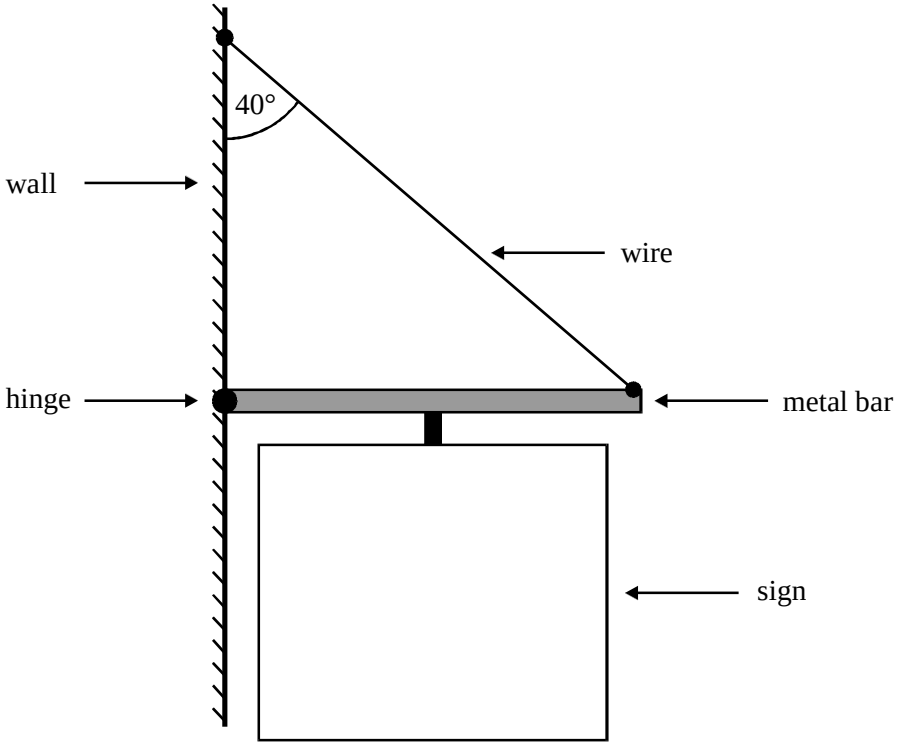
1. A public house sign is fixed to a vertical wall as shown in the diagram.



A uniform metal bar 0.75 m long is fixed to the wall by a hinged joint that allows free movement in the vertical plane only. The wire is fixed to the wall directly above the hinge and to the free end of the horizontal metal bar. The wire makes an angle of 40° with the wall.
A single support holds the sign and is mounted at the mid point of the metal bar so that the weight of the sign acts through that point.

(a) (i) Draw on the diagram three arrows showing the forces acting on the metal bar, given that the system is in equilibrium. Label the arrows A, B and C.

(ii) State the origin of the forces.

A .....

B .....

C .....

(5)

(b) The combined mass of the metal bar and sign is 12 kg and the mass of the wire is negligible. By taking moments about the hinged end of the bar, or otherwise, calculate the tension in the wire.

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(4)
(Total 9 marks)

2. As part of a quality check, a manufacturer of fishing line subjects a sample to a tensile test. The sample of line is 2.0 m long and is of constant circular cross-section of diameter 0.50mm. Hooke's law is obeyed up to the point when the line has been extended by 52mm at a tensile stress of 1.8×10^8 Pa.
The maximum load the line can support before breaking is 45 N at an extension of 88 mm.

(a) Calculate

(i) the value of the Young modulus,

.....

.....

.....

(ii) the breaking stress (assuming the cross-sectional area remains constant),

.....

.....

.....

(iii) the breaking strain.

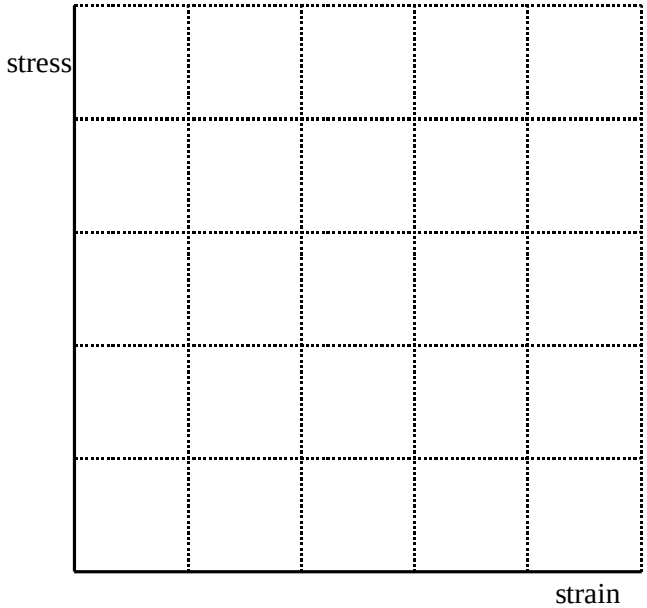
.....

(5)

(b) Sketch a graph on the axes below to show how you expect the tensile stress to vary with strain. Mark the value of stress and corresponding strain at

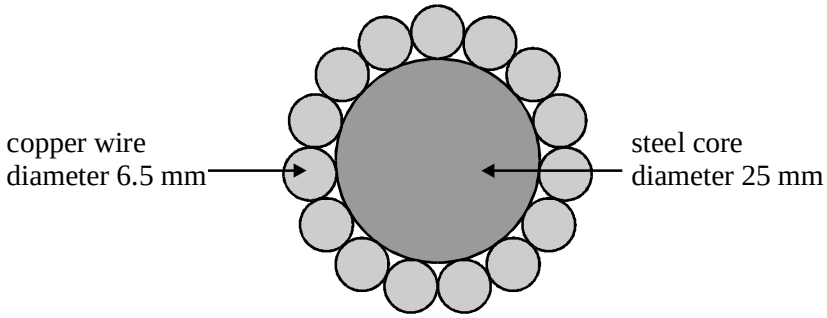
(i) the limit of Hooke's law,

(ii) the breaking point.



(4)
(Total 9 marks)

3. The cross-section of an overhead power cable is shown below. The cable consists of a hard steel core surrounded by fifteen straight, thick copper wires.



100m lengths of cable are suspended between adjacent pylons as part of an electricity distribution system.

Calculate the mass of a 100m length of the cable.

density of copper = 8.93×10^3 kg m^{-3}
density of steel = 7.80×10^3 kg m^{-3}

mass of hard steel core .....

.....

.....

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mass of copper wires .....

.....

.....

.....

mass of cable .....

(Total 4 marks)

4. Explain the differences between an undamped progressive transverse wave and a stationary transverse wave, in terms of (i) amplitude, (ii) phase and (iii) energy transfer.

(i) amplitude

progressive wave .....

.....

stationary wave .....

.....

(ii) phase

progressive wave .....

.....

stationary wave .....

.....

(iii) energy transfer

progressive wave .....

.....

stationary wave .....

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(Total 5 marks)

5. The diagram for this question is drawn to scale and 1 mm on the diagram represents an actual distance of 5 mm.

S_1 and S_2 are identical *coherent* transmitters emitting, in phase, microwaves with a wavelength of 25 mm. They are positioned 250mm apart on a horizontal surface and a detector can be placed anywhere along the line YY′ which is in the same plane as the transmitters and parallel to the line containing S_1 and S_2.

(a) Explain what is meant by *coherent.*

.....

.....

(2)

(b) By making measurements on the diagram and using the scale, determine the number of wavelengths in the path

(i) S_1R,

.....

.....

(ii) S_2R.

.....

.....

(iii) Use your answers to (i) and (ii) to determine whether or not you expect the signal received by a detector placed at R to be a maximum. Explain your answer.

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(5)

(c) Describe how you would expect the signal strength to vary as the detector is moved from R to P via Q.

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(2)

(d) Calculate the frequency of the microwaves.

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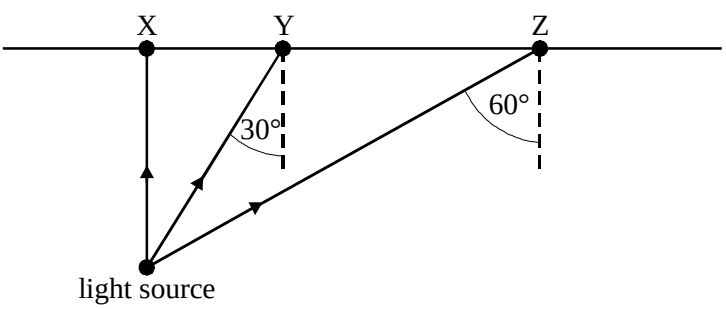
(1)
(Total 10 marks)

6. A small intense light source is 1.5 m below the surface of the water in a large swimming pool, as shown in the diagram.



(i) Complete the paths of rays from the light source which strike the water surface at X, Y and Z.

(ii) Calculate the diameter of the disc through which light emerges from the surface of the water.

speed of light in water = 2.25×10^8 m s^{-1}
speed of light in air = 3.00×10^8 m s^{-1}

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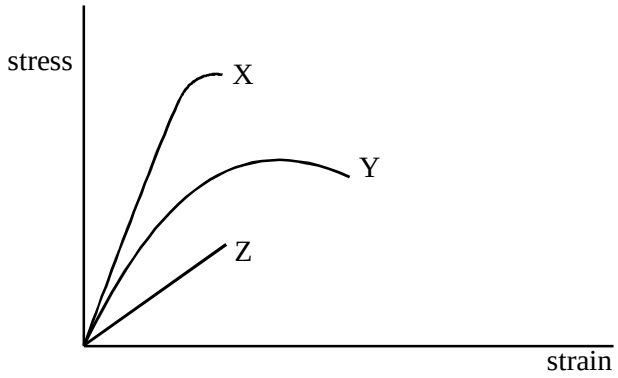
(Total 7 marks)

7. The diagram shows tensile stress-strain curves for three different materials X, Y and Z.



For each material named below, state which curve is typical of the material, giving the reasoning behind your choice.

(a) copper .....

reasoning .....

.....

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.....

(b) glass .....

reasoning .....

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.....

.....

(c) hard steel .....

reasoning .....

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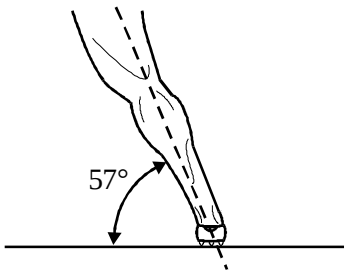
(Total 6 marks)

8. An athlete is analysing his shot putting technique so as to improve his performance. He finds that the optimum performance is achieved when the angle which his leg makes with the ground is 57° immediately before releasing the shot. The maximum force he can exert on the ground is 650 N at an angle of 57° to the ground.



(a) Draw and label arrows on the diagram above to represent

(i) *T*, the force the foot exerts on the ground,

(ii) *N*, the normal reaction of the ground on the foot,

(iii) *F*, the frictional force of the ground on the foot.

(3)

(b) Calculate the magnitude of

(i) the frictional force *F*,

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.....

(ii) the normal reaction of the ground *N*.

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(2)
(Total 5 marks)

9. (a)

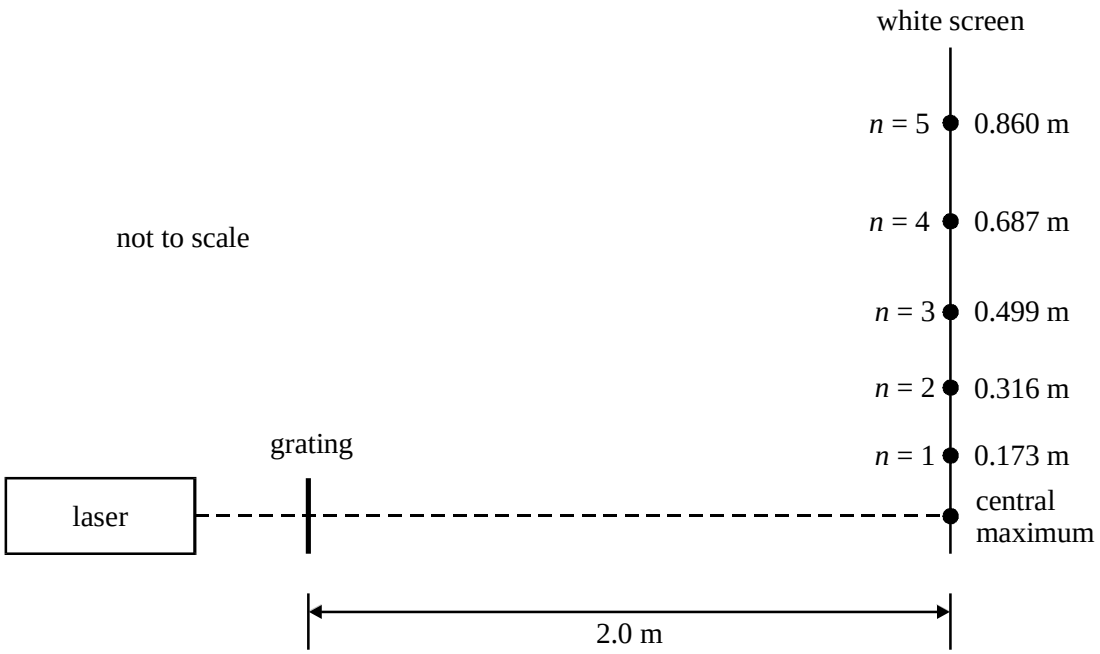

figure 1

In a laboratory experiment, monochromatic light of wavelength 633 nm from a laser is incident normal to a diffraction grating. The diffracted waves are received on a white screen which is parallel to the plane of the grating and 2.0 m from it. Figure 1 shows the positions of the diffraction maxima with distances measured from the central maximum.

By means of a graphical method, use all these measurements to determine a mean value for the number of rulings per unit length of the grating.

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(Allow one sheet of graph paper)

(6)

(b) Describe and explain the effect, if any, on the appearance of the diffraction pattern of

(i) using a grating which has more rulings per unit length,

.....

.....

.....

(ii) using a laser source which has a shorter wavelength,

.....

.....

.....

(iii) increasing the distance between the grating and the screen.

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(6)

(c) Figure 2, below, shows the diffracted waves from four narrow slits of a diffraction grating similar to the one described in part (a). The slit separation
AB = BC = CD = DE = d and EQ is a line drawn at a tangent to several wavefronts and which makes an angle θ with the grating.

