2.3 Work, Energy & Power

Question Paper

Course	DP IB Physics
Section	2. Mechanics
Topic	2.3 Work, Energy & Power
Difficulty	Hard

Time allowed: 70

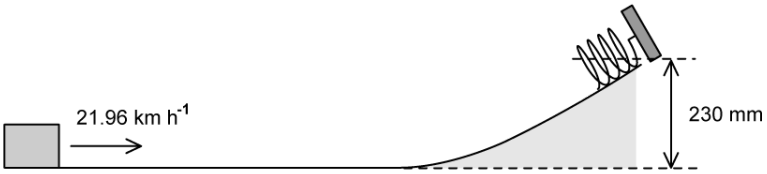
Score: /52

Percentage: /100

Question 1a

A packing company have a contraption involving an inclined plane and a spring. It is used to pack and seal their boxes.

A box of mass 4800 g with an initial speed 21.96 km h^{-1} begins to move up a smooth incline.



The box is momentarily brought to rest after colliding with a spring of spring constant 195 N m^{-1}. It stops a vertical distance of 230 mm above its initial position.

(a)
Calculate the compression of the spring in mm.

[3]

[3 marks]

Question 1b

On a different set up, the inclined plane is rough and has a coefficient of friction of 0.3. A new box comes to rest part way up the slope after 2.12 seconds.

(b)
Determine the height the box reaches at the point it comes to rest.

You may use the result:

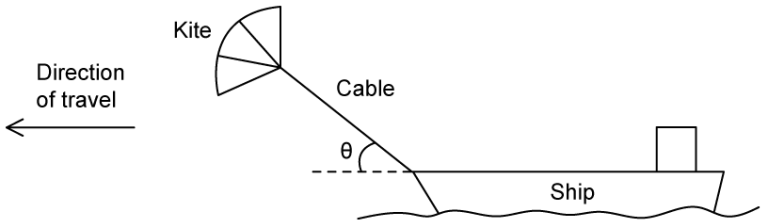
$$\tan\theta = \frac{\sin\theta}{\cos\theta}$$

[4]

[4 marks]

Question 2a

Some cargo ships use kites together with the ships engine to move heavy pieces of cargo.



The tension in the cable that connects the kite to the ship is 475 kN. The kite is pulling on the ship at an angle of θ to the horizontal plane of the ship's deck. The ship travels at a steady speed of 14.76 km hr^{-1} when its engines operate with a power output of 5.9 MW. The work done by the engines is 0.365 GJ when turned on for 0.09 hours.

(a)
Calculate the efficiency of the kite.

[4]

[4 marks]

Question 2b

The ship continues its journey using both the engine and the kite to maintain the same constant speed. After 0.09 hours with the engine on, the ship drives into a spring net erected between two rocky outcrops. Upon impact, the net force from the ship acts parallel to the direction of extension of twelve identical springs in the net and the ship comes to a complete stop with the springs in the net extended. The ship has a mass of 2200 metric tonnes.

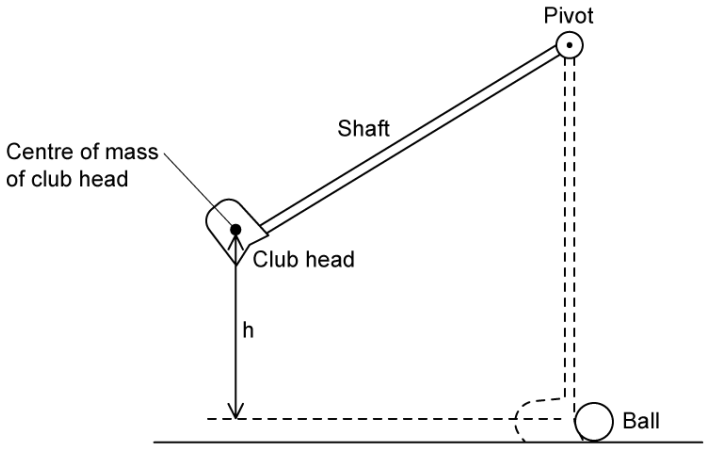
(b)
Calculate the extension of one of the springs in the net to the nearest millimetre. Assume no energy is lost upon impact.

[3]

[3 marks]

Question 3a

A golfing team are conducting investigations into the optimum angles at which golfers should hold their clubs to swing for the ball.



Golf club A is held at an angle of 30° to the vertical at the pivot and golf club B at an angle of 45°. Both golf clubs are 1.05 m long and have the same mass.

(a)
Compare the maximum speeds of the club heads just before they hit the ball.

[5]

[5 marks]

Question 3b

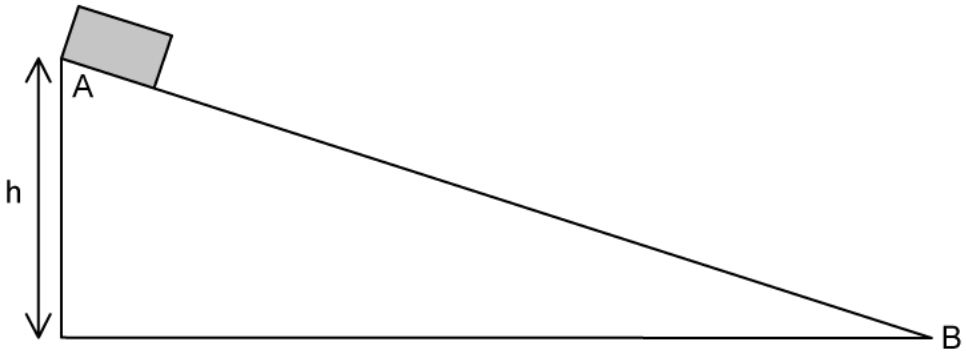
(b)
Obtain an expression to calculate the time of swing for golf club A if the time of swing for golf club B is 0.23 seconds.
Assume no additional force is applied to the golf clubs apart from their weight during the swing.

