Session 1

General Tips and Tricks

1. (Do NOT use a calculator for this question)
   A rocket travels through space at a speed $v = \beta c$ relative to Earth such that it is length contracted to half its rest length. The equation for total energy is given by

$$E_T = \frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}}$$

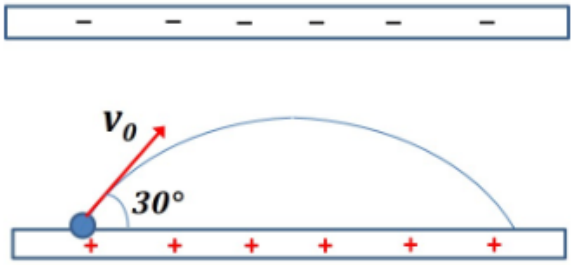
   By first considering the above energy equation when $v = 0$ (i.e. when it is at rest), calculate the ratio of the rocket's total energy to its rest energy.

2. State 5 valid equations for Work which are on (or can be easily derived from) the formula sheet.
   Note that $W = \Delta E_k = \frac{1}{2}m(v_f^2 - v_i^2)$ is not valid as it is the definition of work.

Advanced Mechanics

1. A projectile is fired with intial velocity $u = 25\, m\, s^{-1}$ at an angle $\theta = 35°$ above the horizontal at an intial height of $h = 2\, m$ above the ground.
   At what time will it hit the ground?

2. A particle with charge $q = -6.7 \times 10^{-5}\,C$ and mass $m = 1.2 \times 10^{-3} kg$ is fired from the positive plate of a capacitor at speed $v_0 = 10^{-2}\,m\,s^{-1}$ at an angle $\theta = 30°$ from the positive plate. If there is a potential difference of $30V$ and a gap between the plates of $d = 10^{-2}\,m$, calcualte the time it takes for the particle to touch the plate again.



3. A satellite of mass $m = 1234\,kg$ is launched from Earth's surface with some velocity v to an orbital radius of $r_o = 9.87 \times 10^6\,m$.

   (a) Calculate its change in gravitational potential energy.

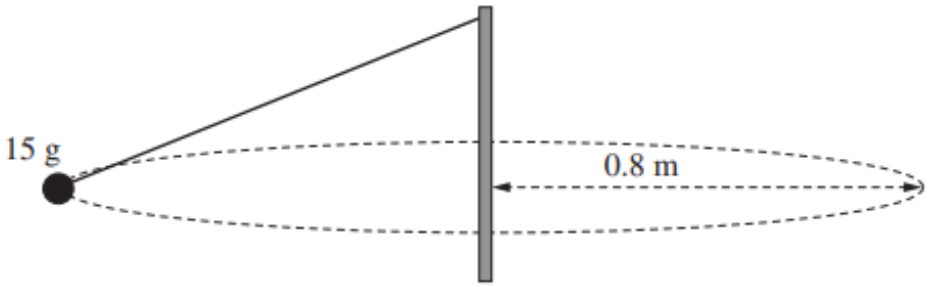
   (b) If the satellite loses $5.00 \times 10^9\,J$ due to air resistance as heat and maintains a constant velocity throughout the trip, calculate the work done by the rocket.

4. A cyclist is travelling with uniform speed at a constant height of $3\,m$ on a banked curve on a theoretically frictionless circular track.

   (a) Draw a free body diagram labelling the forces acting on the cyclist and showing the direction of the net force.

   (b) If the banked curve was at an angle of $\theta = 25^\circ$ with a radius of $r = 30\,m$, determine the net force acting on a $70\,kg$ cyclist.

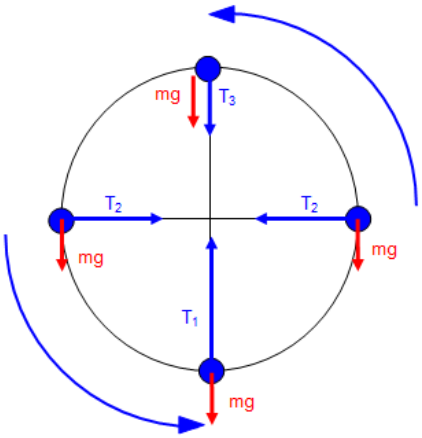
5. A $15\,g$ metal ball bearing on a string is swung around a pole in a circle of radius $0.8\,m$. The plane of the circular path is horizontal. The angular velocity of the motion is $4\pi\,rad\,s^{-1}$.