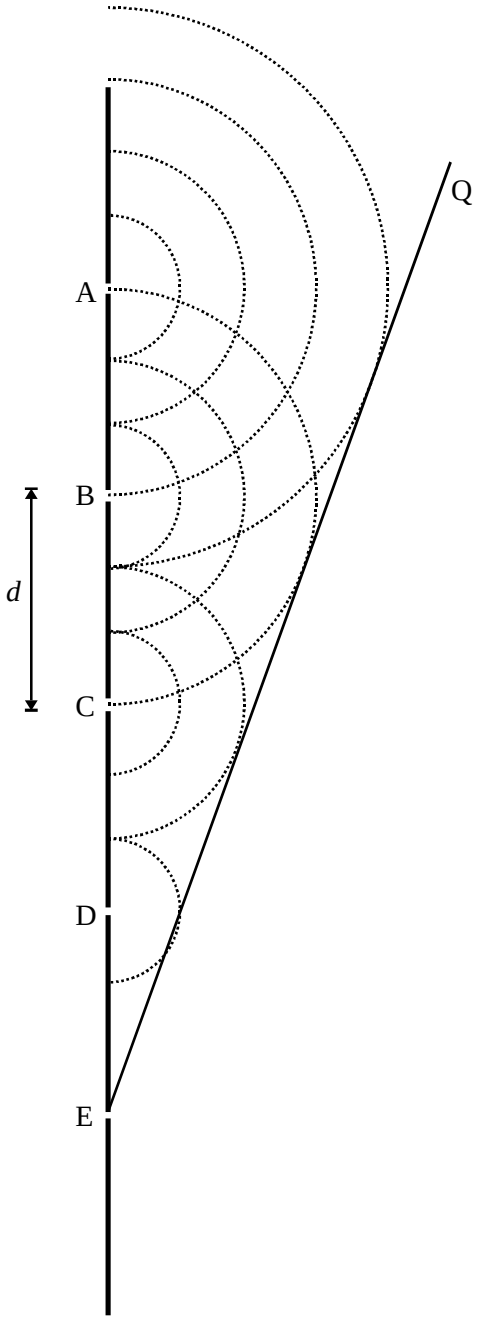

figure 2

(i) Explain why the waves advancing perpendicular to EQ will reinforce if superposed.

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(ii) Show that this will happen when $\sin\theta = \frac{\lambda}{d}$.

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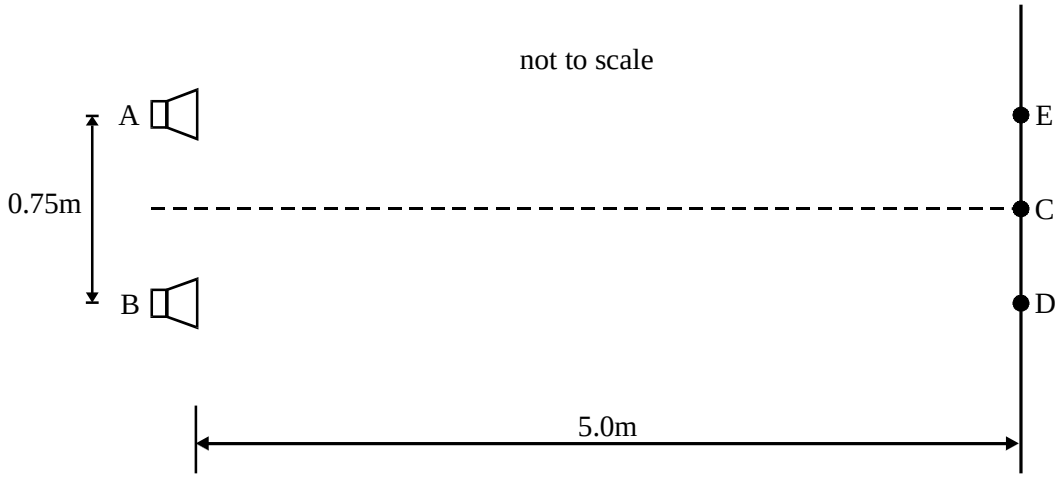
(3)
(Total 15 marks)

10. The diagram shows two identical loudspeakers, A and B, placed 0.75 m apart. Each loudspeaker emits sound of frequency 2000 Hz.



Point C is on a line midway between the speakers and 5.0 m away from the line joining the speakers. A listener at C hears a maximum intensity of sound. If the listener then moves from C to E or D, the sound intensity heard decreases to a minimum. Further movement in the same direction results in the repeated increase and decrease in the sound intensity.
speed of sound in air = 330 m s^{-1}

(a) Explain why the sound intensity

(i) is a maximum at C,

.....

.....

.....

(ii) is a minimum at D or E.

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.....

(4)

(b) Calculate

(i) the wavelength of the sound,

.....

.....

(ii) the distance CE.

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(4)
(Total 8 marks)

11. (a)

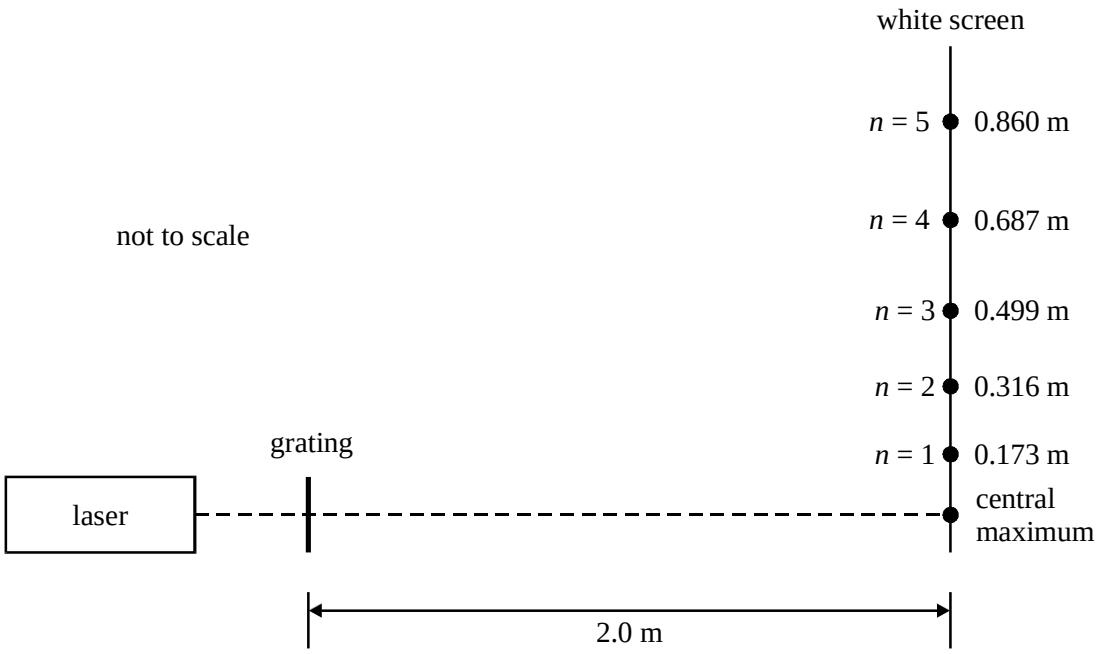

figure 1

In a laboratory experiment, monochromatic light of wavelength 633 nm from a laser is incident normal to a diffraction grating. The diffracted waves are received on a white screen which is parallel to the plane of the grating and 2.0 m from it. Figure 1 shows the positions of the diffraction maxima with distances measured from the central maximum.

By means of a graphical method, use all these measurements to determine a mean value for the number of rulings per unit length of the grating.

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(Allow one sheet of graph paper)

(6)

(b) Describe and explain the effect, if any, on the appearance of the diffraction pattern of

(i) using a grating which has more rulings per unit length,

.....

.....

.....

(ii) using a laser source which has a shorter wavelength,

.....

.....

.....

(iii) increasing the distance between the grating and the screen.

.....

.....

.....

(6)

(c) Figure 2, below, shows the diffracted waves from four narrow slits of a diffraction grating similar to the one described in part (a). The slit separation AB = BC = CD = DE = d and EQ is a line drawn at a tangent to several wavefronts and which makes an angle θ with the grating.

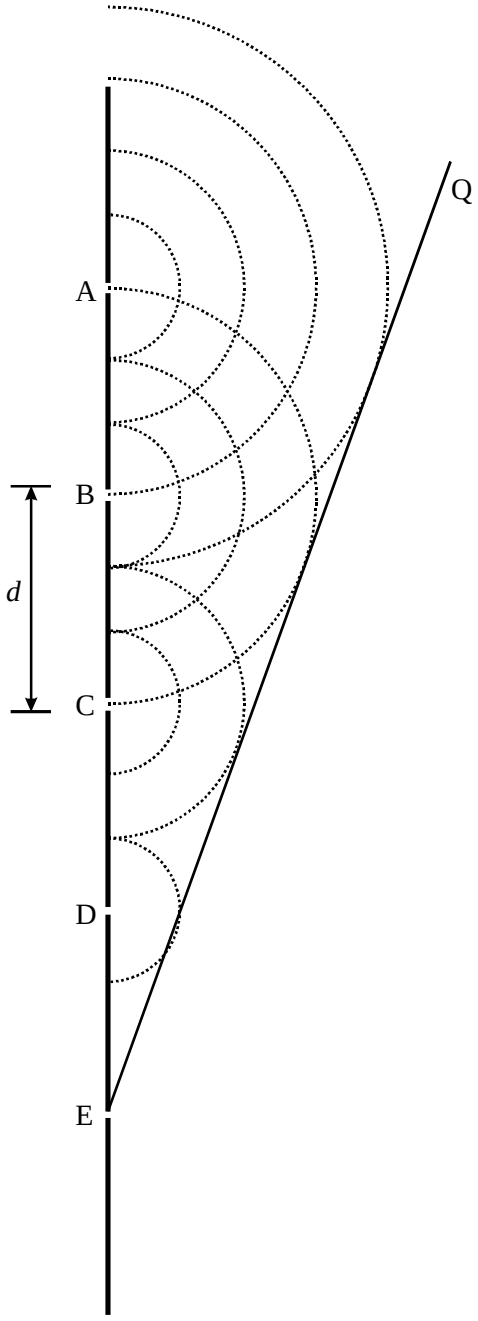

figure 2

(i) Explain why the waves advancing perpendicular to EQ will reinforce if superposed.

.....

.....

.....

(ii) Show that this will happen when $\sin\theta = \frac{\lambda}{d}$.

.....

.....

.....

(3)
(Total 15 marks)

12. (a) Describe an experiment to determine the Young modulus for a material in the form of a wire. Draw a labelled diagram and explain how you would make the necessary measurements. Show how you would use your measurements to calculate the result.

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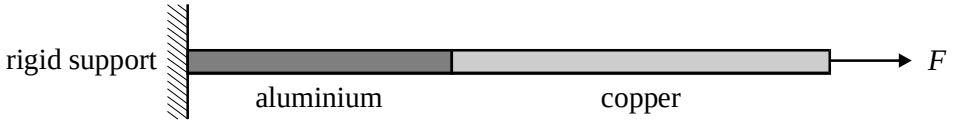
(8)

(b)



A copper wire and an aluminium wire, each of diameter 0.72 mm, are joined end to end as shown in the diagram with the aluminium wire fixed at right angles to a rigid support. A steadily increasing force, *F*, is applied. Use data from the Data Sheet to

(i) explain which wire will yield,

.....

.....

.....

(ii) determine the value of F at which yield should occur.

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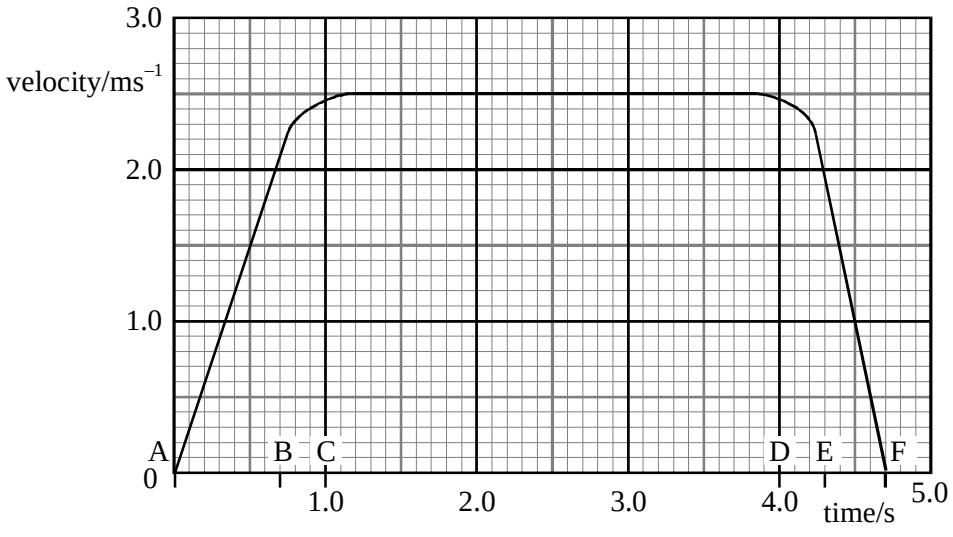
(4)
(Total 12 marks)

13. A mass of 1500kg is attached to a cable and raised vertically by a crane. The graph shows how its velocity varies with time.



(a) Determine

(i) the initial uniform acceleration of the mass, ...

.....

.....

(ii) the distance travelled by the mass while it is accelerating upwards.

.....

.....

.....

(3)

(b) (i) Calculate the tension in the cable in the intervals

AB, ...

.....

.....

.....

CD. .....

.....

(ii) State in which interval of the motion the tension in the cable is least.

.....

(4)

(c) Calculate the power supplied by the crane during the interval CD.

.....

.....

(2)
(Total 9 marks)

14. A cyclist rides along a road up an incline at a steady speed of 9.0 m s^{-1}. The mass of the rider and bicycle is 70kg and the bicycle travels 15 m along the road for every 1.0 m gained in height. Neglect energy loss due to frictional forces.

(a) (i) Calculate the component of the weight of the bicycle and the rider that acts along the incline.

.....

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.....

.....

(ii) Calculate the power developed by the cyclist in riding up the slope.

.....

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.....

(4)

(b) The cyclist stops pedalling and the bicycle freewheels up the incline for a short time.

(i) State the energy change taking place as the bicycle freewheels up the slope.

.....

.....

(ii) Calculate the distance travelled along the slope from when the cyclist stops pedalling to where the bicycle comes to rest.

.....

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.....

(3)
(Total 7 marks)

15. The Thrust SSC car raised the world land speed record in 1997. The mass of the car was 1.0×10^4 kg. A 12s run by the car may be considered in two stages of constant acceleration. Stage one was from 0 to 4.0 s and stage two 4.0 s to 12 s.

(i) In stage one the car accelerates from rest to 44 m s^{-1} in 4.0 s. Calculate the acceleration produced and the force required to accelerate the car.

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(ii) In stage two the car continued to accelerate so that it reached 280 m s^{-1} in a further 8.0 s. Calculate the acceleration of the car during stage two.

.....

.....

(iii) Calculate the distance travelled by the car from rest to reach a speed of 280 m s^{-1}.

.....

.....

(Total 6 marks)

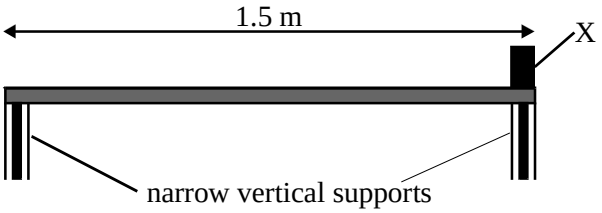
16. (a) State the principle of moments.

