CAIE 9709 Paper 4 - Mechanics Summary

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1 Velocity and acceleration - CGP(13-16)

- The equations of **constant acceleration** are: (能背的都背下来！)

$$v = u + at$$
$$s = \frac{1}{2}(u+v)t$$
$$s = ut + \frac{1}{2}at^2$$
$$s = vt - \frac{1}{2}at^2$$
$$v^2 = u^2 + 2as$$

  These are often known as `SUVAT` equations.

- A displacement-time graph shows the position of an object at different times.
  The gradient is equal to the velocity.

- A velocity-time graph shows how quickly an object is moving at a given time.
  The gradient is equal to the acceleration.
  The area under the graph is equal to the displacement.

2 Force and motion in one dimension

- A force is something that influences the motion of an object. Its size is measured in newtons (N).

- Force is related to acceleration by the equation: net force = mass × acceleration. 牛二-$F_{\text{net}} = ma$

- Objects acted on only by the force of gravity have an acceleration of $g = 10\ \text{ms}^{-2}$.

- The weight of an object is the force on it due to gravity and has magnitude $W = mg$.

- The reaction force or normal contact force is the force on an object due to being in contact with another object or surface. It acts perpendicular to the surface and is usually denoted by R (or sometimes N).

3 Forces in two dimensions

- A force can be split into components using the idea that force is a vector and can be written as the sum of other vectors.

- The components are usually found in two perpendicular directions with the force as the hypotenuse of a right-angled triangle and the other two sides as components.

- Directions chosen are usually horizontally and vertically, parallel and perpendicular to a slope, or parallel and perpendicular to the direction of motion.

- Resolving perpendicular to an unknown force means the unknown will not appear in the equation.

- When the direction of acceleration is unknown it is normally best to find components of a resultant force and use them to find the direction and magnitude of the resultant.

4 Friction

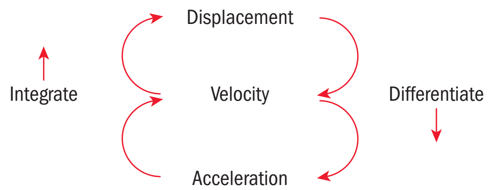
- Friction can take any value up to the limiting value, which depends on the normal contact force, R, and the coefficient of friction, μ.
- $F \leq \mu R$
- If there is motion, or the object is on the point of slipping or in limiting equilibrium, friction will take the maximum possible value.
- The total contact force is the combination of the normal contact force and the friction.
- If a situation becomes different because a force changes or the direction of motion switches, the normal contact force may be affected, so the friction may change. It is best to draw a new diagram every time a different situation arises.

5 Connected particles

- 牛三-作用力与反作用力
  Newton's third law states that for every action there is an equal and opposite reaction. This means that in every interaction there is a pair of forces that have the same magnitude, but which act in opposing directions.
- When a string passes over a **smooth** pulley, the magnitude of the tension is unchanged but the direction can change.
- Newton's second law can be applied to a system of connected objects, either to the entire system or to individual components of the system, provided they move with the same acceleration and in the same direction.

6 General motion in a straight line

- $$v = \frac{\mathrm{d}s}{\mathrm{d}t}$$
  $$a = \frac{\mathrm{d}v}{\mathrm{d}t} = \frac{\mathrm{d}^2 s}{\mathrm{d}t^2}$$
  $$s = \int v \,\mathrm{d}t$$
  $$v = \int a \,\mathrm{d}t$$



- You may be able to check numerical differentiation and numerical integrals on your calculator. If you have an equation solver on your calculator, you may also find this helpful. However, you will need to show full working in the examination.

7 Momentum 动能

- A body of mass m kg moving with speed v ms^{-1} has momentum given by mv.
- Momentum is conserved in impacts 动能守恒. The total momentum is constant.
- $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

8 Work and energy

- The work done (做工), in joules, by a force of magnitude F N in moving a body a distance d m in the direction of the force is:
$$W = Fd.$$

- The work done, in joules, by a force of magnitude F N in moving a body a distance d m at an angle θ to the direction of the force is:
$$W = Fd\cos(\theta).$$

- The kinetic energy, in joules, of a body of mass m kg moving with speed v ms^{-1} is:
$$\text{KE} = \frac{1}{2}mv^2.$$

- The gravitational potential energy (重力势能), in joules, of a body of mass m kg at height h m above the base level is:
$$\text{GPE} = mgh$$

9 The work-energy principle and power

- The work-energy principle states that for any motion:
increase in kinetic energy = total work done by all forces
$$\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = \sum Fs$$
where the 'total work done' is the sum of the work done by forces with a component in the direction of motion (forces that speed up the motion) − the work done against forces with a component in the direction opposing the motion (forces that slow down the motion).

- The work-energy principle can also be written as:
increase in mechanical energy = total work done by forces that help to speed the body up − total work done by forces that help to slow the body down
(In both cases 'forces' excludes the weight of the body.)

- Kinetic energy and potential energy are types of mechanical energy. Other forms of energy (heat, light, sound, chemical, electrical , nuclear etc.) are non-mechanical energy.

- A consequence of the work-energy principle is that for a system of conservative forces the total mechanical energy is constant. We call this conservation of mechanical energy.

- Power (功率) is measured in Watts. The power of an engine, in watts, is the rate at which that engine can work:
$$\text{power} = \text{work done} \div \text{time taken}$$

- The power of an engine is also the product of the driving force of the engine and the velocity in the direction of the driving force: power $= Fv$, where F is the driving force of the engine.