(a) Calculate the magnitude of the centripetal force on the ball bearing.

(b) Calculate the tension in the string if the string is $1\,m$ long.

6. A ball of mass $m = 50\,g$ is in circular motion in the vertical plane and is attached to a string of length $l = 20\,cm$. When the ball is at its highest position its velocity is $v_h = 1.4\,m\,s^{-1}$.

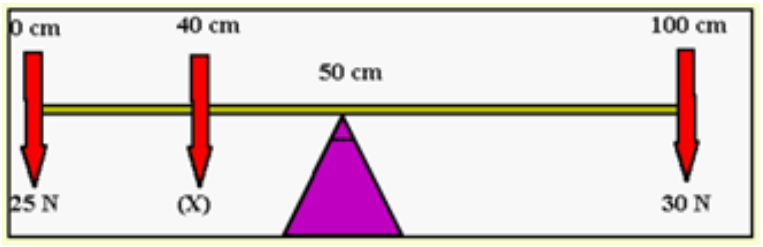


(a) Determine the tension in the string at the highest position.

(b) What is the speed of the ball at the lowest point in its motion?

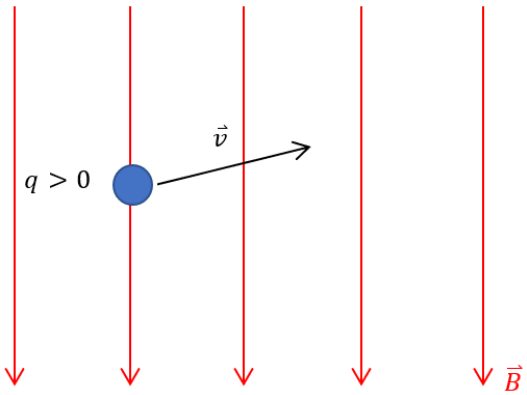
(c) Therefore, determine the tension in the string at the lowest point.

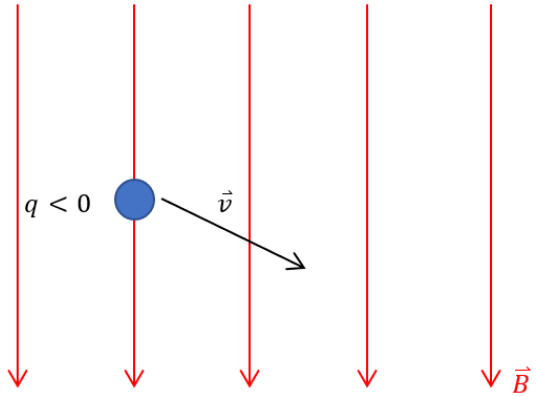
7. Calculate the strength of the force X given the beam is of a uniform denstity and there is no net torque on the beam.