.....

.....

(2)

(b) (i) A uniform plank of length 1.5m and mass 9.0kg is placed horizontally on two narrow vertical supports as shown. A block, X, of mass 3.0 kg is placed at the end of the plank immediately above the centre of the right-hand support.



Calculate the magnitude of the downward force on

the right-hand support,.....

.....

.....

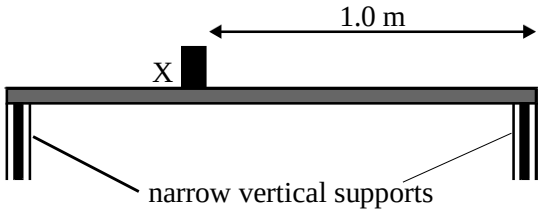
.....

the left-hand support.....

.....

.....

(ii) The block X is now moved so that its centre of mass is immediately above a point 1.0 m from the right hand edge of the plank.



Calculate the magnitude of the downward force on

the right-hand support,.....

.....

.....

.....

.....

the left-hand support.....

.....

.....

(6)
(Total 8 marks)

17. (a) For a sound wave travelling through air, explain what is meant by *particle displacement, amplitude* and *wavelength.*

Particle displacement.....

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amplitude .....

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.....

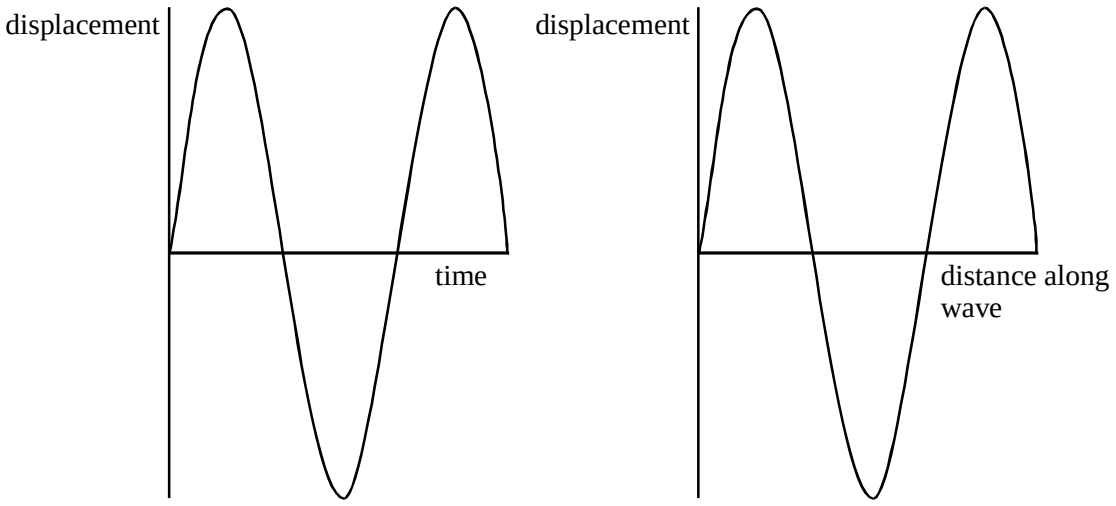
wavelength.....

.....

.....

(4)

(b)



Graph A shows the variation of particle displacement with **time** at a point on the path of a progressive wave of constant amplitude.

Graph B shows the variation of particle displacement with **distance** along the same wave at a particular instant.

(i) Show on graph A

(1) the wave amplitude, *a*,

(2) the period, *T*, of the vibrations providing the wave.

(ii) Show on graph B

(1) the wavelength of the wave, λ,

(2) two points, P and Q, which are always $\pi/2$ out of phase.

(4)
(Total 8 marks)

18. (a) A helium-neon laser produces monochromatic light of wavelength 632.8 nm which falls normally on a diffraction grating. A first order maximum is produced at an angle of 18.5° measured from the normal to the grating.

Calculate

(i) the number of lines per metre on the grating,

.....

.....

.....

(ii) the highest order which is observable.

.....

.....

.....

(6)

(b) When the grating is used with a different monochromatic source, the first order maximum is observed at an angle of 17.2°

Calculate the wavelength of this second source.

.....

.....

.....

(2)
(Total 8 marks)

19. (a) Explain what is meant by *critical angle* and *total internal reflection.*

.....

.....

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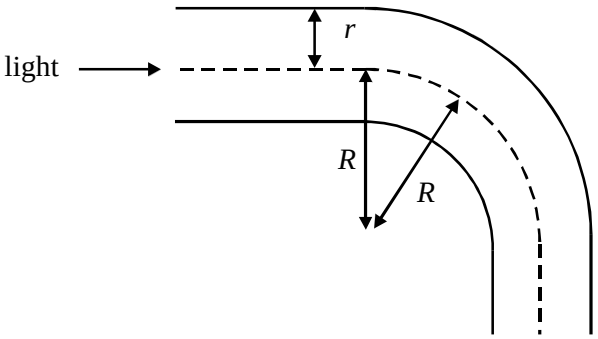
.....

.....

(3)

(b) The diagram shows a cylindrical optical fibre, of radius *r*, bent into an arc of radius *R*. A ray of light entering along the axis strikes the internal surface of the fibre at an angle of incidence θ and is internally reflected.



Draw the angle θ on the diagram and hence show that

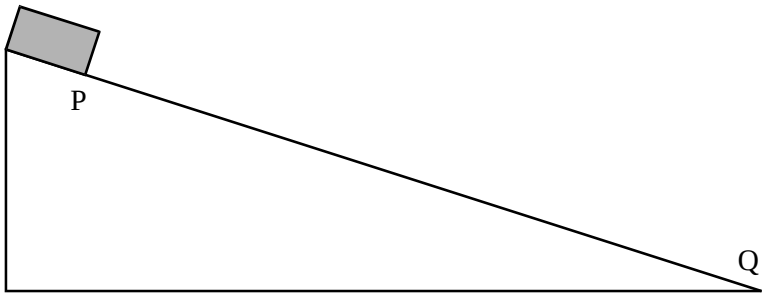
$$\sin\theta = \frac{R}{R+r}.$$

.....

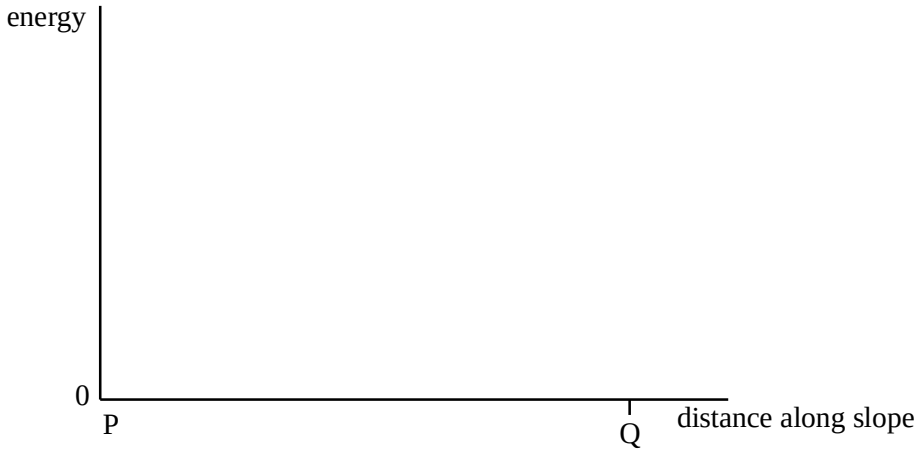
.....

(2)
(Total 5 marks)

20. (a) The diagram shows an object at rest at the top of a straight slope which makes a fixed angle with the horizontal.



(i) The object is released and slides down the slope from P to Q with negligible friction. Assume that the potential energy is zero at Q. Sketch a graph showing the potential energy at different distances measured along the slope, and label it A. On the same set of axes, sketch a second graph showing the kinetic energy of the object at different distances along the slope and label it B.



(ii) Using the same axes as in part (i), sketch a third graph, labelled C, showing the kinetic energy at different distances along the slope when there is a constant frictional force between the object and the surface.

(iii) Use your knowledge of the principle of conservation of energy to explain the important features of the graphs you have drawn in part (i) and part (ii).

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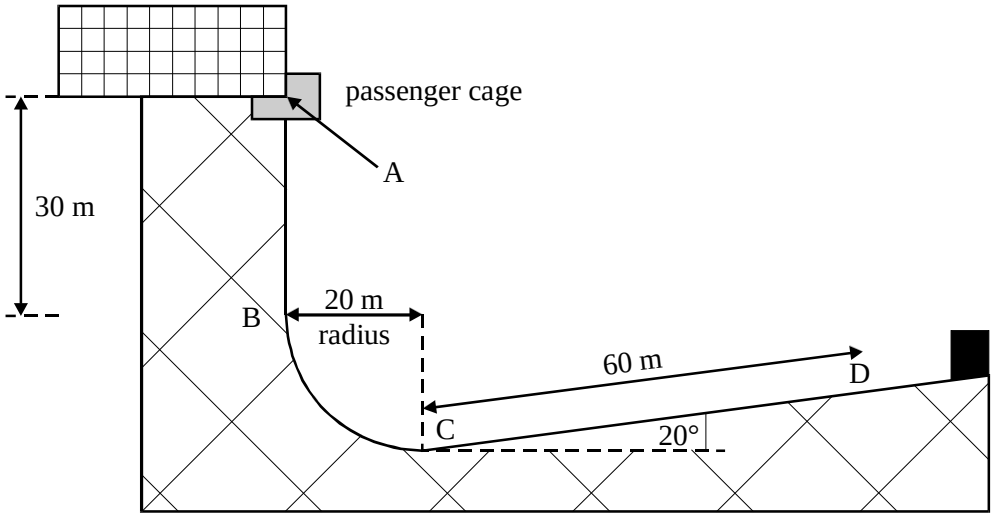
(6)

(b) In a theme park ride, a cage containing passengers falls freely a distance of 30 m from A to B and travels in a circular arc of radius 20m from B to C. Assume that friction is negligible between A and C. Brakes are applied at C after which the cage with its passengers travels 60m along an upward sloping ramp and comes to rest at D. The track, together with relevant distances, is shown in the diagram. CD makes an angle of 20° with the horizontal



(i) Calculate the speed of the cage at C

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(ii) Calculate the force required on a passenger of mass 80 kg for circular motion at C and state the direction of this force.

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(iii) If the mass of the cage and passengers is 620 kg, determine the gain in gravitational potential energy in travelling from C to D.

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(iv) Calculate the average resistive force exerted by the brakes between C and D

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.....

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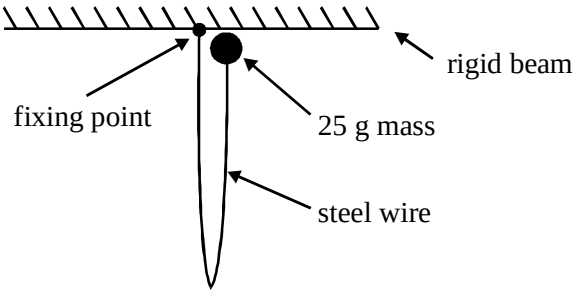
(9)
(Total 15 marks)

21. One end of a steel wire of length 1.2 m and 2.0 mm diameter is attached to a rigid beam.
A 25 g mass is attached to the free end of the steel wire and placed against the underside of the beam as shown.



The 25 g mass is released and falls freely until the wire becomes taut. The kinetic energy of the falling mass is converted to elastic potential energy in the wire as the wire extends to a maximum of 1.0 mm. Energy converted to other forms is negligible.

For **maximum** extension of the wire, complete parts (i) to (v).

(i) Show that the elastic potential energy stored by the extended wire is 0.29 J.

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.....

(ii) Calculate the tension in the wire.

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.....

(iii) Calculate the stress in the wire.

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(iv) Calculate the strain of the wire.

.....

.....

(v) Hence, calculate the Young modulus for the steel of the wire.

.....

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(Total 9 marks)

22. (a) A double slit interference experiment is set up in a laboratory using a source of yellow monochromatic light of wavelength 5.86×10^{-7}m. The separation of the two **vertical** parallel slits is 0.36 mm and the distance from the slits to the plane where the fringes are observed is 1.80 m.

(i) Describe the appearance of the fringes.

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(ii) Calculate the fringe separation, and also the angle between the middle of the central fringe and the middle of the second bright fringe.

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(iii) Explain why more fringes will be seen if each of the slits is made narrower, assuming that no other changes are made.

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(8)

(b) Light of wavelength 5.86×10^{-7} m falls at right angles on a diffraction grating which has 400 lines per mm.

(i) Calculate the angle between the straight through image and the first order image.

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.....

(ii) Determine the highest order image which can be seen with this arrangement.

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(5)

(c) Give **two** reasons why the diffraction grating arrangement is more suitable for the accurate measurement of the wavelength of light than the two-slit interference arrangement.

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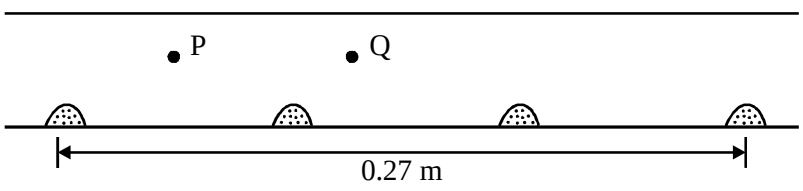
(2)
(Total 15 marks)

23. Stationary waves in air can be demonstrated using a long horizontal tube which contains fine powder. With a loudspeaker connected to a signal generator positioned at one end of the tube, stationary waves are formed by reflection of waves from the ends of the tube. The diagram shows part of the tube in such an arrangement. The powder forms heaps at nodes.

Speed of sound waves in air = 340 m s^{-1}



(a) Determine

(i) the wavelength of the waves,

.....

(ii) the frequency of vibration of the loudspeaker.

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.....

(2)

(b) Distinguish between longitudinal waves and transverse waves and state which type of wave is being generated in the tube.

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(3)

(c) P and Q are two points in the tube. Compare the motion of air particles at P with the motion of air particles at Q with reference to

(i) frequency,

.....

.....

(ii) amplitude,

.....

.....

(iii) phase.

