearrange for velocityCalculate the escape velocity of an object at the Earth’s surface.Explain how it is possible for rockets to leave the surface of the Earth travelling at a speed much lower than the escape velocity………………………………………………………………….…………….……………………………………………………….………………..………………………………………………………………….…………….……………………………………………………….………………..………………………………………………………………….…………….……………………………………………………….……………….. |

**Tuesday: Orbits Exam Questions**

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| **Q31.**      The diagram below shows the orbits of two Earth satellites, a communications satellite in a geosynchronous orbit and a monitoring satellite in a low orbit that passes over the poles.**Q31(a)**      The time period, *T*, of any satellite in a circular orbit around a planet is proportional to *r*3/2, where *r* is the radius of its orbit measured from the centre of the planet. For a satellite in a low orbit that passes over the poles of the Earth, *T* is 105 minutes when *r* is 7370 km.**Q31(ai)**      Calculate the height above the surface of the Earth, in km, of a satellite in a geosynchronous circular orbit.Give your answer to an appropriate number of significant figures.      height above surface .............................. km **(4)****Q31(aii)**      Calculate the centripetal force acting on the polar orbiting satellite if its mass is 650 kg.     centripetal force ................................ N **(2)****(Total 6 marks)****Q32.**      Two satellites P and Q, of equal mass, orbit the Earth at radii *R* and 2*R* respectively. Which one of the following statements is correct?**A**      P has less kinetic energy and more potential energy than Q.**B**      P has less kinetic energy and less potential energy than Q.**C**      P has more kinetic energy and less potential energy than Q.**D**      P has more kinetic energy and more potential energy than Q.**(Total 1 mark)****Q33.**    An artificial satellite of mass *m* is in a stable circular orbit of radius *r* around a planet of mass *M*. Which one of the following expressions gives the speed of the satellite? *G* is the universal gravitational constant.**A**  **B**  **C**  **D** **(Total 1 mark)****Q34(aii)**     A mass *m* is at a height *h* above the surface of a planet of mass *M* and radius *R*.The gravitational field strength at height *h* is *g*. By considering the gravitational force acting on mass *m*, derive an equation from Newton’s law of gravitation to express *g* in terms of *M*, *R*, *h* and the gravitational constant *G*.   **(2)****Q34(bi)**     A satellite of mass 2520 kg is at a height of 1.39 × 107 m above the surface of the Earth. Calculate the gravitational force of the Earth attracting the satellite.Give your answer to an appropriate number of significant figures.   force attracting satellite ........................................ N **(3)****Q34(bii)**     The satellite in part (bi) is in a circular polar orbit. Show that the satellite would travel around the Earth three times every 24 hours.      **(5)** **(Total 10 marks)****Q35.**      As a comet orbits the Sun the distance between the comet and the Sun continually changes. As the comet moves towards the Sun this distance reaches a minimum value.Which one of the following statements is **incorrect** as the comet approaches this minimum distance?**A**       The potential energy of the comet increases.**B**       The gravitational force acting on the comet increases.**C**       The direction of the gravitational force acting on the comet changes.**D**       The kinetic energy of the comet increases.**(Total 1 mark)****Q36.**     A planet of mass *M* and radius *R* rotates so rapidly that loose material at the equator only just remains on the surface. What is the period of rotation of the planet? *G* is the universal gravitational constant.**A**        **B**        **C**        **D**       **(Total 1 mark)** |

**Wednesday: Satellites Extended Writing**

Artificial satellites can be placed in a geosynchronous or polar orbit and have different applications because of their different orbits in relation to the rotation of the Earth. Compare the principal features of the geosynchronous and polar orbits and explain the consequences for possible uses of satellites in these orbits. You should include:

* Features and uses of geosynchronous and polar orbit satellites
* Choose one use and justify why this type of orbit is most suitable
* A derivation of Kepler’s third law of planetary motion ($T^{2}∝r^{3}$)
* Show that the radius of a geo-synchronous orbit must be 4.23 × 107 m
* A description of what escape velocity is, a calculation of the escape velocity of Earth and an explanation of why objects leaving the Earth travel at speed below the escape velocity.

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**Wednesday: Fields Comparisons and Orbits Definitions**

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| Field Strength | The force per unit mass/charge acting at that point in the field. |
| Gradient | On a graph of potential against distance this represents the field strength. |
| More Positive | As an electron moves towards a negative charge the electric potential will become … |
| Towards | Electric field lines flow ……….. a negative charge. |
| Along | A proton in an electric field will move ………… a field line. |
| More Positive | As a proton moves towards a positive charge the electric potential will become … |
| Radial | The type of field where field strength changes with distance. |
| More Negative | As a proton moves towards a negative charge the electric potential will become … |
| Area Under the Line | On a graph of field strength against distance this represents the potential. |
| Potential | The work done per unit mass/charge against the field to bring a point mass/charge from infinity to the point. |
| Scalar | Gravitational potential is this type of quantity. |
| Against | Potentials will be positive when working ………. the field. |
| Against | An electron in an electric field will move ………… a field line. |
| Centre | When calculating gravitational forces, field strength or potentials we use the distance from the … |
| Zero | The potential at infinity. |
| Surface | When dealing with heights of orbit we could we given the distance from the … |
| Concentration | Field strengths can be compared using the ……….. of the field lines. |
| Escape Velocity | The speed an object must be launched at to leave the surface of a planet. |
| Geostationary | A higher satellite orbit primarily used for communication. |
| Vector | Field strength is this type of quantity. |
| From | Electric field lines flow ……….. a positive charge. |
| More Negative | As an electron moves towards a positive charge the electric potential will become … |
| Polar | A low satellite orbit primarily used for observing. |
| Uniform | The type of field where field strength is constant. |
| With | Potentials will be negative when working ………. the field. |
| Equipotential | A line where the value of potential is the same all the way along it. |

