2.3 Work, Energy & Power

Question Paper

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

Time allowed: 80

Score: /61

Percentage: /100

Question 1a

A box of mass 5.8 kg with initial speed 7.2 m s^{-1} begins to move up a smooth incline.

The box is momentarily brought to rest after colliding with a spring of spring constant 210 N m^{-1}. It stops a vertical distance of 0.65 m above its initial position.

(a)

(i)
Calculate the initial energy of the box

(ii)
Determine an equation for the final energy of the box when it collides with the spring

[4 marks]

Question 1b

(b)
Hence, or otherwise, calculate the amount by which the spring is compressed.

[3 marks]

Question 1c

There is now a constant frictional force of 16 N opposing the motion of the box as it moves along the slope uphill part of its path. The incline is at an angle of 22° from the horizontal.

(c)
Calculate the magnitude of the work done on the box as it travels uphill.

[3 marks]

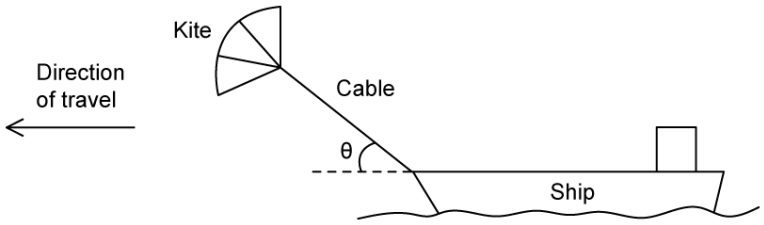
Question 1d

(d)
Hence, or otherwise, calculate the new amount by which the spring is compressed.

[3 marks]

Question 2a

Some cargo ships use kites working together with the ship's engines to move the vessel.



The tension in the cable that connects the kite to the ship is 350 kN. The kite is pulling the ship at an angle of θ to the horizontal. The ship travels at a steady speed of 3.9 m s^{-1} when the ship's engines operate with a power output of 5.7 MW.

(a)
Calculate the angle θ if the work done on the ship by the kite when the ship travels for 5 minutes, before the engines are cut off, is 355 MJ.

[3 marks]

Question 2b

(b)
When the ship is travelling at 3.9 m s^{-1}, calculate the power that the kite provides.

[3 marks]

Question 2c

(c)
Hence calculate the percentage of the total power required by the ship that the kite provides.

[3 marks]

Question 2d

The kite is taken down and no longer produces a force on the ship. The resistive force F that opposes the motion of the ship is related to the speed v of the ship by

$$F = kv$$

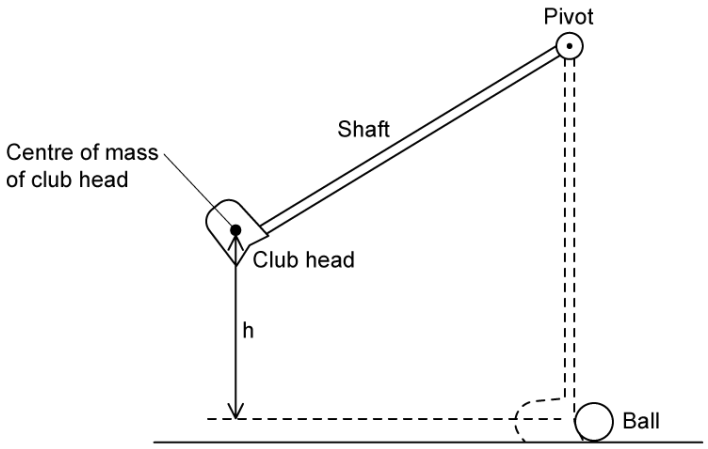
where k is a constant.

(d)
Show that, if the power output of the engines remains at 5.7 MW, the speed of the ship will decrease to about 3.5 m s^{-1}.
Assume that k is independent of whether the kite is in use or not.

[3 marks]

Question 3a

The arrangement shown below is used to test golf club heads.