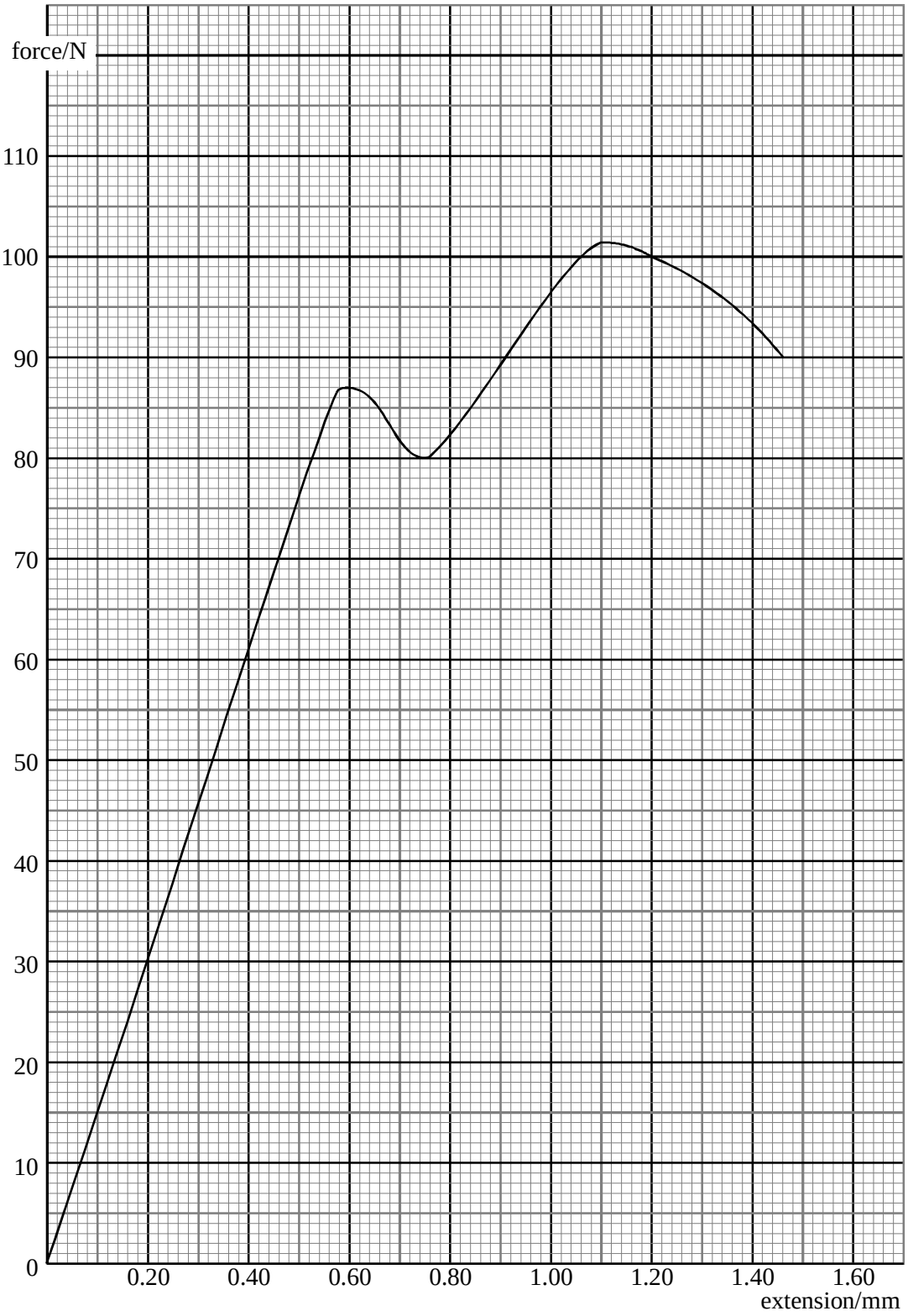
.....

.....

(3)

(Total 8 marks)

24. A student carries out an experiment to investigate how the extension of a steel wire varies with an increasing tensile force. The results of the experiment are shown plotted on the graph. The initial length of the wire is 0.50m and its diameter is 0.80 mm. The wire breaks at an extension of 1.46 mm.



Use information from the graph to determine

the Young modulus for the material,

.....

.....

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.....

.....

an estimate of the yield stress for the material.

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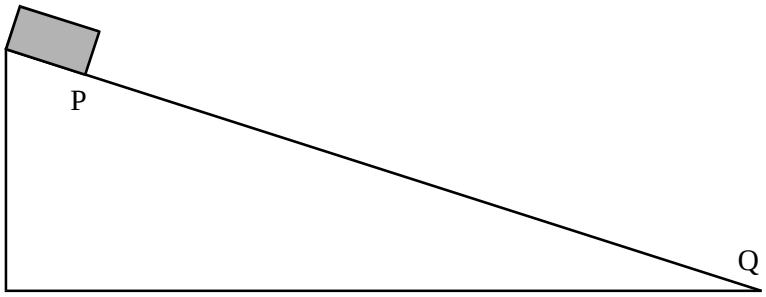
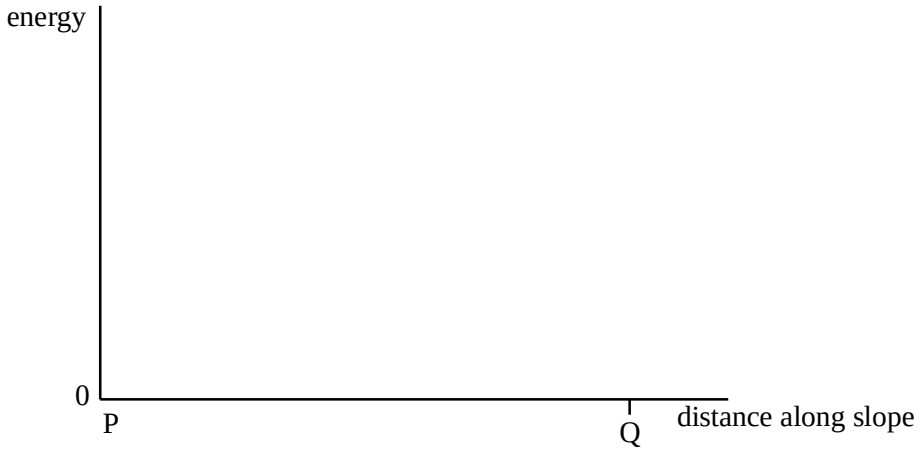
(Total 6 marks)

25. (a) The diagram shows an object at rest at the top of a straight slope which makes a fixed angle with the horizontal.



(i) The object is released and slides down the slope from P to Q with negligible friction. Assume that the potential energy is zero at Q. Sketch a graph shelving the potential energy at different distances measured along the slope, and label it A. On the same set of axes, sketch a second graph showing the kinetic energy of the object at different distances along the slope and label it B.



(ii) Using the same axes as in part (i) sketch a third graph, labelled C, showing the kinetic energy at different distances along the slope when there is a constant frictional force between the object and the surface.

(iii) Use your knowledge of the principle of conservation of energy to explain the important features of the graphs you have drawn in part (i) and part (ii).

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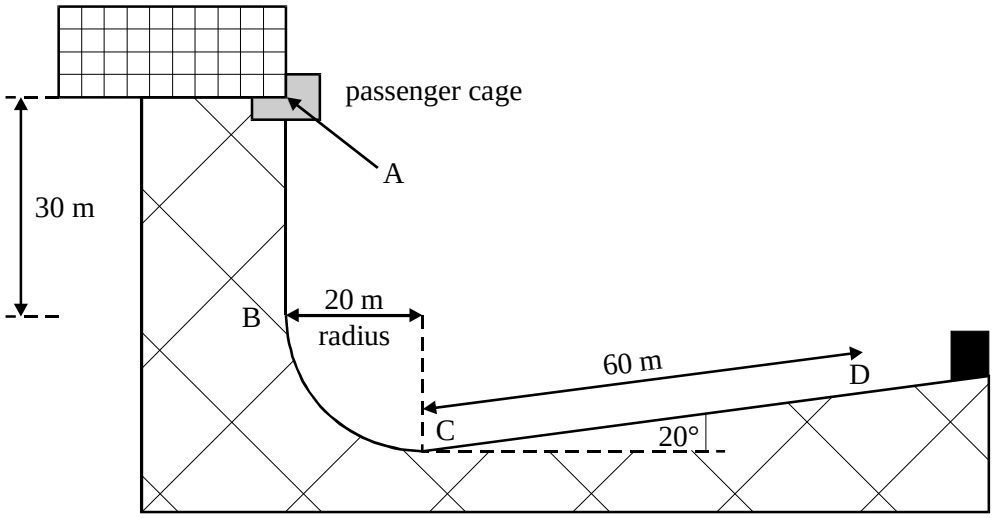
.....

(6)

(b) In a theme park ride, a cage containing passengers falls freely a distance of 30 m from A to B and travels in a circular arc of radius 20 m from B to C. Assume that friction is negligible between A and C. Brakes are applied at C after which the cage with its passengers travels 60 m along an upward sloping ramp and comes to rest at D. The track, together with relevant distances, is shown in the diagram. CD makes an angle of 20° with the horizontal.



(i) Calculate the speed of the cage at C.

.....

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.....

(ii) Calculate the force required on a passenger of mass 80 kg for circular motion at C and state the direction of this force.

.....

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(iii) If the mass of the cage and passengers is 620 kg, determine the gain in gravitational potential energy in travelling from C to D.

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(iv) Calculate the average resistive force exerted by the brakes between C and D.

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(9)
(Total 15 marks)

26. (a) A double slit interference experiment is set up in a laboratory using a source of yellow monochromatic light of wavelength 5.86×10^{-7} m. The separation of the two **vertical** parallel slits is 0.36 mm and the distance from the slits to the plane where the fringes are observed is 1.80 m.

(i) Describe the appearance of the fringes.

.....

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.....

(ii) Calculate the fringe separation, and also the angle between the middle of the central fringe and the middle of the second bright fringe.

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(iii) Explain why more fringes will be seen if each of the slits is made narrower, assuming that no other changes are made.

.....

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(8)

(b) Light of wavelength 5.86×10^{-7} Tim falls at right angles on a diffraction grating which has 400 lines per mm.

(i) Calculate the angle between the straight through image and the first order image.

.....

.....

.....

(ii) Determine the highest order image which can be seen with this arrangement.

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(5)

(c) Give **two** reasons why the diffraction grating arrangement is more suitable for the accurate measurement of the wavelength of light than the two-slit interference arrangement.

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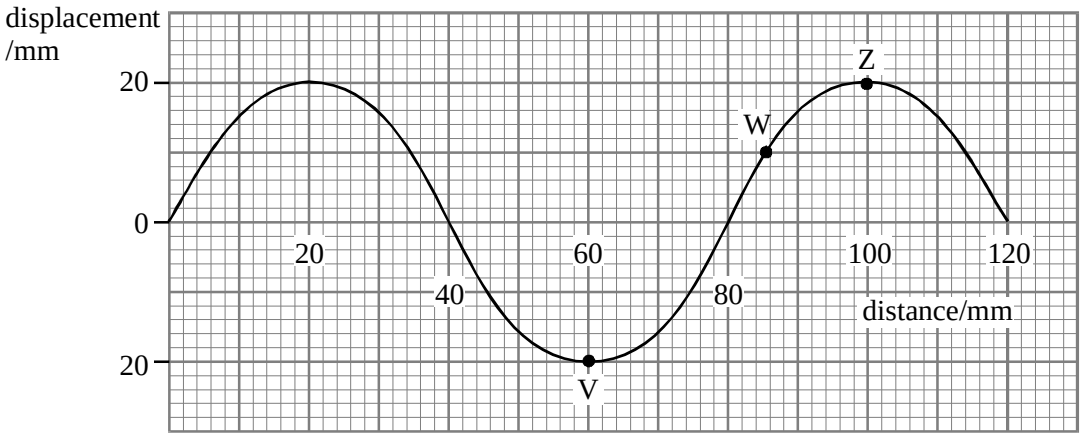
(2)

(Total 15 marks)

27. The graph shows the variation of displacement of the particles with distance along a stationary transverse wave at time $t = 0$ when the displacement of the particles is greatest. The period of the vibrations causing the wave is 0.040 s.



(a) Using the same axes,

(i) draw the appearance of the wave at $t = 0.010$ s, labelling this graph B,

(ii) draw the appearance of the wave at $t = 0.020$ s, labelling this graph C,

(iii) show an antinode labelled A and a node labelled N.

(3)

(b) (i) Describe the motion of the particle at V, giving its frequency and amplitude.

.....

.....

(ii) State the amplitude of the particle at W and its phase relations with the particle at V and the particle at Z.

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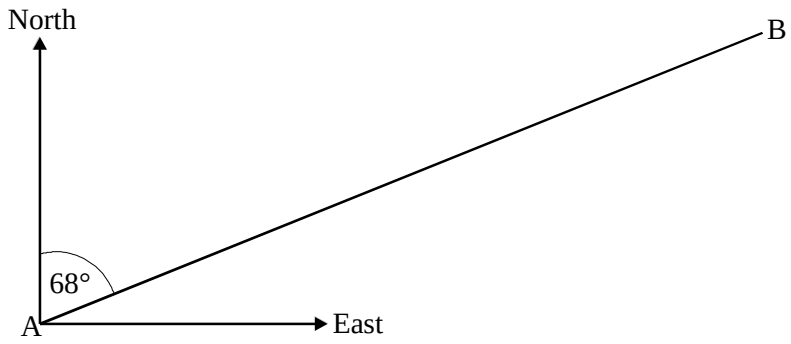
(6)

(Total 9 marks)

28. A microlight is a small aircraft powered by a petrol engine. The diagram represents the flight path, AB, of a microlight on a short horizontal training flight.



(a) On its outward journey, the wind velocity is 7.5 m s^{-1} due North and the resultant velocity of the microlight is 20 m s^{-1} in a direction 68 East of North, so that it travels along AB.

(i) Show that for the aircraft to travel along AB at 20 m s^{-1} it should be pointed due East.

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(ii) The driving force of the aircraft engine is 2.0×10^3 N. Calculate the work done by the engine if the aircraft travels 10 km on its outward journey.

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.....

(iii) Calculate the output power of the aircraft engine for the outward journey.

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(6)

(b) After flying 10 km, the aircraft turns round and returns along the same flight path at a resultant velocity of 14 m s^{-1}. Assuming that the turn-round time is negligible, calculate the average speed for the complete journey.

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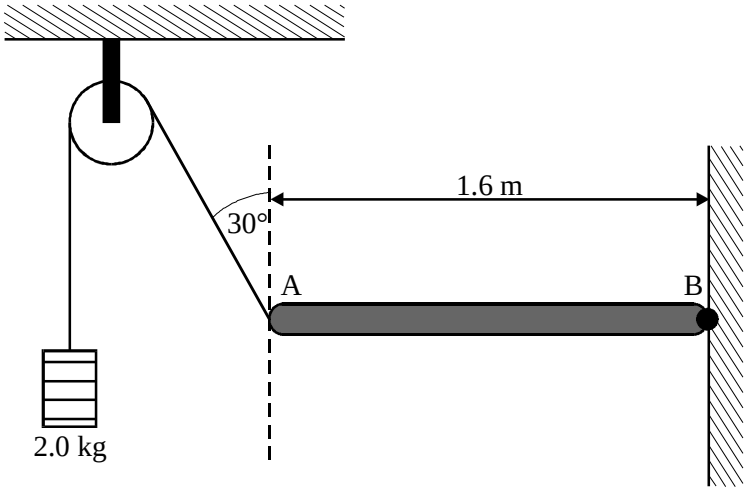
(2)
(Total 8 marks)

29. The diagram shows a uniform bar, AB, which is 1.6 m long and freely pivoted to a wall at B. The bar is maintained horizontal and in equilibrium by an angled string which passes over a pulley and which carries a mass of 2.0 kg at its free end.