[4]

[4 marks]

Question 4a

An object is at rest at the top of a straight slope that makes a fixed angle with the horizontal at a distance *h* above the ground.



The object is released and slides down the slope from A to B with negligible friction. Assume that the potential energy is zero at B.

(a)
Sketch and explain a graph showing:

(i)
The variation of gravitational potential energy of the object along the slope, label P.

[2]

(ii)
The variation of kinetic energy of the object along the slope, label K.

[3]

(iii)
The variation of kinetic energy of the object along the slope when there is a frictional force between the object and the surface, label F.

[3]

[8 marks]

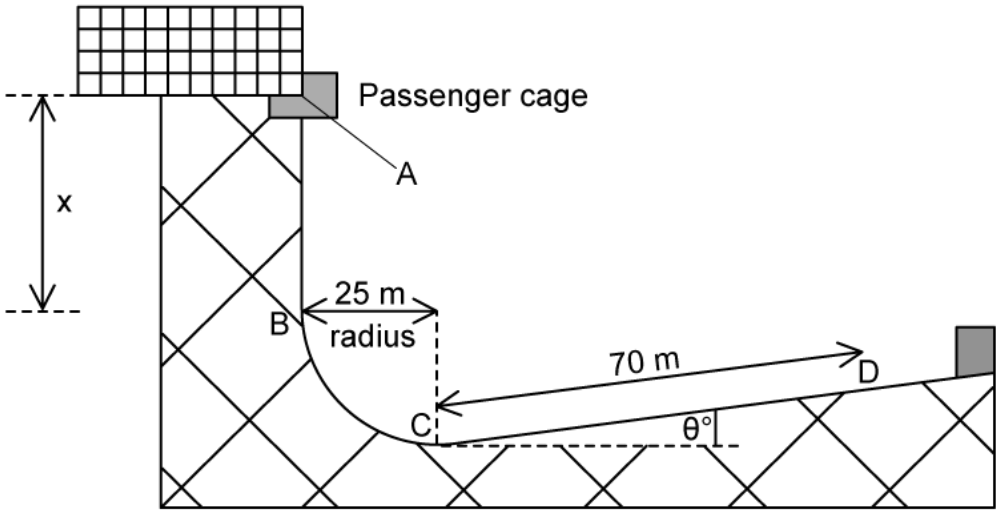
Question 4b

In a theme park ride, a cage containing passengers falls freely a distance of x m from A to B and travels in a circular arc of radius 25 m. from B to C. The force required for circular motion on a passenger of mass 63.25 kg is 0.064×10^2 kN.

The equation for calculating centripetal force on an object moving in an arc is:

$$F = \frac{mv^2}{r}$$

Brakes are applied at C after which the cage with its passengers travels 70 m along an upward sloping ramp and comes to rest at D. The track, together with relevant distances, is shown in the diagram. CD and makes an angle θ with the horizontal.



The total mass of the cage and passengers is 3.556×10^2 kg. The average resistive force exerted by the brakes between C and D is 4.4×10^3 N.

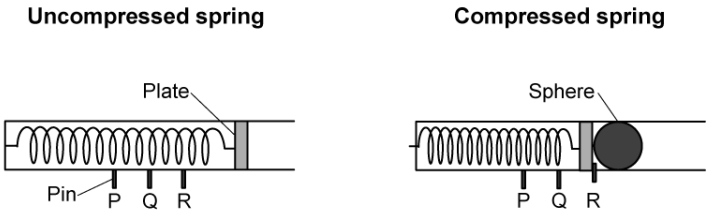
(b)
Calculate the angle of the ramp to the horizontal, θ.

[5]

[5 marks]

Question 5a

The diagram below shows a projectile launcher with a spring in both a compressed and uncompressed position. When the spring is compressed, in preparation for launching the projectile, the plate is held in place by a pin at three different positions, *P*, *Q* and *R*. When the pin is released the sphere is launched.



A student hypothesises that the spring constant of the spring inside the launcher has the same value for different compression distances.

(a)
The student plans to test the hypothesis by launching the sphere using the launcher.
(i)
State a physics principle or law that can be used in designing and conducting an experiment to test this hypothesis.

[1]

(ii)
Hence, or otherwise, show that $k = \frac{2mgh}{x^2}$

Measurements can be made with equipment usually found in a school laboratory using the principle or law stated in part (i).

[3]

[4 marks]

Question 5b

(b)
Design an experimental procedure to test the hypothesis.

(i)
In the table below suggest the quantities, their symbols and the equipment used to measure each.

Quantity to be measured	Symbol	Measuring equipment

[3]

(ii)
Describe the best procedure that can be used to test the hypothesis.

[5]

[8 marks]

Question 5c

(c)
Assess how the experimental data can be analysed to confirm or dispel the hypothesis.

[4]

[4 marks]