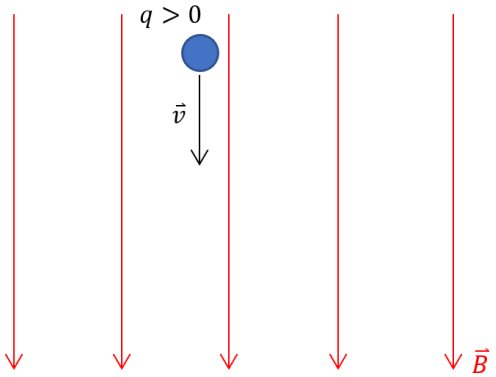


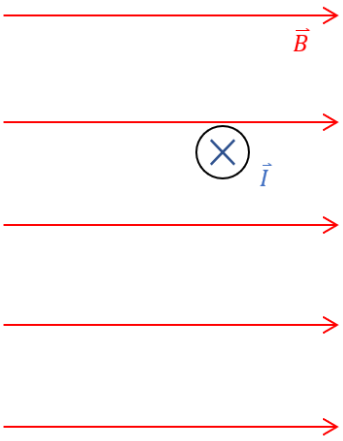
Electromagnetism

1. For each of the following, draw the resultant force vector



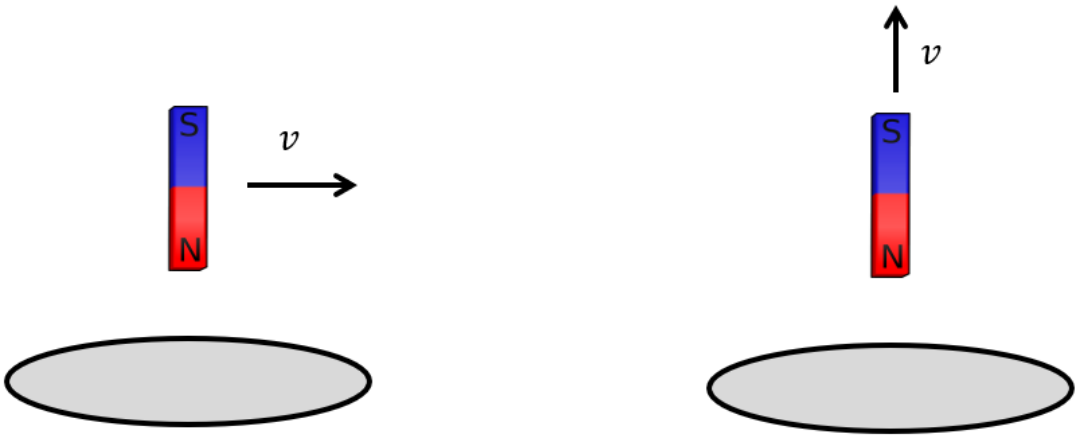




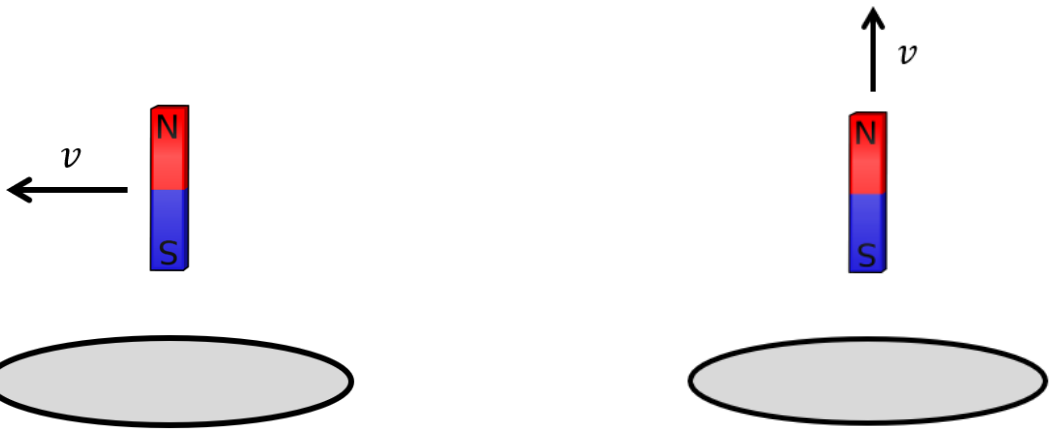


2. Draw the direction of the induced current and resultant magnetic field.