(a) The pulley is positioned as shown in the diagram, with the string at 30° to the vertical.

(i) Calculate the tension, *T*, in the string.

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.....

(ii) Show that the mass of the bar is approximately 3.5 kg.

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.....

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(4)

(b) A mass, M, is attached to the bar at a point 0.40 m from A. The pulley is moved horizontally to change the angle made by the string to the vertical, and to maintain the rod horizontal and in equilibrium.
Determine the largest value of the mass, M, for which this equilibrium can be maintained.

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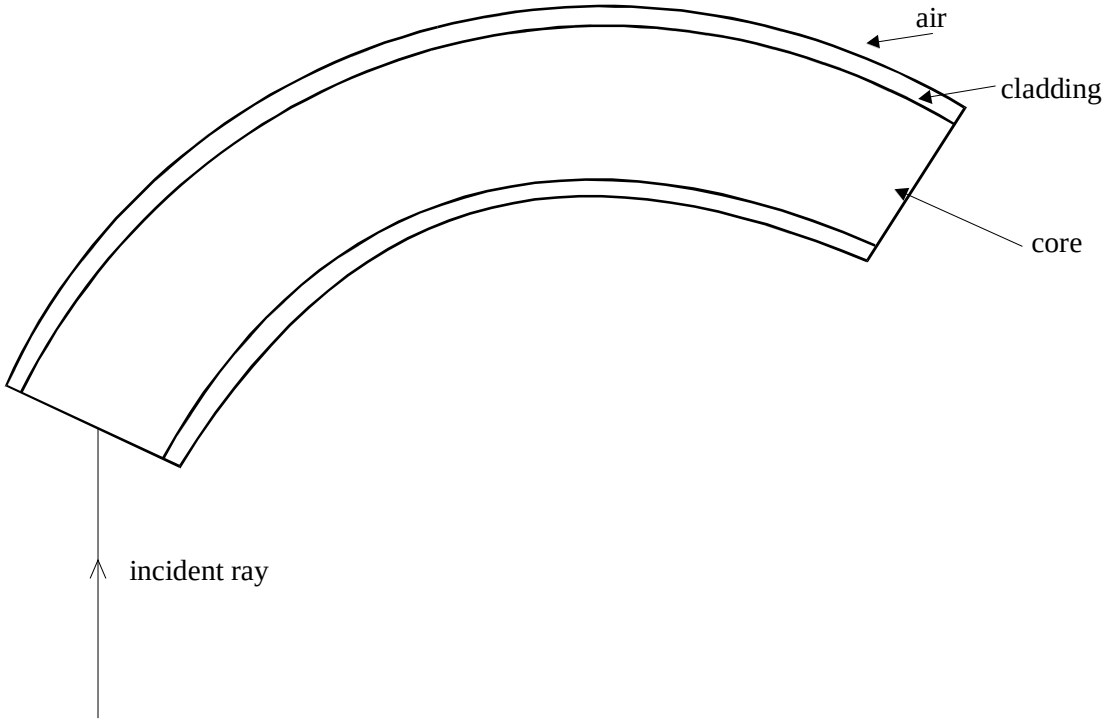
(4)
(Total 8 marks)

30. (a) The diagram shows a 'step index' optical fibre. A ray of monochromatic light, in the plane of the paper, is incident in air on the end face of the optical fibre as shown in the diagram.



(i) Draw on the diagram the complete path followed by the ray until it emerges at the far end.

(ii) Name the process which occurs as the ray enters the end of the optical fibre.

.....

(iii) The core has a refractive index of 1.50, clad in a material of refractive index 1.45. Calculate the critical angle of incidence at the core-cladding interface.

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(7)

(b) (i) Give **one** reason why a cladding material is used in an optical fibre.

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(ii) In part (a)(iii), the cladding material has a refractive index of 1.45. Explain why it would be advantageous to use cladding material of refractive index less than 1.45.

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(3)

(c) State **one** use of optical fibres.

.....

(1)
(Total 11 marks)

31. (a) State the condition necessary for the equilibrium of three coplanar forces acting at a point.

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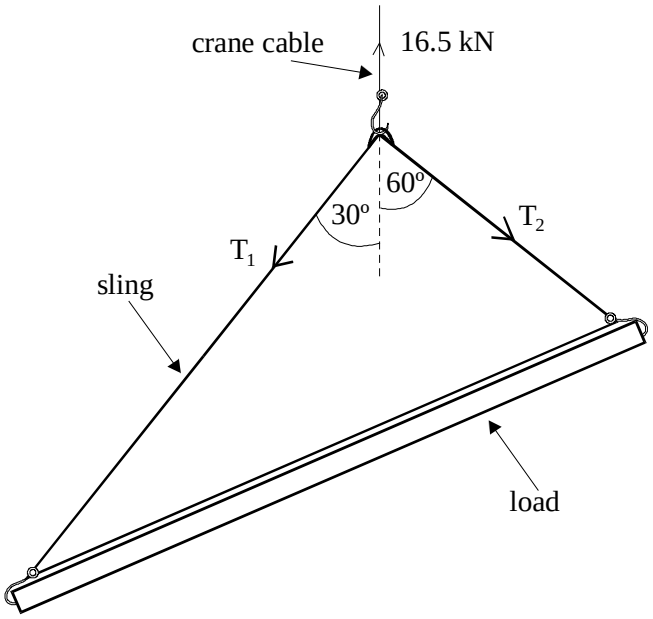
.....

(1)

(b) The diagram shows a crane hook in equilibrium under the action of a vertical force of 16.5 kN in the crane cable and tension forces T_1 and T_2 in the sling.



Find the tension forces T_1 and T_2 acting in the sling. You may **either** calculate these forces **or** find them by scale drawing. In either case you should show your method clearly.

.....

.....

T_1 = ...

.....

.....

T_2 = ...

(4)
(Total 5 marks)

32. (a) (i) Define the moment exerted by a force F about a point P. You may draw a diagram if you wish,

.....

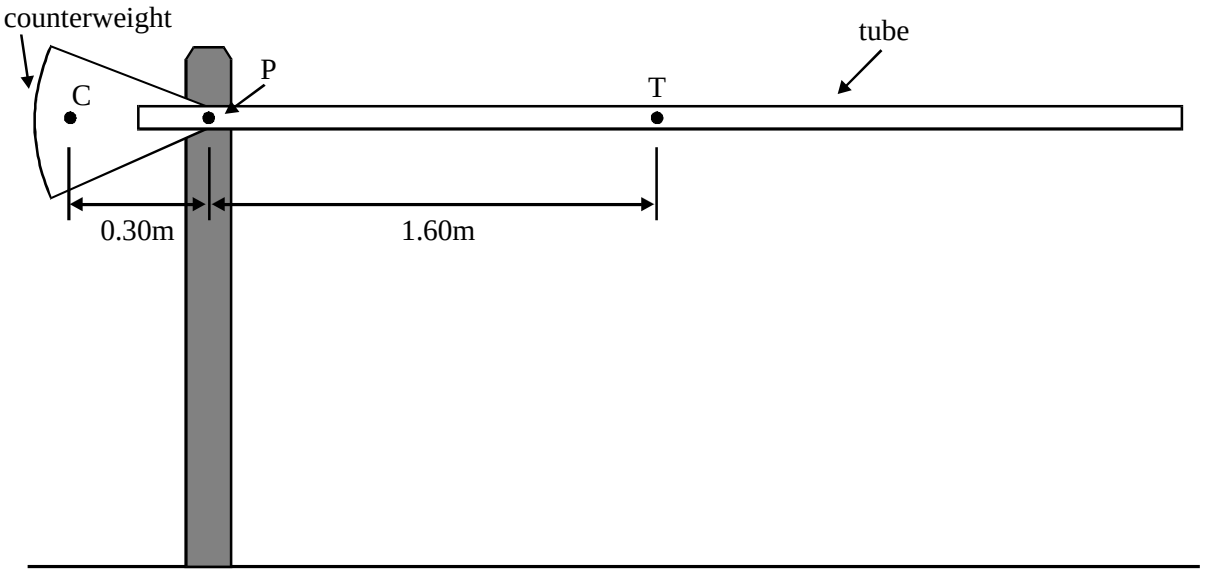
.....

.....

(ii) State the unit of moment .....

(3)

(b) The long arm of the car-park barrier shown in the diagram is a tube of mass 12.0 kg which is free to rotate about a fixed pivot P near one end. A counterweight is attached firmly to one end of the tube so that the barrier is in equilibrium with its long arm horizontal. Points C and T on the diagram show the locations of the centre of mass of the counterweight and tube, respectively.



(i) Draw on the diagram the lines of action and directions of all the forces acting on the tube and counterweight.

(ii) Calculate the weight of the tube.

.....

(iii) Calculate the mass of the counterweight.

.....

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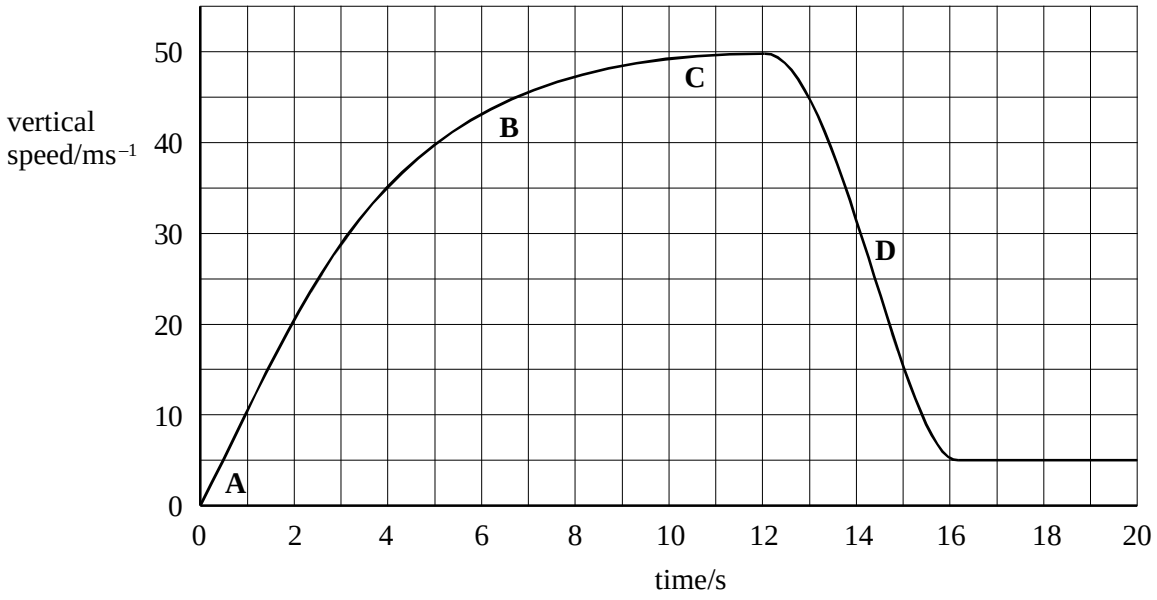
(5)
(Total 8 marks)

33. The graph shows how the vertical speed of a parachutist changes with time during the first 20 s of his jump. To avoid air turbulence caused by the aircraft, he waits a short time after jumping before pulling the cord to release his parachute.



(a) Regions A, B and C of the graph show the speed before the parachute has opened. With reference to the forces acting on the parachutist, explain why the graph has this shape in the region marked

(i) A, ...

.....

.....

.....

(ii) B, ...

.....

.....

(iii) C. .....

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.....

(6)

(b) Calculate the maximum deceleration of the parachutist in the region of the graph marked D, which shows how the speed changes just after the parachute has opened. Show your method clearly,

.....

.....

.....

(2)

(c) Use the graph to find the total vertical distance fallen by the parachutist in the first 10 s of the jump. Show your method clearly.

.....

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.....

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(4)

(d) During his descent, the parachutist drifts sideways in the wind and hits the ground with a vertical speed of 5.0 m s^{-1} and a horizontal speed of 3.0 m s^{-1}. Find

(i) the resultant speed with which he hits the ground,

.....

.....

.....

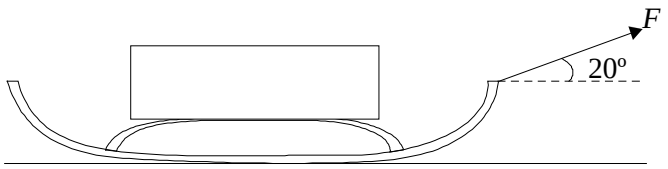
(ii) the angle his resultant velocity makes with the vertical.

.....

.....

(2)
(Total 14 marks)

34. A heavy sledge is pulled across snowfields. The diagram shows the direction of the force *F* exerted on the sledge. Once the sledge is moving, the average horizontal force needed to keep it moving at a steady speed over level ground is 300 N.



(a) Calculate the force *F* needed to produce a horizontal component of 300 N on the sledge.

.....

.....

(1)

(b) (i) Explain why the work done in pulling the sledge **cannot** be calculated by multiplying *F* by the distance the sledge is pulled.

.....

.....

.....

(ii) Calculate the work done in pulling the sledge a distance of 8.0 km over level ground.

.....

.....

(iii) Calculate the average power used to pull the sledge 8.0 km in 5.0 hours.

.....

.....

.....

(6)

(c) The same average power is maintained when pulling the sledge uphill. Explain **in terms of energy transformations** why it would take longer than 5.0 hours to cover 8.0 km uphill.

