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PHYSICS

2006

Trial Examination 1

Motion in one and two dimensions
Electronics and photonics
Investigating materials and their use in structures

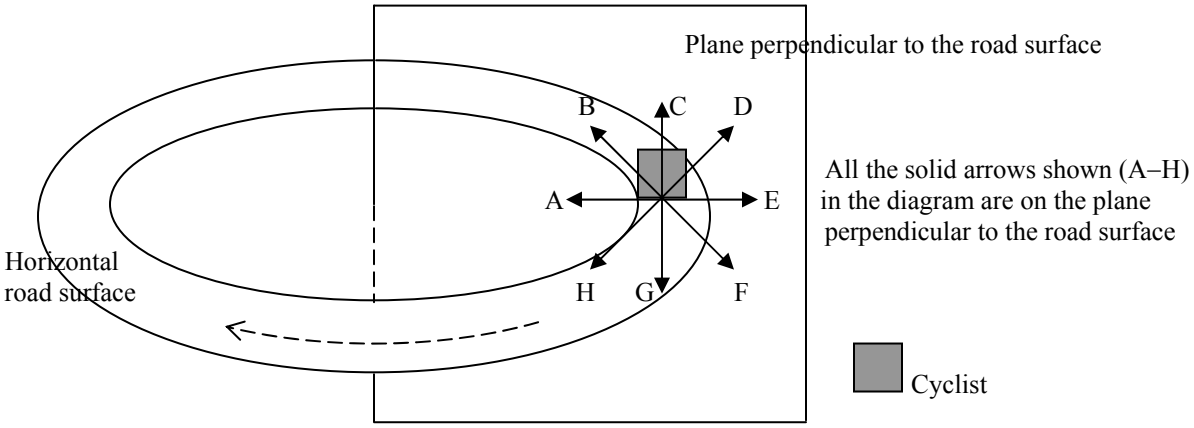
Area of study 1 − Motion in one and two dimensions

A cyclist (total mass of the person and the cycle is 80 kg) makes a turn at a roundabout of radius 8.0 m at constant speed 5.0 ms^{-1}. The surface of the road is horizontal. You may assume no resistance force against the circular motion.

Question 1 What is the magnitude of the friction force between the tyres and the road surface? 3 marks

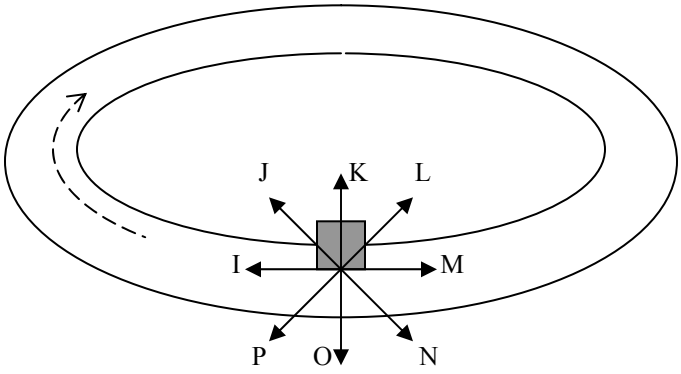
N

Question 2 Which arrow is best to show the direction of the reaction force of the road surface on the tyres? 2 marks

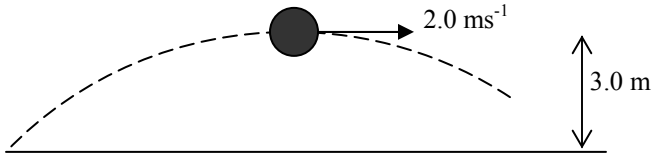


Now the cyclist is slowing down by braking during the turn.

Question 3 Which arrow in the following diagram is best to show the direction of the net force on the cyclist? 2 marks
Note: In the following diagram all the solid arrows shown (I–P) are on the same plane as (i.e. parallel to) the road surface.



A projectile has a speed of 2.0 ms^{-1} at the highest point of its path. At that moment it is 3.0 m above the point of projection. Ignore air resistance in **question 4** and **question 5**.