(a) Method 1

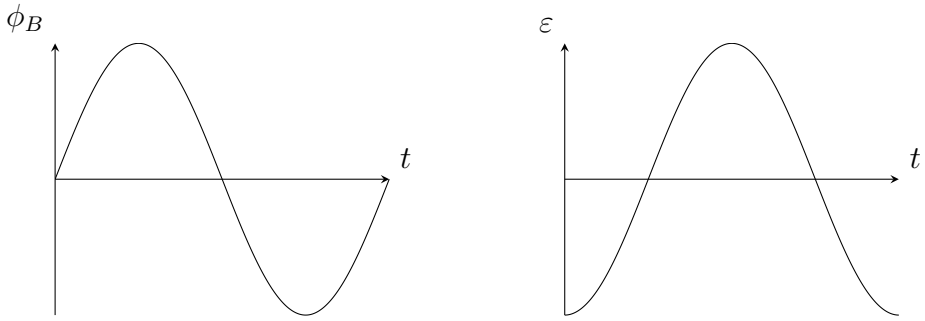


(b) Method 2

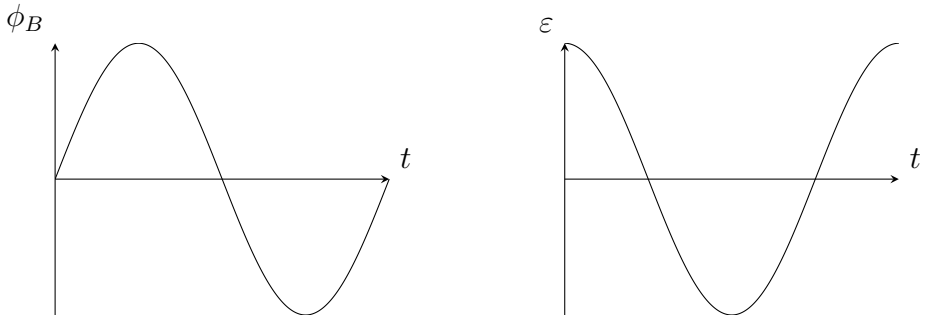


3. Which of these pairs of graphs are accurate? (There are multiple)

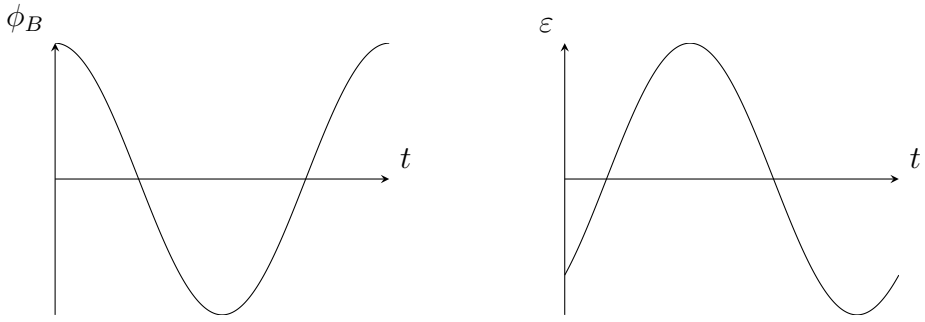
(a)



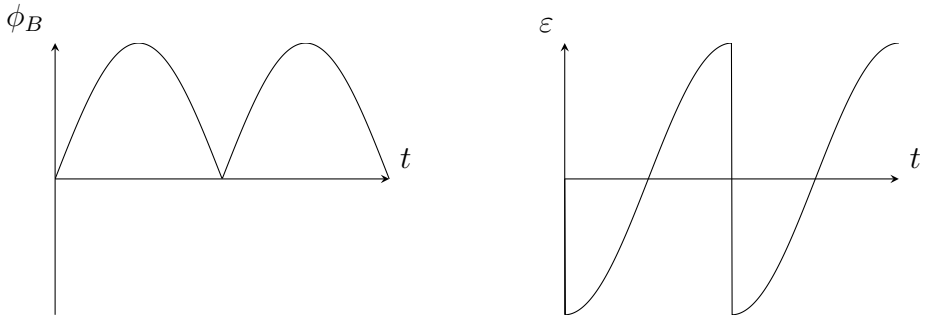
(b)