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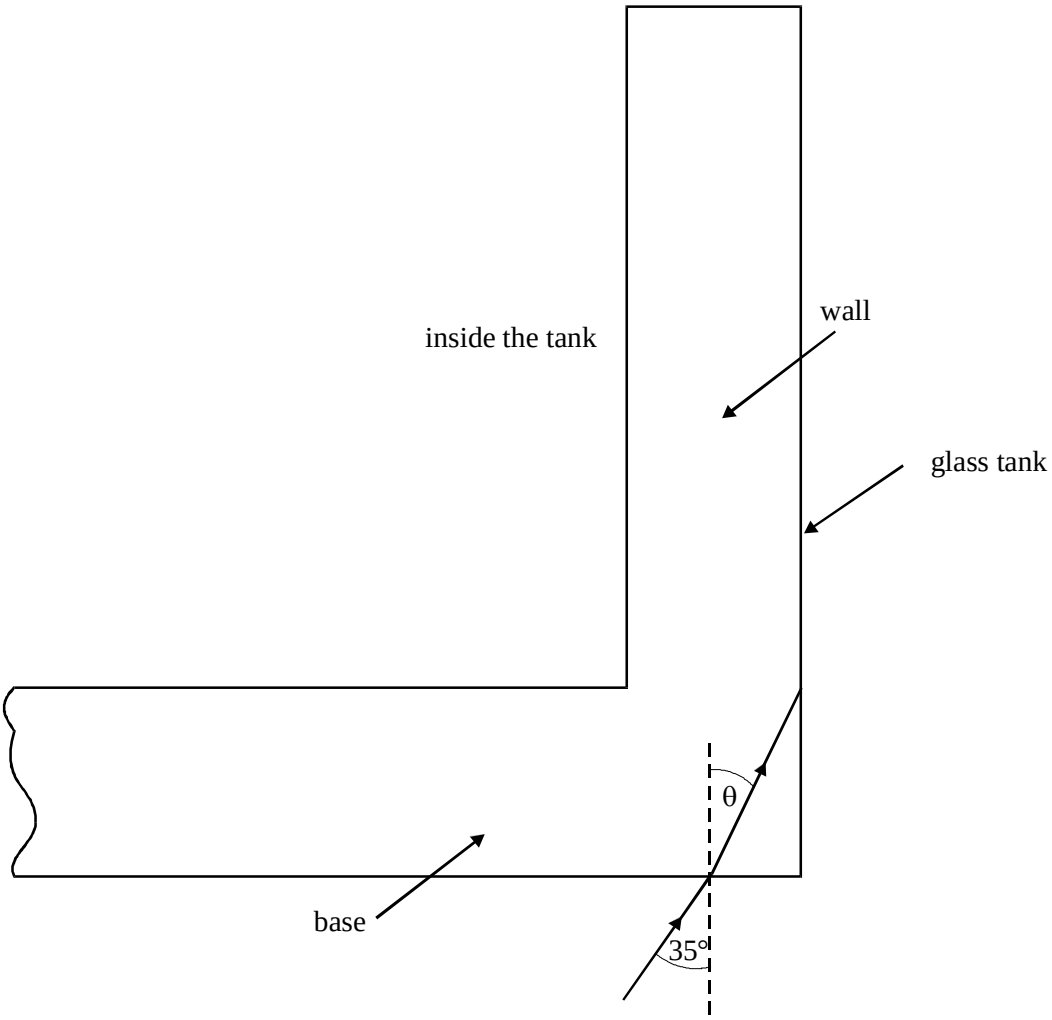
(3)

(Total 10 marks)

35. The diagram shows a cross-section of one wall and part of the base of an empty fish tank, viewed from the side. It is made from glass of refractive index 1.5. A ray of light travelling in air is incident on the base at an angle of 35° as shown.



(a) Calculate the angle θ.

.....

.....

.....

.....

(2)

(b) (i) Calculate the critical angle for the glass-air interface.

.....

.....

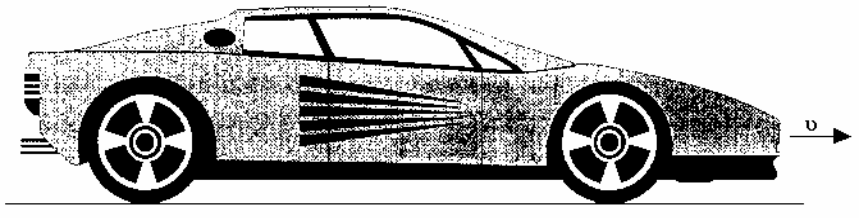
.....

(ii) Hence, draw on the diagram the continuation of the path of the ray through the glass wall and out into the air. Mark in the values of all angles of incidence, refraction and reflection.

(6)

(Total 8 marks)

36. The diagram shows a car travelling at a constant velocity along a horizontal road.



(a) (i) Draw and label arrows on the diagram representing the forces acting on the car.

(ii) Referring to Newton's Laws of motion, explain why the car is travelling at constant velocity.

.....

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.....

.....

(5)

(b) The car has an effective power output of 18 kW and is travelling at a constant velocity of 10 m s^{-1}. Show that the total resistive force acting is 1800 N.

.....

.....

.....

(1)

(c) The total resistive force consists of two components. One of these is a constant frictional force of 250 N and the other is the force of air resistance, which is proportional to the square of the car's speed.

Calculate

(i) the force of air resistance when the car is travelling at 10 m s^{-1},

.....

.....

(ii) the force of air resistance when the car is travelling at 20 m s^{-1},

.....

.....

(iii) the effective output power of the car required to maintain a constant speed of 20 m s^{-1} in a horizontal road.

.....

.....

.....

(4)
(Total 10 marks)

37. (a) The torque of a couple is given by

torque = Fs.

(i) With the aid of a diagram explain what is meant by a couple. Label F and s on your diagram.

.....

.....

.....

.....

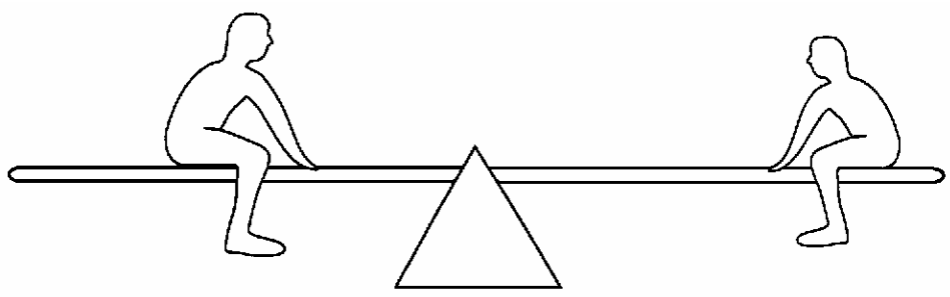
.....

(ii) State the unit for the torque of a couple.

.....

(4)

(b) The see-saw shown in the diagram consists of a uniform beam freely pivoted at the centre of the beam. Two children sit opposite each other so that the see-saw is in equilibrium.



Explain why

(i) the see-saw is in equilibrium,

.....

.....

.....

.....

(ii) the weight of the beam does not affect equilibrium.

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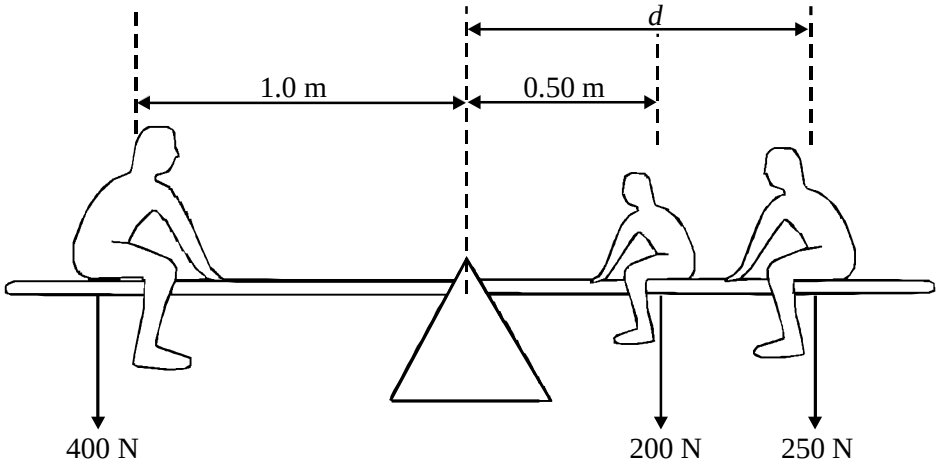
.....

.....

(3)

(c) The diagram shows the see-saw with three children of weights 400N, 250N and 200N sitting so that the see-saw is in equilibrium.



Calculate the distance, *d*.

.....

.....

.....

.....

(2)

(Total 9 marks)

38. Athlete A, competing in a 100 m race, crosses the finish line in a time of 10.2 s. At the start, the athlete accelerates uniformly to a top speed in 2.0 s and then remains at a constant speed for the remainder of the race.

(a) Calculate

(i) the average speed of the athlete over the full distance,

.....

.....

(ii) the maximum speed of the athlete if the acceleration were 5.4 m s^{-2},

.....

.....

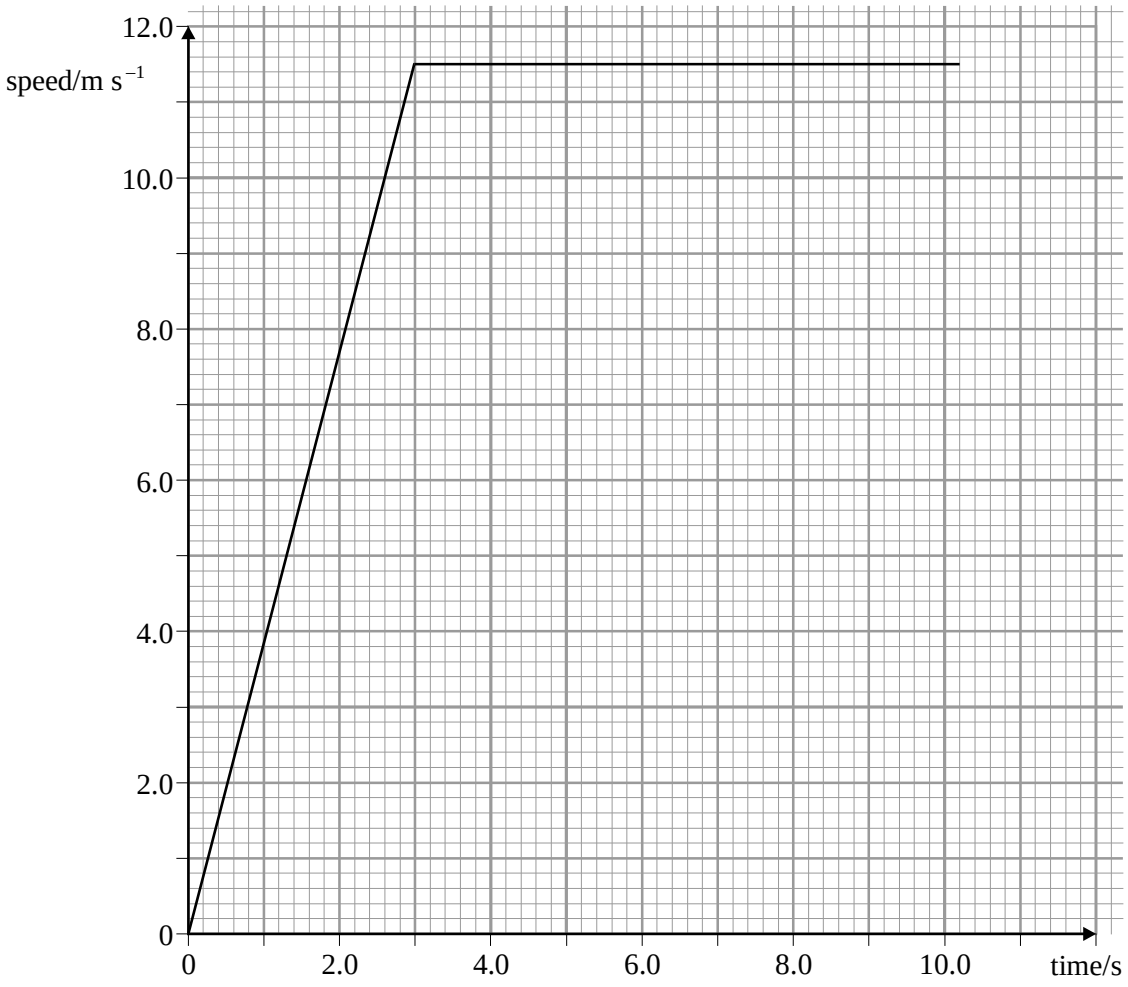
(iii) the distance travelled by the athlete whilst accelerating.

.....

.....

(4)

(b) The graph is a speed time graph for athlete B in the same race.



Using the **same** axes, draw a speed time graph for athlete A.

(3)

(c) Some time after the start of the race the two athletes are running at the same speed. Use your graph to determine

(i) the time at which this occurs,

.....

(ii) the distance covered by the athletes up to this time,

Athlete A: .....

.....

Athlete B: .....

.....

(iii) how far apart the athletes are at this time.

.....

(4)
(Total 11 marks)

39. (a) When determining the Young modulus for the material of a wire, a *tensile stress* is applied to the wire and the *tensile strain* produced is measured.

(i) State the meaning of

tensile stress .....

.....

tensile strain .....

.....

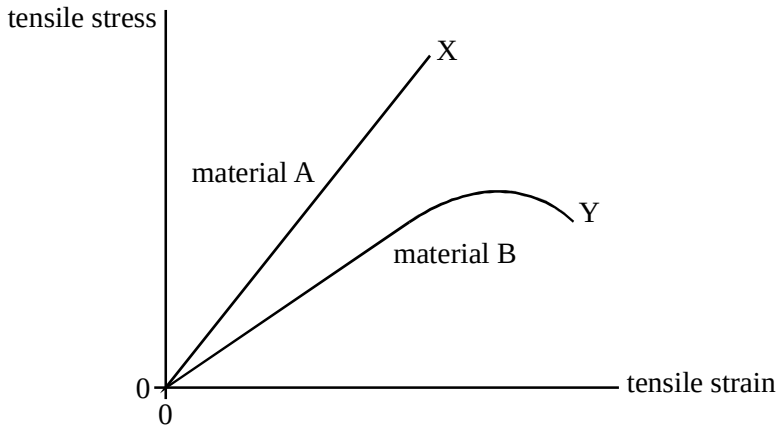
(ii) Define the Young modulus.

.....

.....

(3)

(b) The graph represents tensile stress-tensile strain curves for two different materials A and B. X and Y are the respective points at which each material fractures.



(i) One of the materials is brittle, the other ductile. State which material is brittle.

.....

(ii) Making use of the curves in the graph, describe the behaviour of each material as it is stretched from its original state to breaking point.

material A .....

.....

material B .....

.....

(iii) State, giving a reason, which material has the greater value of the Young modulus.

.....

.....

(5)

(c) A vertical steel piano wire of length 1.5 m and cross-sectional area 1.3×10^{-6} m^2 supports a load of 80N.

Given that the Young modulus for steel = 2.10×10^{11} Pa, calculate the extension in the wire produced by this load.

.....

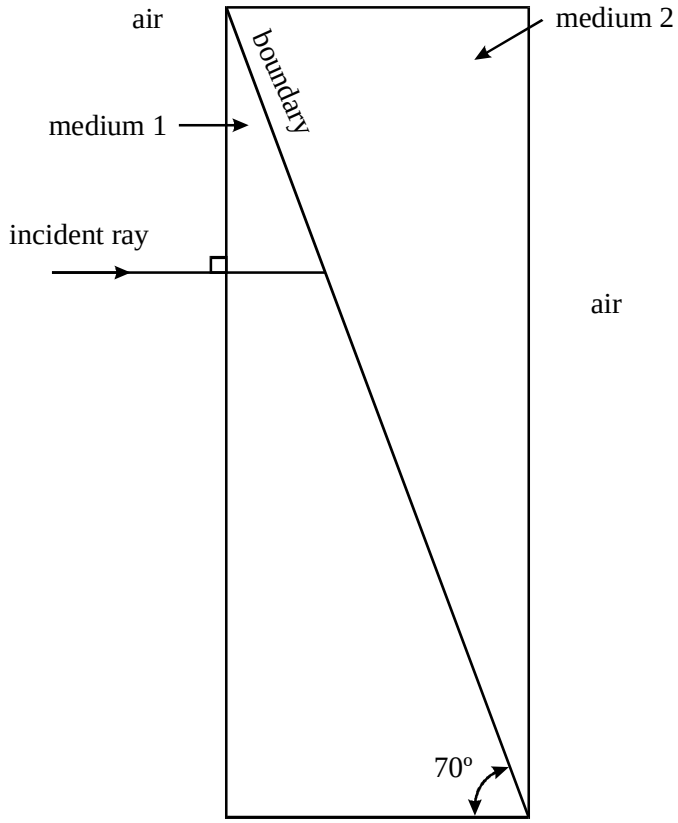
.....