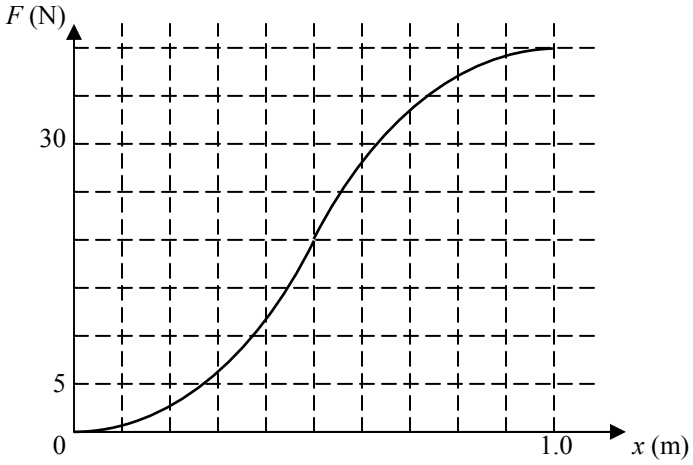


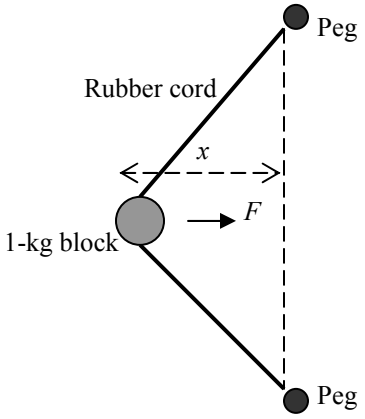
Question 4 Calculate the speed of the projectile immediately after projection. 3 marks

ms^{-1}

Question 5 Calculate the angle that the direction of motion of the projectile makes with the horizontal at the point of projection. 3 marks

The following graph shows the relationship between force F (newtons) and extension x (metres) of a 0.70 m long rubber cord used as a catapult. You may assume the rubber cord has negligible mass.





Question 6 Find the strain energy of the rubber cord when x = 1.0 m. 2 marks

J

When x = 1.0 m, the 1-kg block is catapulted a distance of 2.5 m from the point of release along a horizontal floor.

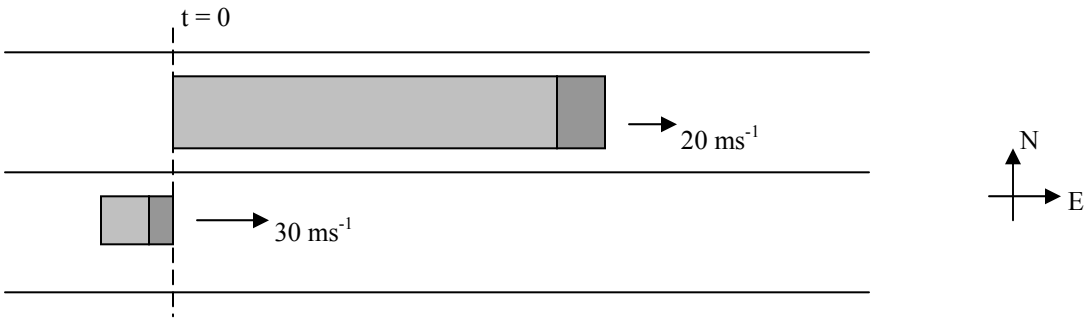
Question 7 Calculate the magnitude of the force of friction between the block and the floor. 3 marks

N

Question 8 Calculate the maximum kinetic energy of the block. 3 marks

J

A long truck (20 m) and a car (4.0 m) travel in the same direction on two adjacent lanes. At t = 0, the front of the car aligns with the rear of the truck. To an observer at rest on the roadside, the truck has a constant speed of 20 ms^{-1} and the car 30 ms^{-1}.



Question 9 Determine the velocity of the car observed by the truck driver. 2 marks

ms^{-1}

Question 10 Calculate the time required (from t = 0) for the car to overtake the truck such that the rear of the car aligns with the front of the truck.

4 marks

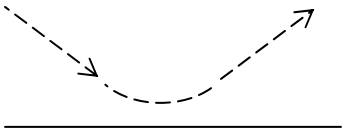
s

A ball bounces off a **frictionless** floor **elastically**.

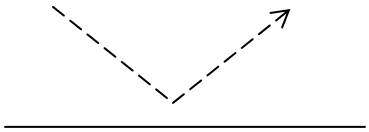
Question 11 Which one of the following diagrams best shows the path of the centre of mass of the ball before and after the bounce?