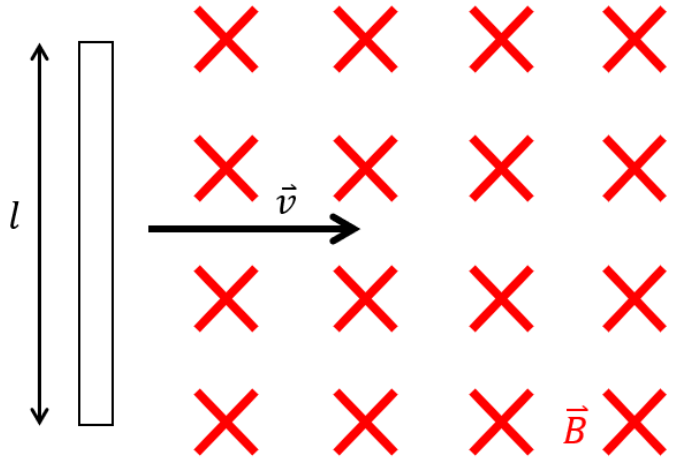
(c)



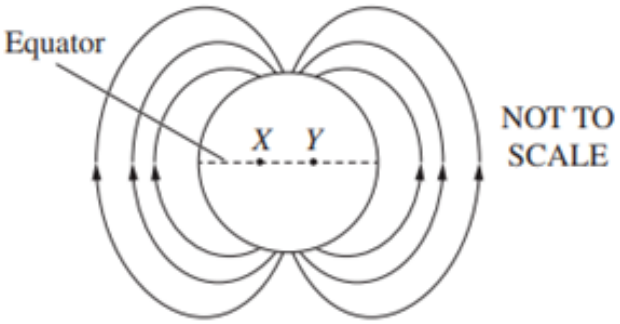
(d)



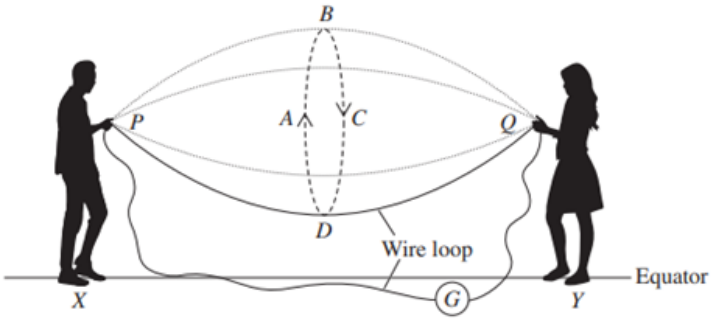
4. A rod of length $l = 0.2\,m$ moves through a magnetic field of strength $B = 4\,T$ at a speed $v = 2\,m\,s^{-1}$ as shown below.
   Showing all working, calculate the induced EMF in the rod.



5. The Earth's magnetic field is shown in the following diagram.



Two students standing a few metres apart on the equator at points X and Y, where Earth's magnetic field is parallel to the ground, hold a loop of copper wire between them. Part of the loop is rotated like a skipping rope as shown, while the other part is motionless on the ground.



At what point during the rotation of the wire does the maximum current flow in a direction from P to Q through the moving part of the wire?

A. A

B. B

C. C

D. D

6. A square coil with perimeter $4L$ and n turns rotates in a uniform magnetic field of strength B. The frequency of its rotation is f.
   What is the average induced EMF (ε)?

7. Sketch the graphs of emf and torque on a motor as a function of its angular velocity if the motor has a constant input voltage and is powering a fan.

8. A big DC electric motor has a variable resistor in series with it. When the motor is switched on, a large resistance is set, and as the motor speeds up, this resistance is reduced to zero. Why is a large resistance needed when the motor is switched on but no resistance is needed when the motor is operating at its normal speed? (4)

9. Compare the DC motor and the AC induction motor. Include: (6)

- Diagrams of AC and DC motors
- Explanation of the squirrel cage and its function
- Discussion about the differences in how/when they are used

10. An electric motor is used to lift a load vertically. As the load is lifted, weights are added to increase the load.

(a) Explain how the rotation speed of the motor changes as the load increase. (2)

(b) Explain how the current in the coils change as the load increases. (2)