.....

(2)

(Total 10 marks)

40. Two prisms made from different glass are placed in perfect contact to form a rectangular block surrounded by air as shown. Medium 1 has a smaller refractive index than medium 2.



(a) A ray of light in air is incident normally on medium 1 as shown. At the boundary between medium 1 and medium 2 some light is transmitted and the remainder reflected.

(i) Sketch, without calculation, the path followed by the refracted ray as it enters medium 2 and then emerges into the air.

(ii) Sketch, without calculation, the path followed by the reflected ray showing it emerging from medium 1 into the air.

(4)

(b) The refractive index of medium 1 is 1.40 and that of medium 2 is 1.60.

(i) Give the angle of incidence at the boundary between medium 1 and medium 2.

.....

(ii) Calculate the angle of refraction at this boundary.

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.....

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.....

(4)

(c) Calculate the critical angle for a ray passing from medium 2 into the air.

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.....

.....

(2)
(Total 10 marks)

41. (a) (i) Define acceleration.

.....

(ii) State why acceleration is a vector quantity.

.....

.....

(2)

(b) State what feature of a velocity-time graph may be used to calculate

(i) acceleration,

.....

(ii) displacement.

.....

(2)

(c) The graph in **Figure 1** shows how the displacement of a runner from a fixed point, along a straight track, varies with time.

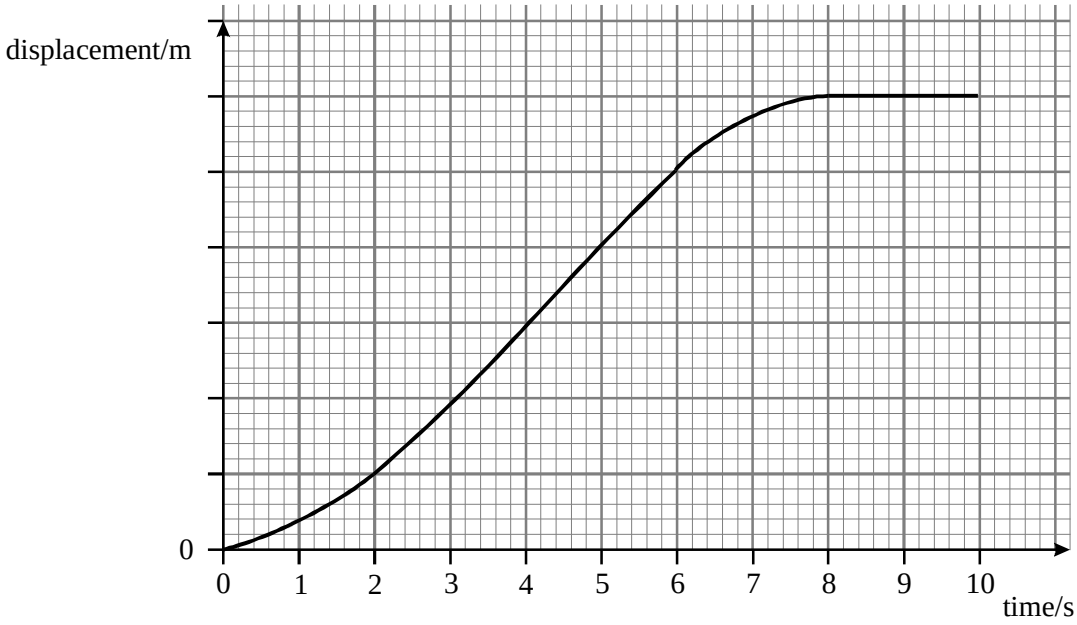


Figure 1

Without calculation, sketch on the grid in **Figure 2** a graph to show how the velocity of the same runner varies over the same period. The time scales are the same on both graphs.

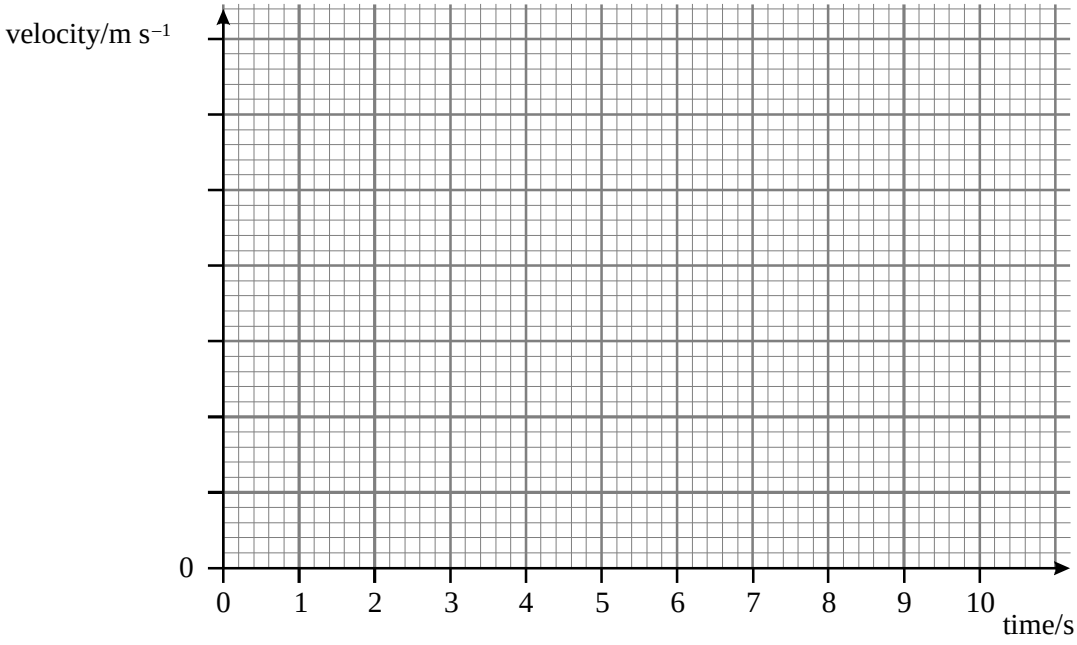
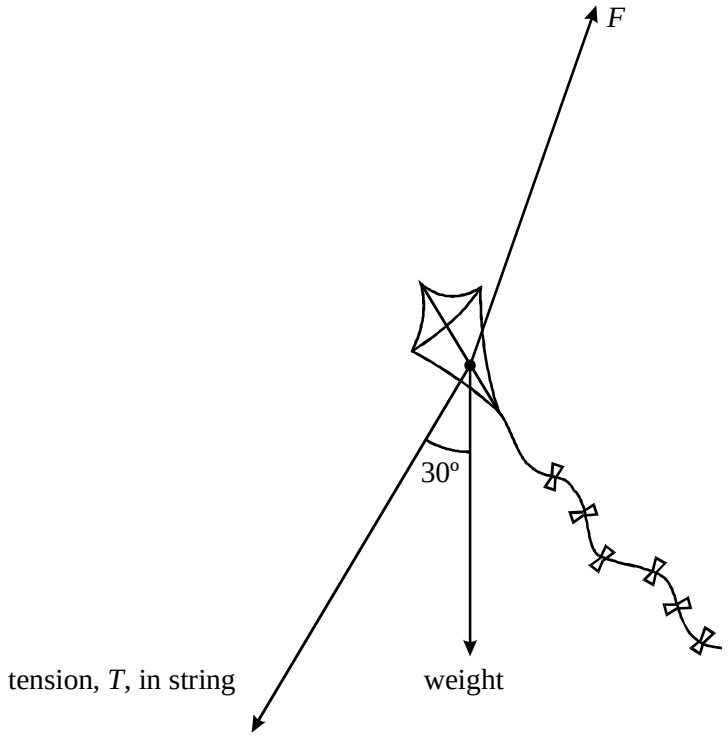


Figure 2

(4)
(Total 8 marks)

42. The diagram shows the forces acting on a stationary kite. The force *F* is the force that the air exerts on the kite.



(a) Show on the diagram how force *F* can be resolved into horizontal and vertical components.

(2)

(b) The magnitude of the tension, *T*, is 25 N.
Calculate

(i) the horizontal component of the tension,

.....

(ii) the vertical component of the tension.

.....

(2)

(c) (i) Calculate the magnitude of the vertical component of *F* when the weight of the kite is 2.5 N.

.....

(ii) State the magnitude of the horizontal component of *F*.

.....

(iii) Hence calculate the magnitude of F.

.....

.....

(4)
(Total 8 marks)

43. (a) State the principle of moments.

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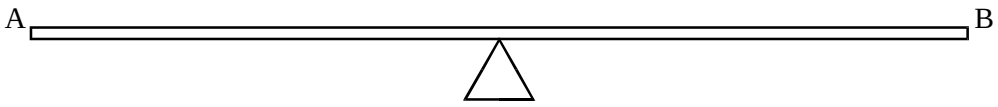
(2)

(b) The diagram shows a uniform metre ruler, AB, freely pivoted at its centre of mass.



Explain what is meant by the centre of mass.

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.....

(1)

(c) A 1.0 N weight is placed on the ruler 0.30 m from the middle of the ruler towards A.

(i) Explain which way the pivot must be moved in order for equilibrium to be restored.

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(ii) Calculate the distance the pivot needs to be moved to restore equilibrium when the weight of the ruler is 0.50 N.

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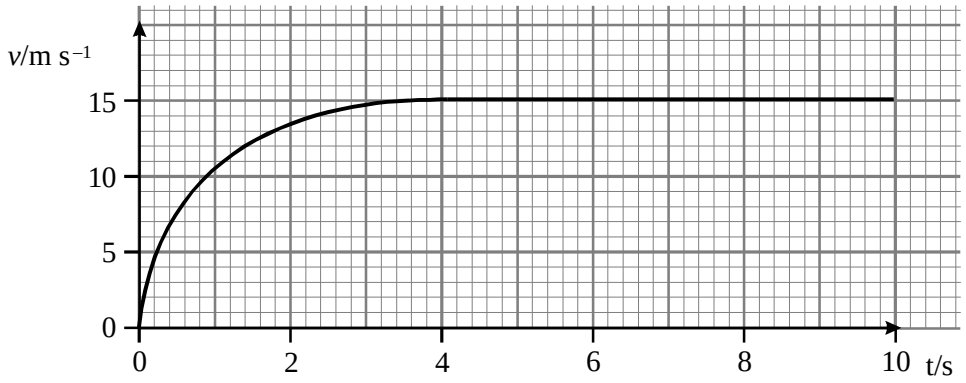
(5)
(Total 8 marks)

44. The graph represents the motion of a car of mass 1.4×10^3 kg, travelling in a straight line.



(a) Describe, without calculation, how the *resultant* force acting on the car varies over this 10 second interval.

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(2)

(b) Calculate the maximum kinetic energy of the car.

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(2)

(c) At some time later, when the car is travelling at a steady speed of 30 m s^{-1}, the useful power developed by the engine is 20 kW. Calculate the driving force required to maintain this speed.

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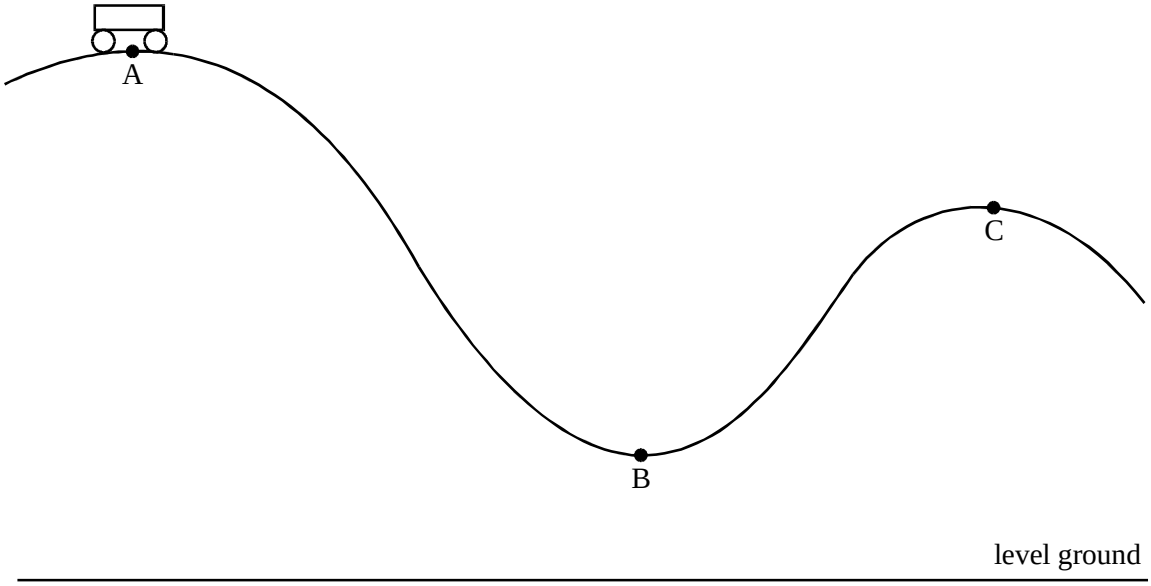
(2)
Total 6 marks)

45. The figure shows the track of a funfair ride.



Carriages are pulled up to the highest point, A, of the ride and then released so that they follow the path ABC.

(a) Point A is 18 m above the ground and point C is 12 m above the ground. Show that the maximum possible speed of the carriage at C is 11 m s^{-1}.

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(3)

(b) The actual speed at C is less than 11 m s^{-1}. Describe the energy changes that take place as the carriage moves from A to B to C.

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(4)

(Total 7 marks)

46. (a) A cricketer throws a ball vertically upwards so that the ball leaves his hands at a speed of 25 m s^{-1}. If air resistance can be neglected, calculate

(i) the maximum height reached by the ball,

.....

.....

(ii) the time taken to reach maximum height,

.....

.....

(iii) the speed of the ball when it is at 50% of the maximum height.

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(4)

(b) When catching the ball, the cricketer moves his hands for a short distance in the direction of travel of the ball as it makes contact with his hands. Explain why this technique results in less force being exerted on the cricketer's hands.

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(2)
(Total 6 marks)

47. (a) (i) Draw and label suitable apparatus required for measuring the Young modulus of a material in the form of a long wire.