2 marks

A

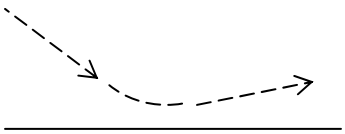


B

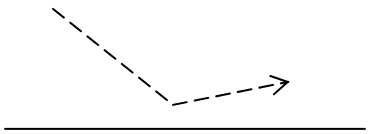


C

D



E



Question 12 Use contact time, energy and momentum considerations to explain your answer to question 11. 4 marks

The moon is in circular orbit around the earth.
The earth is in circular orbit around the sun.
Radius of the earth = 6.38×10^6 m
Distance between the earth and the moon = 3.82×10^8 m
Distance between the earth and the sun = 1.50×10^{11} m
Mass of the sun = 1.99×10^{30} kg
Mass of the earth = 5.98×10^{24} kg
Mass of the moon = 7.36×10^{22} kg
G = 6.67×10^{-11} N m^2 kg^{-2}

Question 13 Determine the value of the ratio

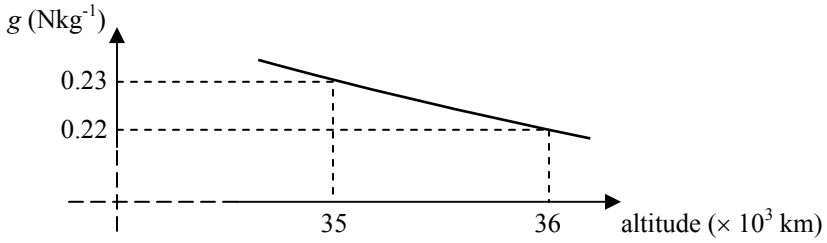
$$\frac{\textit{gravitational field strength of the sun experienced by the earth}}{\textit{gravitational field strength of the sun experienced by the moon}}$$

1 mark

Question 14 Calculate the speed of the earth in orbit around the sun. 2 marks

ms^{-1}

At an altitude of 36000 km, the gravitational field of the earth is 0.22 Nkg^{-1}. At an altitude of 35000 km, it is increased to 0.23 Nkg^{-1}.



Question 15 If an object is allowed to fall from rest towards the earth at an altitude of 36000 km, calculate the speed of the object after falling 1.0 km.

2 marks

ms^{-1}

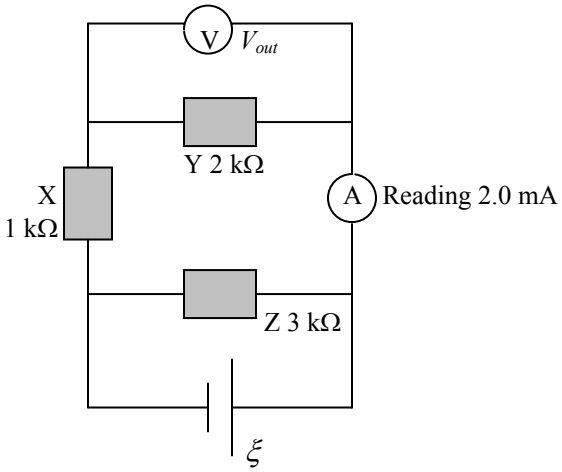
Question 16 If an object is allowed to fall from rest towards the earth at an altitude of 36000 km, estimate the speed of the object after falling 1.0×10^3 km.

2 marks

ms^{-1}

Area of study 2 − Electronics and photonics

Consider the following circuit consisting of ohmic resistors X, Y and Z. A voltmeter V and an ammeter A are connected to the circuit. You may assume the voltmeter and ammeter do not alter the nature of the circuit. The voltmeter measures the output voltage of the circuit. The circuit is powered by a battery ξ of negligible internal resistance. The ammeter reading is 2.0 mA.



Question 1 Determine the output voltage. 2 marks

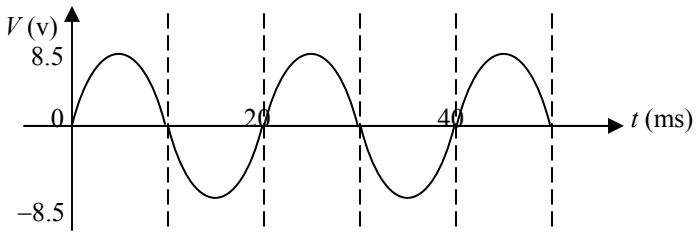
volts

Question 2 Determine the emf ξ of the power supply. 2 marks

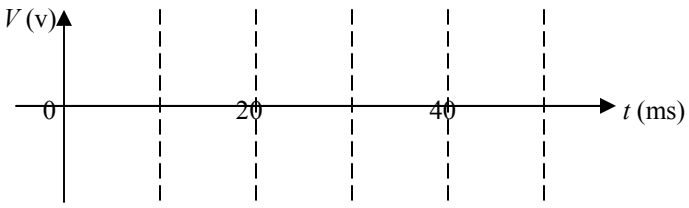
volts

Question 3 Which one or more of the ohmic resistors can be removed to give the same output voltage? 2 marks

Now the battery is replaced by a sinusoidal ac voltage source V, the variation of V is shown in the graph below. The voltmeter is replaced by a CRO.

