The **topics** and **types of questions** examined in this Achievement Standard. Use this sheet to plan and organise your study so that you cover everything that is required.

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3.4 MECHANICAL SYSTEMS AS 90521

Demonstrate understanding of mechanical systems

3.4 1. Translational motion

- centre of mass (1 and 2 dimensions)
- conservation of momentum and impulse (2 dimensions only)
- objects moving in a circle under the influence of 2 or more forces
  - velocity and acceleration of object
  - resultant force on object
  - examples may include: banked corners, vertical circles, Newton's Law of gravitation, satellite motion

In November 2006, flight engineer Mikhail Tyurin hit a golf ball while he was in space, orbiting Earth on a mission on the International Space Station.

(a) The golf ball was a special light design with a mass of only 3.0×10^{-3} kg. The shot took place in low Earth orbit, 350 km above the surface of the Earth. Calculate the force of gravity between the ball and the Earth.

The universal gravitational constant = 6.67×10^{-11} m^3 kg^{-1} s^{-2}

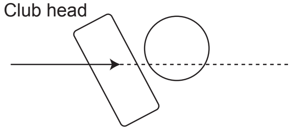
The radius of the Earth at the equator = 6.38×10^6 m

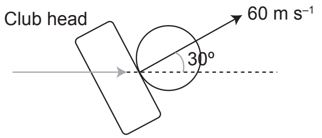
Mass of the Earth = 5.97×10^{24} kg

(b) Explain why the tiny, light ball could remain in a stable orbit at the same velocity as the massive, heavy space station.

(c) Consider a golf shot as a collision between a club head, of mass 0.20 kg, and the ball. Velocities are measured relative to the orbiting space craft. The ball (mass 3.0×10^{-3} kg) is initially stationary. After being hit, it has a velocity of 60 m s^{-1}.

(i) Calculate the momentum lost by the club head during the collision and show the direction of this lost momentum on the 'After collision' diagram.

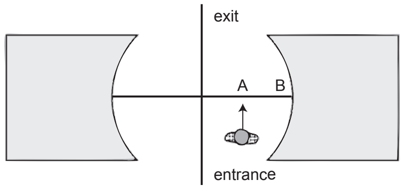




3.4 2. Rotational motion

- rotational motion with constant angular speed and constant angular acceleration
- torque
- rotational inertia
- angular momentum
- rotational kinetic energy
- conservation of angular momentum
- conservation of energy

Revolving doors like the one below are used in many big buildings. You may assume that the effects of friction can be ignored in this question.



Jenny enters a revolving door, which is initially stationary (as shown above). She pushes on the door at point A: it accelerates at 0.48 rad s^{-2}. She stops pushing when it reaches an angular velocity of 0.58 rad s^{-1}.

(a) Jenny pushes, at right angles to the door, with a force of 132 N at a point 83 cm from the central axis. Show that she exerts a torque of 110 N m.

(b) Show that the rotational inertia of the door is 230 kg m^2.

(c) Calculate the rotational kinetic energy gained by the door from Jenny.

(d) Explain how this gain in energy is related to the force Jenny exerted on the door.

(e) Dorothy tells Jenny that by pushing at B (see diagram above), she can get the door rotating to the same speed in the same time with less force. Discuss whether this idea is correct.

3.4 3. Simple harmonic motion

- displacement, velocity and acceleration
- time and frequency of particle undergoing SHM
- forced SHM, resonance
- the reference circle, phasors
- conservation of energy

Helen took a yo-yo and set it swinging like a simple pendulum. She measured the amplitude in the horizontal direction and found it to be 0.100 m. She then measured the period and found it to be 2.20 seconds. Mass of yo-yo = 3.20×10^{-2} kg.

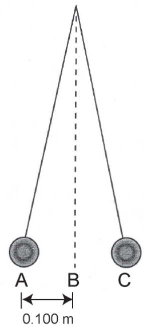
(a) Show that the angular frequency of this pendulum was 2.86 rad s^{-1}.

Helen released the pendulum from position A at time t=0 seconds.

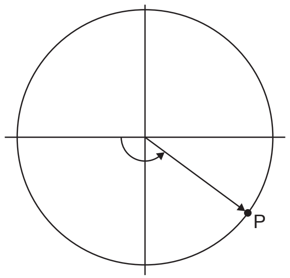
(b) Whereabouts in the motion does the pendulum have maximum acceleration?

(c) Show that the maximum velocity of the pendulum is 0.286 ms^{-1}.

(d) By considering conservation of energy, calculate the potential energy of the pendulum at position C, one of the points of maximum displacement.



(e) The reference circle to the right shows the position P of the pendulum after 1.00 seconds. Calculate the horizontal distance of the pendulum from the centre of its swing at this time using the reference circle.



(f) Sketch on an axes, for the first complete cycle following release of the pendulum (from position A at time t=0 seconds), the graphs of:

(i) velocity against time

(ii) acceleration against time.

On the vertical axes, include appropriate maximum values and, on the time axis, the period value.