The shaft of a club is pivoted and the centre of mass of the club head is raised by a height *h* before being released. The club head then falls back to the vertical position where it strikes the ball.

(a)
Calculate the maximum speed of the club head achieved when *h* = 75 cm.

[3 marks]

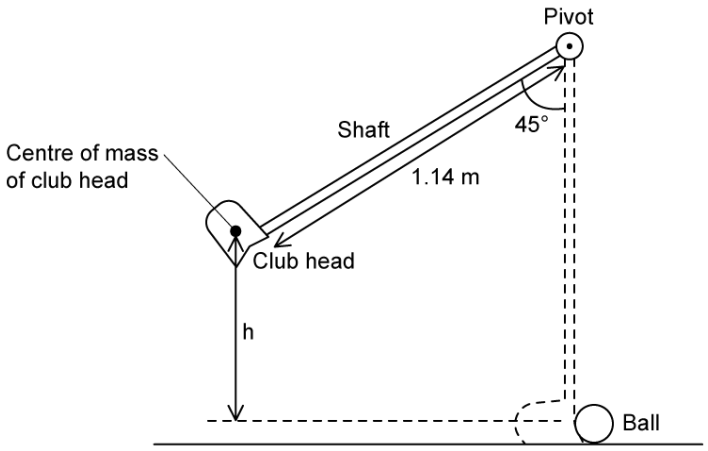
Question 3b

(b)
Explain why, in reality, the speed of the ball will not be the same as the maximum speed of the club head.

[3 marks]

Question 3c

The optimal launch angle for a projectile, such as a golf ball, is 45°. Another experiment is carried out with a golf club that has a shaft 1.14 m long.



(c)
Calculate the maximum speed this club head achieves just before it hits the ball.

[3 marks]

Question 3d

The golf club head has a mass of 200 g and has a power of 460 mW just before it hits the ball.

(d)
Show that time taken for the golf club swing is about 1.4 s.

[3 marks]

Question 4a

A motor is used to lift a 50 kg mass from rest up a vertical distance of 18 m in 0.3 minutes.

(a)
Calculate the minimum power requires to the lift the mass.

[3 marks]

Question 4b

(b)
Explain why the power of the motor is only a minimum.

[2 marks]

Question 4c

A different motor is used to lift an identical mass through the same distance in the same amount of time with an overall efficiency of 38 %. The mass experiences a resistive force of 170 N.

(c)
Calculate the work required from the motor.

[3 marks]

Question 4d

(d)
Hence, determine the average power input to the motor.

[3 marks]

Question 5a

The top speed of a car with a mass of 1400 kg whose engine is delivering 490kW of power is 530 km h^{-1}.

(a)
Calculate the force from the engine on the car.

Assume that air resistance is negligible.

[3 marks]

Question 5b

The car now travels at a new constant velocity up a hill of incline 25°.

(b)
Determine the decrease in velocity from the previous motion of the car as it travels up the hill with the same power.

[4 marks]

Question 5c

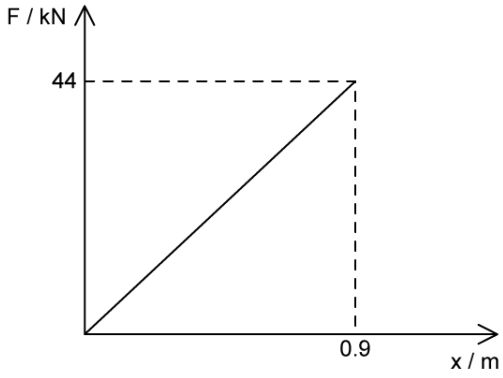
The car engine cuts off whilst travelling up the incline.

(c)
Assuming there are no resistive forces, calculate the distance travelled by the car from when the engine cuts off to when it has a gravitational potential energy of 110 kJ.

[3 marks]

Question 5d

A spring in the car's suspension system has the following force-displacement graph.



(d)
Using the area under the graph, show that the spring constant of the spring is about 49 kN m^{-1}.

[3 marks]