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| Against | Against | Along | Area Under the Line |
| Centre | Concentration | Equipotential | Escape Velocity |
| Field Strength | From | Geostationary | Gradient |
| More Negative | More Negative | More Positive | More Positive |
| Polar | Potential | Radial | Scalar |
| Surface | Towards | Uniform | Vector |
| With | Zero |  |  |

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| **Thursday: Fields Comparison Notes**Contact forces include: ..…………………………………….…………….……………………………………………………….………………..……………………………………………………………………….……….……………………………….………………………………………..Non-contact forces include: ……………………………………….……….……………………………….………………………………………………………………………………………………………….…………….……………………………………………………….………………..What is meant by the term ‘force field’?………………………………………………………………….…………….……………………………………………………….………………..……………………………………………………………………….……….……………………………….………………………………………..

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|  | **Gravitational Fields** | **Electric Fields** |
| Force acts on: |  |  |
| Nature of force: |  |  |
| Constant of proportionality: |  |  |
| Equation for the size of the force: |  |  |
| Scalar or vector? |  |  |
| Unit for force: |  |  |

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|  | **Gravitational Fields** | **Electric Fields** |
| Field lines show: |  |  |
| Direction of field lines: |  |  |
| Definition of field strength: |  |  |
| Scalar or vector? |  |  |
| Unit for field strength: |  |  |
| Equation for field strength in a radial field: |  |  |
| Connection between field lines and field strength: |  |  |

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|  | **Gravitational Fields** | **Electric Fields** |
| Definition of potential: |  |  |
| Equation for the potential in a radial field: |  |  |
| Scalar or vector? |  |  |
| Unit for potential: |  |  |
| Value of potential at infinity: |  |  |
| When are potentials negative? |  |  |
| When are potentials positive? |  |  |
| Work done in moving between two points of different potential: |  |  |
| Scalar or vector? |  |  |
| Unit for work done: |  |  |
| Connection between field lines and equipotential lines: |  |  |
| Work done in moving along an equipotential line: |  |  |

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|  | **Gravitational Fields** | **Electric Fields** |
| Potential from graph of field strength against distance: |  |  |
| Field strength from graph of potential against distance: |  |  |
| Equation linking field strength and potential: |  |  |
| What happens when an object enters the field at right angles to the field lines? |  |  |

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**Friday: Fields Comparison Exam Questions**

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| **Q57.**       A small sphere, of mass *m* and carrying a charge *Q*, is suspended from a thread and placed in a uniform horizontal electric field of strength *E*. When the sphere comes to rest the thread makes an angle *θ* with the vertical and the tension in it is *T*, as shown in the diagram. *W* is the weight of the sphere and *F* is the electric force acting on it.Under these conditions, which one of the following equations is **incorrect**?**A**      *T sin θ = EQ***B**     *T* = *mg* cos*θ* + *EQ* sin*θ***C**     *T*2 = (*EQ*)2 + (*mg*)2**D**     *mg* = *EQ* tan*θ* **(Total 1 mark)****Q58.**       When a charge moves between two points in an electric field, or a mass moves between two points in a gravitational field, energy may be transferred.Which one of the following statements is correct?**A**      No energy is transferred when the movement is parallel to the direction of the field.**B**      The energy transferred is independent of the path followed.**C**      The energy transferred is independent of the start and finish points.**D**      Energy is transferred when the movement is perpendicular to the field lines.**(Total 1 mark)****Q59.**       In the equation *X* = , *X* represents a physical variable in an electric or a gravitational field, *a* is a constant, *b* is either mass or charge and *n* is a number.Which line, **A** to **D**, in the table provides a consistent representation of *X*, *a* and *b* according to the value of *n*?The symbols *E*, *g*, *V* and *r* have their usual meanings.

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|  | ***n*** | ***X*** | ***a*** | ***b*** |
| **A** | 1 | *E* |  | charge |
| **B** | 1 | *V* |  | mass |
| **C** | 2 | *g* | *G* | mass |
| **D** | 2 | *V* | *G* | charge |

**(Total 1 mark)****Q60.**       Two protons are 1.0 × 10–14 m apart. Approximately how many times is the electrostatic force between them greater than the gravitational force between them? (Use the Data and Formulae booklet)**A**       1023**B**       1030**C**       1036**D**       1042**(Total 1 mark)****Q61.**       A uniform electric field of electric field strength *E* is aligned so it is vertical. An ion moves vertically through a small distance Δ*d* from point X to point Y in the field.There is a uniform gravitational field of field strength *g* throughout the region.Which line, **A** to **D**, in the table correctly gives the gravitational potential difference, and the electric potential difference, between X and Y?

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|   | **Gravitational potential difference** | **Electric potential difference** |
| **A** | $$g∆d$$ | $$E∆d$$ |
| **B** | $$g∆d$$ | $$\frac{E}{∆d}$$ |
| **C** | $$\frac{g}{∆d}$$ | $$E∆d$$ |
| **D** | $$\frac{g}{∆d}$$ | $$\frac{E}{∆d}$$ |

**(Total 1 mark)****Q62.**      The gravitational constant, G, is a constant of proportionality in Newton’s law of gravitation. The permittivity of free space, ε0, is a constant of proportionality in Coulomb’s law.When comparing the electrostatic force acting on a pair of charged particles to the gravitational force between them, the product ε0G can appear in the calculation.Which is a unit for ε0G?**A** C2 kg–2**B** C2 m–2**C** F kg2 N–1 m–2**D** it has no unit **(Total 1 mark)** |

**Saturday: Scalars, Vectors and Moments Checklist**

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