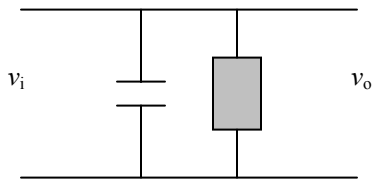


Question 4 Sketch the output voltage measured by the CRO. 3 marks

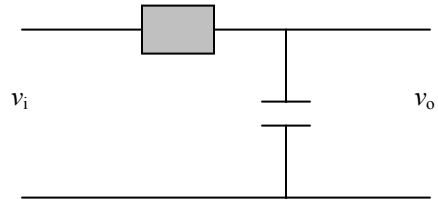


Consider the following circuits. Each one consists of an ohmic resistor and a capacitor:

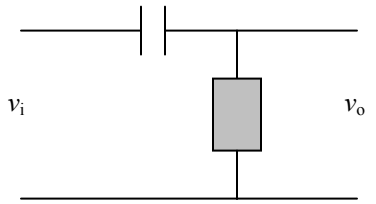
A



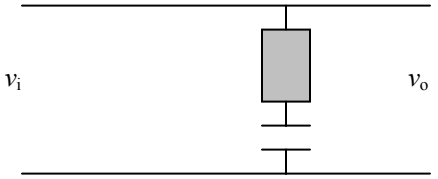
B



C



D

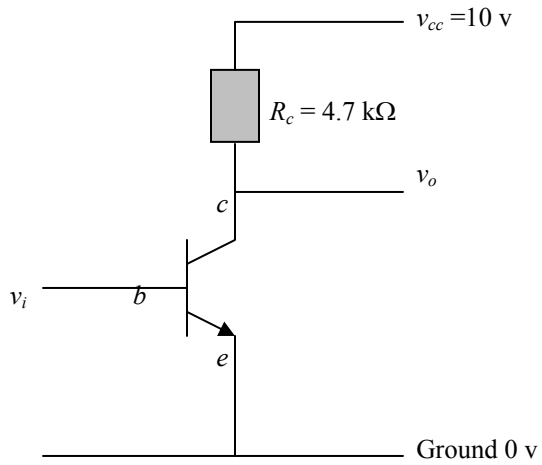


The input signal v_i consists of sinusoidal (ac) and constant (dc) voltages.

Question 5 Which circuit (one or more) has nearly constant dc voltage at output v_o? 2 marks

Question 6 Which circuit (one or more) has ac voltage only at output v_o? 2 marks

Consider the following circuit consisting of an ohmic resistor R_c connected in series with the collector terminal of an *npn* BJT and a dc source v_{cc}.



Suppose v_i is set at a constant value of 0.700 v, i.e. the *npn* BJT is in dc operating condition. Base current i_b = 14.5 μA. Current gain is 100.

Question 7 Calculate the collector current i_c and emitter current i_e. 2 marks

i_c	mA	i_e	mA

Question 8 Show that the output voltage v_o is 3.2v. 2 marks

v

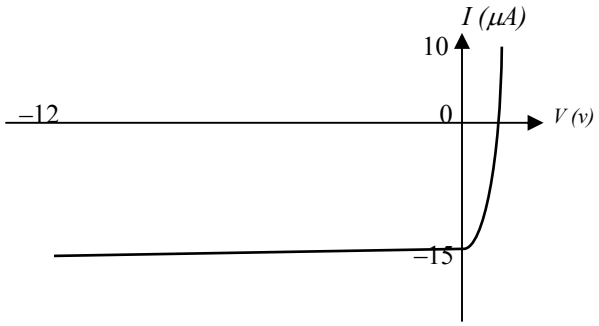
Now v_i is changed to 0.705 v, v_o is found to be 1.7v.