11. Relate Lenz's Law to the law of conversation of energy and apply the law of conservation of energy to: (3)

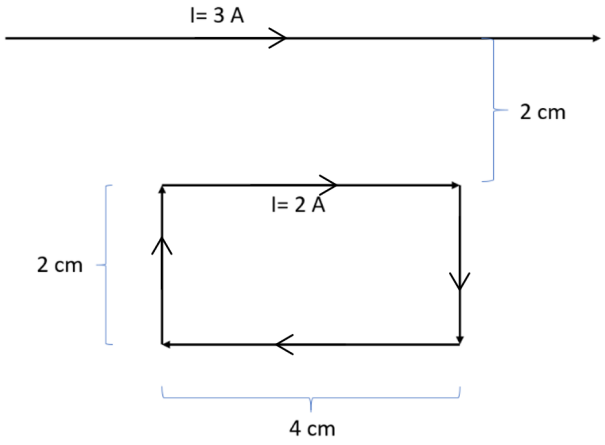
    - DC Motors
    - Magnetic braking

12. Evaluate qualitatively the limitations of the ideal transformer model and the strategies used to improve transformer efficiency, including but not limited to: (4)

    - Incomplete flux linkage
    - Eddy currents and resistive heat production

13. Most motors found in the household are AC induction motors. Describe the Physics behind the operation of an AC induction motor. Note a labelled diagram may help your explanation. (3)

14. A current carrying wire is near a current carrying loop.



Consider the situation shown in the diagram above where a wire carrying a current of $3A$ is placed near a rigid rectangular loop carrying a current of $2A$ (clockwise). Calculate the net force acting on the wire loop. (You may consider the wire to be parallel to the long side of the rectangle.)

The Nature of Light

1. Explain how the model of light has progressed throughout history with reference to: (9)

    - Newton
    - Huygens
    - Young
    - Maxwell
    - Malus
    - Einstein
    - Schrodinger

2. Describe Maxwell's contribution to the development of the model of light. (3)

3. Using the formula for the angular location of a Maxima due to double slit diffraction ($d \sin\theta_m = m\lambda$) derive the formula for the distance of a single maxima from the centre and the distance between two slits.

4. Describe TWO historical attempts to measure the sped of light. Include relevant diagrams. (4)

5. Discuss the statement: "The limitations of classical physics gave birth to Quantum Physics." (6)

6. Describe how limitations in the classical model of physics led to the Quantum Model. Discuss with reference to the Photoelectric Effect. (4)

7. Describe how the spectra of stars can provide information on FOUR of the star's properties. (4)

Special Relativity

1. State Einstein's two postulates. (2)

2. Relate the speed of light to the fundamental properties of the universe.

3. Analyse and evaluate the evidence for Special Relativity. (4)

4. How did Einstein's theory of special relativity and his explanation of the photoelectric effect lead to the reconceptualisation of the model of light? (6)

5. Describe investigations of historical and contemporary methods used to determine the speed of light. (6)

6. With the aid of a diagram, explain the difference between polarised and unpolarised light. (3)

From the Universe to the Atom

1. Describe the experimental setup Chadwick used to discover the neutron. Include relevant diagrams. (3)

2. Describe the historical progression of the atom, refer to all key models and the experiments which led to their development. (8)

3. Outline the properties of a Proton and its constituent parts and the resulting interactions that the proton can partake in. (6)

4. If an electron and positron each moving at speed $0.25c$ and with kinetic energy $E_k = \frac{1}{32} m_e c^2$ annihilate, calculate the total energy of the released photons. ($E = mc^2$ gives intrinsic rest energy)

5. One of the most important equations in Physics is $E = mc^2$. Justify this statement. (7)

6. Describe THREE fusion processes used by stars. Include relevant equations and diagrams where they are useful.

7. Explain FOUR requirements necessary for a controlled fission chain reaction of Uranium-235 to be sustained. (4)

8. Draw a flow chart to outline the various lifecycles of stars.

9. Describe the relationship between the masses of main sequence stars, their luminosities and lifetimes. (3)