Question 9 Determine the voltage gain of the *npn* BJT operating as a voltage amplifier when v_i changes from 0.700 to 0.705 v. 2 marks

Question 10 The lowest output voltage v_o is 0.3 v. Determine i_c in the saturation region. 2 marks

mA

The following graph shows the *i-v* characteristic of a photodiode when it is illuminated with light of 1500 lux.



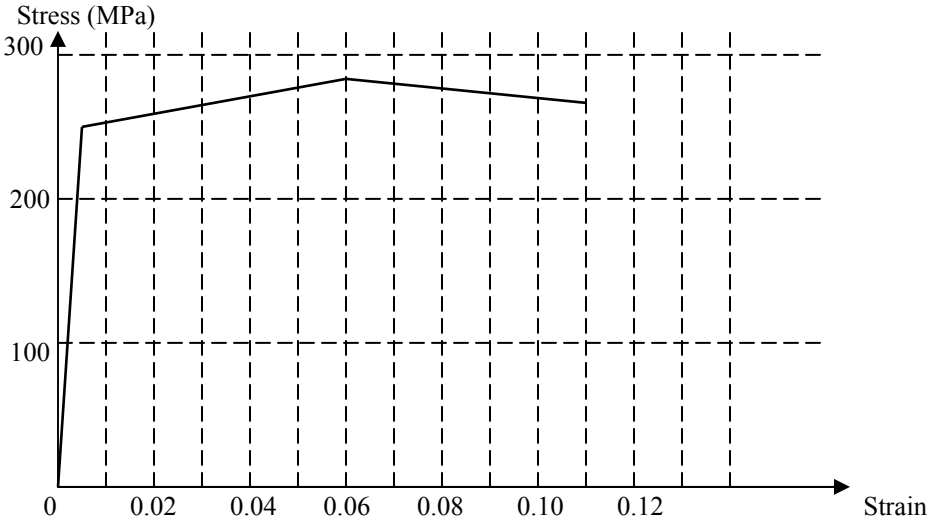
Question 11 What is the approximate current when the photodiode is in photoconductive mode? 2 marks

μA

Question 12 Describe the function of photodiodes in the transfer of information using optical intensity modulated light. 2 marks

Area of study 3.2 − Investigating materials and their use in structures

The results of a tensile test of a 1.30-cm diameter aluminium alloy test bar are presented in the following graph showing the stress-strain curve.



Question 1 Fill in the values (including units) to complete the following table. 4 marks

Yield strength	Tensile strength	Breaking strength	Young's modulus

Question 2 The test bar is 5.00 cm long with zero loading. Calculate its extension when force is applied to produce a tensile stress of 250 MPa.

2 marks

cm

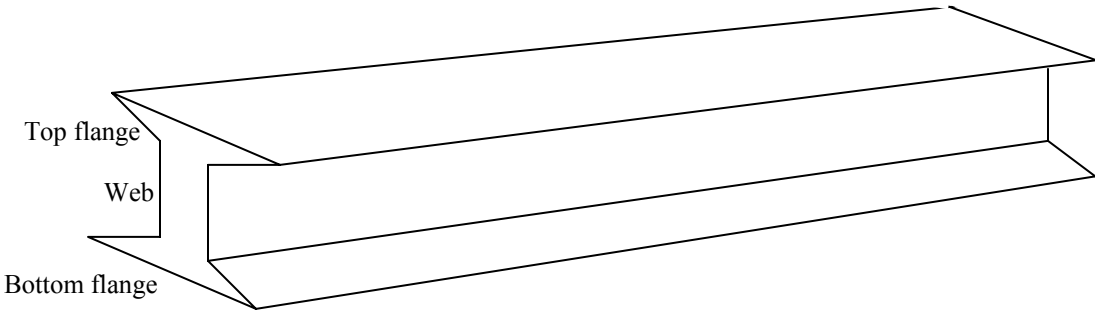
Question 3 What is the magnitude of the force required to give a stress of 250 MPa? 2 marks

N

Question 4 Determine the elastic strain energy for each cubic metre of the alloy when the tensile stress is 250 MPa. 2 marks

J

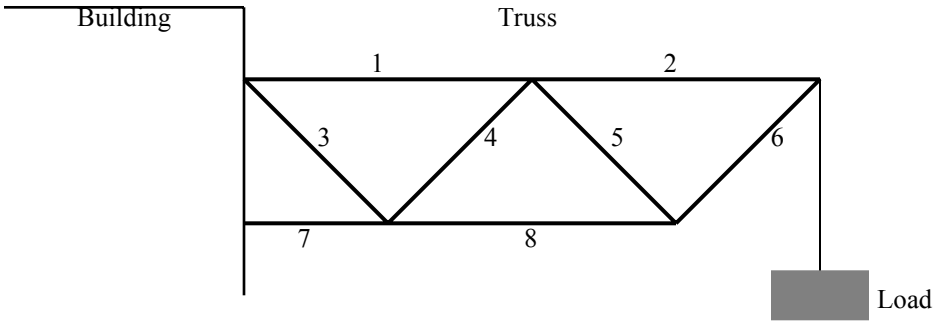
The following diagram shows a common shape of steel beams used in buildings. It is called an H beam. The top and bottom of the beam are called flanges, the middle section is called web.



Question 5 In terms of the different types of stress that the beam has to withstand, explain the functions of the flanges and web in an H beam.

3 marks

Consider the truss shown below. It is in the form of a cantilever. The members of the truss are numbered 1, 2, 3, ….



Question 6 The members that can be replaced by ropes or chains are (one or more answers)

A. 1, 2, 3
B. 1, 2, 5
C. 2, 3, 5
D. 2, 3, 4
E. 1, 4, 5

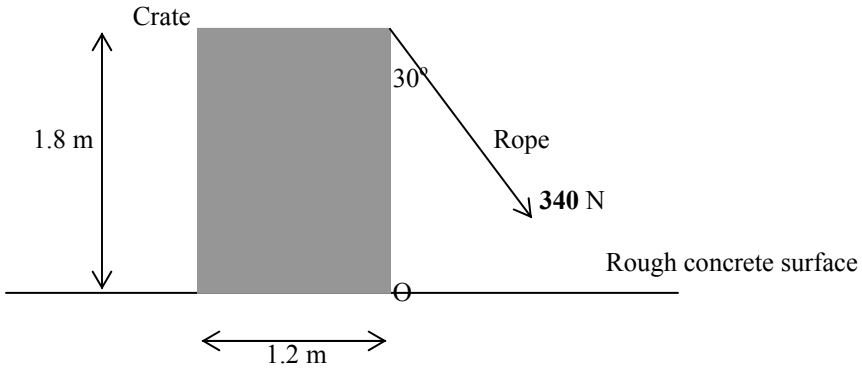
2 marks

Question 7 Let F (either compression or tension) be the force in a member of the truss, e.g. F_1 represents the force in member 1. Which one of the following choices is correct?

A. $F_1 = F_2$ and $F_7 = F_8$
B. $F_1 < F_2$ and $F_7 > F_8$
C. $F_1 > F_2$ and $F_7 < F_8$
D. $F_1 > F_2$ and $F_7 > F_8$
E. $F_1 < F_2$ and $F_7 < F_8$

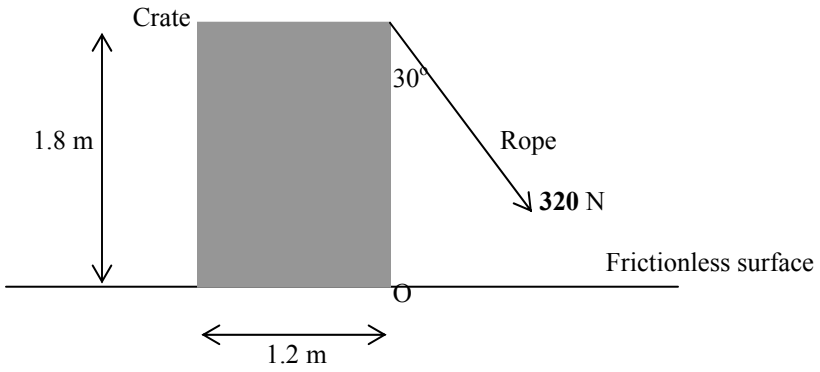
2 marks

A 50.0-kg crate is placed on a rough concrete surface. It is pulled with a rope inclined at 30^o downwards with the vertical. The tension in the rope is 340 N. There is a friction force of 170 N between the crate and the concrete surface.



Question 8 In terms of forces and torques, explain whether the crate is in equilibrium or not. Include calculations in your explanation. 4 marks

Now the crate is placed on a frictionless horizontal surface. It is pulled with the same rope inclined at 30^o downwards with the vertical. The tension in the rope is reduced to 320 N.



Question 9 Describe and explain the effects of the pulling force on the crate. 4 marks