(ii) List the measurements you would make when using the apparatus described in part (i).

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(iii) Describe briefly how the measurements listed in part (ii) would be carried out.

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(iv) Explain how you would calculate the Young modulus from your measurements.

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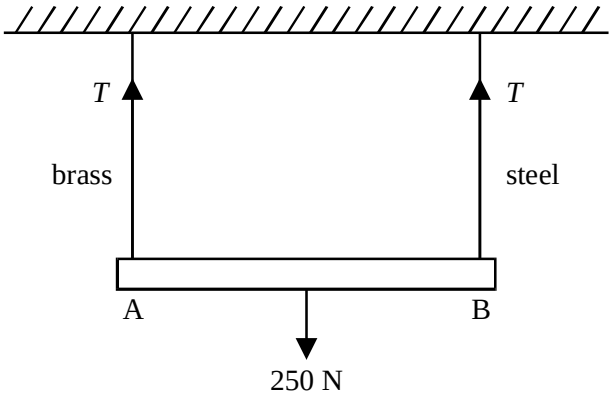
(13)

(b) A uniform heavy metal bar of weight 250 N is suspended by two vertical wires, supported at their upper ends from a horizontal surface, as shown.



One wire is made of brass and the other of steel. The cross-sectional area of each wire is 2.5×10^{-7} m^2 and the unstretched length of each wire is 2.0 m.

the Young modulus for brass = 1.0×10^{11} Pa
the Young modulus for steel = 2.0×10^{11} Pa

(i) If the tension, *T*, in each wire is 125 N, calculate the extension of the steel wire.

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(ii) Estimate how much lower the end A will be than the end B.

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(3)
(Total 16 marks)

48.

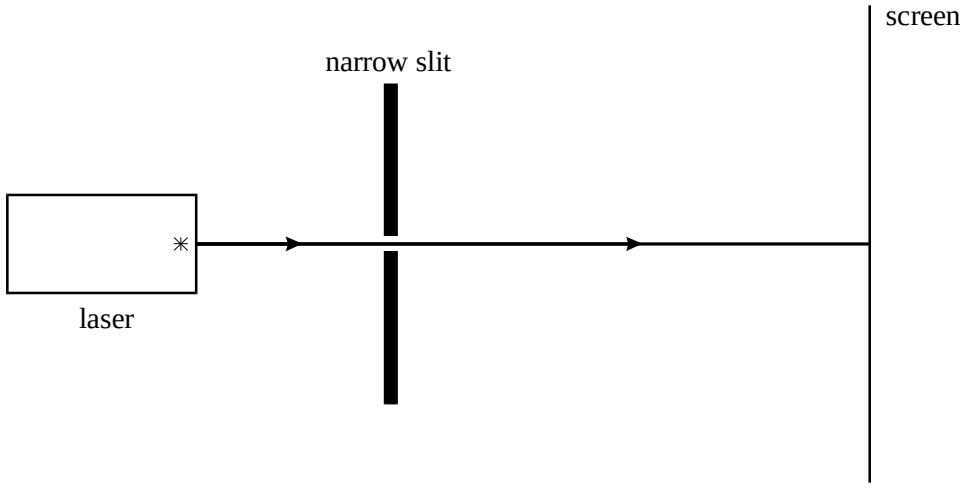

Figure 1

Red light from a laser is passed through a single narrow slit, as shown in **Figure 1**. A pattern of bright and dark regions can be observed on the screen which is placed several metres beyond the slit.

(a) The pattern on the screen may be represented as a graph of intensity against distance along the screen. The graph has been started in outline in **Figure 2.** The central bright region is already shown. Complete this graph to represent the rest of the pattern by drawing on **Figure 2**.

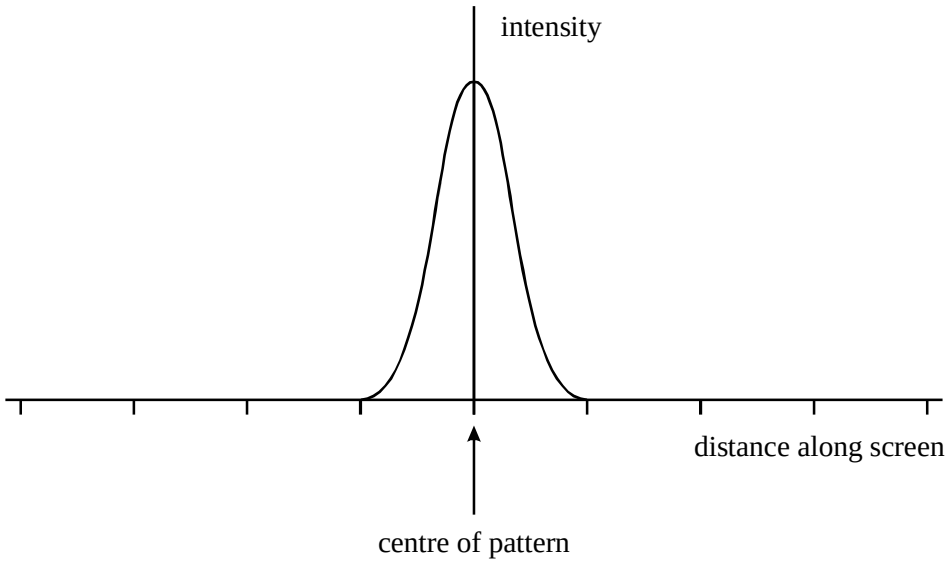

Figure 2

(4)

(b) State the effect on the pattern if each of the following changes is made separately.

(i) The width of the narrow slit is reduced.

.....

.....

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(ii) With the original slit width, the intense red source is replaced with an intense source of green light.

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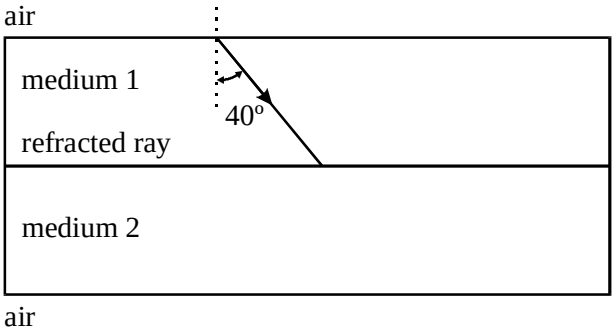
.....

(3)
(Total 7 marks)

49. A glass plate surrounded by air is made up of two parallel sided sheets of glass in perfect contact as shown in the figure. Medium 1, the top sheet of glass, has a smaller refractive index than medium 2.



(a) A ray of light in air is incident on the top sheet of glass and is refracted at an angle of 40° as shown in the figure. At the boundary between medium 1 and medium 2 some light is transmitted and the remainder reflected.

On the figure, sketch without calculation, the following:

(i) the path followed by the transmitted ray showing it entering from the air at the top and emerging into the air at the bottom;

(ii) the path followed by the reflected ray showing it emerging from medium 1 into the air.

(4)

(b) The refractive index of medium 1 is 1.35 and that of medium 2 is 1.65.

(i) Calculate the angle of incidence where the ray enters medium 1 from the air.

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(ii) Calculate the angle of refraction at the boundary between medium 1 and medium 2.

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(5)

(c) Total internal reflection will not occur for any ray incident in medium 1 at the boundary with medium 2.

Explain, without calculation, why this statement is true.

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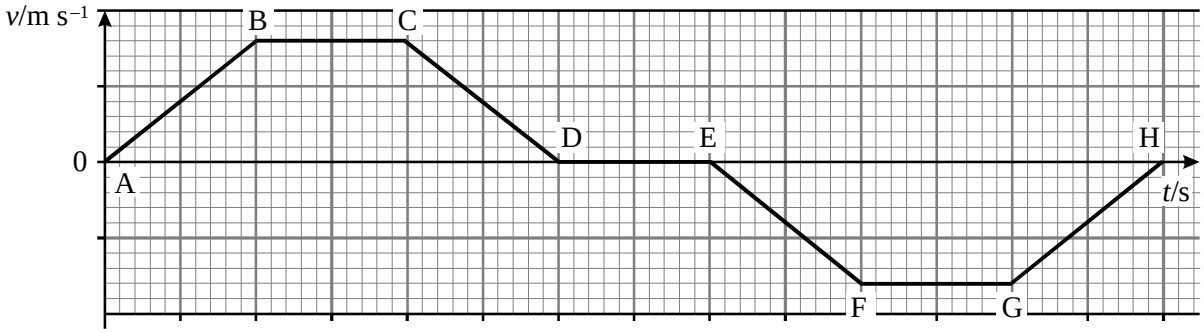
(1)

(Total 10 marks)

50. The graph below shows how the velocity of a toy train moving in a straight line varies over a period of time.



(a) Describe the motion of the train in the following regions of the graph.

AB .....

BC .....

CD .....

DE.....

EF .....

(5)

(b) What feature of the graph represents the displacement of the train?

.....

.....

(1)

(c) Explain, with reference to the graph, why the distance travelled by the train is different from its displacement.

.....

.....

.....

(2)

(Total 8 marks)

51. A car accelerates at a steady rate of 2.5 m s^{-2} along a straight, level road. The mass of the car is 1.3×10^3 kg.

(a) Calculate the magnitude of the resultant force acting on the car.

.....

.....

(2)

(b) When the accelerating car reaches a speed of 2.2 m s^{-1}, the total force opposing the motion of the car is 410 N.

Calculate

(i) the driving force provided by the wheels,

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.....

(ii) the power delivered to the wheels of the car.

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(3)

(c) Explain how the total force opposing the motion of the car is affected when it is travelling up a hill.

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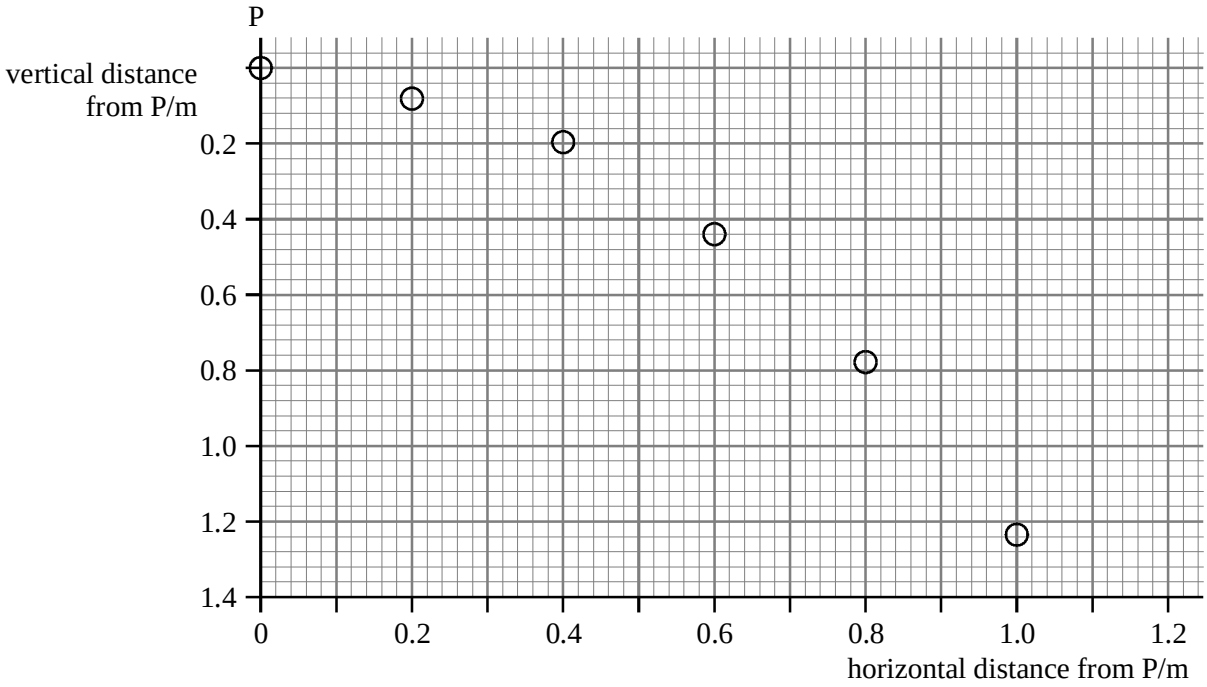
(1)
(Total 6 marks)

52. The graph shows how the position of a steel ball which has been projected horizontally from P changes with time. The position of the ball is shown at constant time intervals.



(a) Explain how the horizontal motion of the ball shows that air resistance is negligible.

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(2)

(b) Explain the vertical motion of the ball.

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(2)

(c) If air resistance were not negligible, describe how this would affect

(i) the horizontal motion of the ball,

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(ii) the vertical motion of the ball.

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(3)
(Total 7 marks)

53. (a) (i) Define the Young modulus for a material.

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.....

(ii) Explain what is meant by the *elastic limit* for a wire.

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.....

(2)

(b) A wire supported at its upper end, hangs vertically. The table shows readings obtained when stretching the wire by suspending masses from its lower end.

load/N	0	2.0	4.0	6.0	7.0	8.0	9.0	10.0	10.5
extension/mm	0	1.2	2.4	3.6	4.2	4.9	5.7	7.0	8.0

(i) Plot a graph of load against extension.

(Allow one sheet of graph paper)

(ii) Indicate on your graph the region where Hooke's law is obeyed.

(iii) The unstretched length of the wire is 1.6m and the area of cross-section 8.0×10^{-8} m^2. Calculate the value of the Young modulus of the material.

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(8)

(c) (i) By considering the work done in stretching a wire, show that the energy stored is given by $\frac{1}{2}Fe$, where F is the force producing an extension e.

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(ii) Calculate the energy stored in the wire in part (b) when the extension is 4.0 mm.

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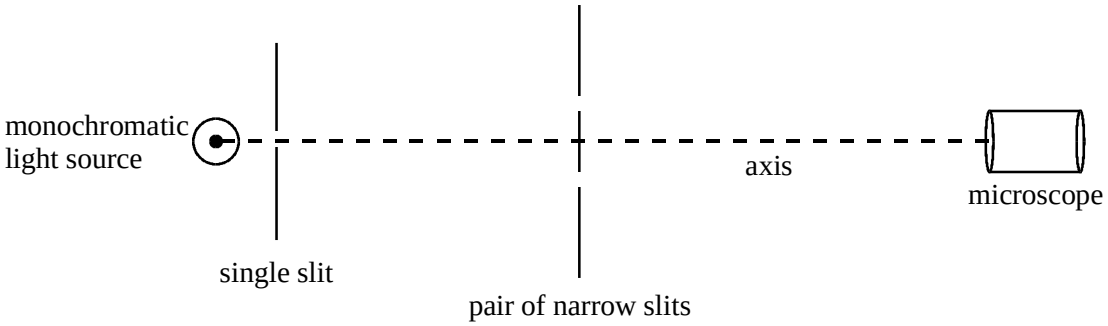
(4)
(Total 14 marks)

54. The diagram shows two closely spaced narrow slits illuminated by light from a single slit in front of a monochromatic light source. A microscope is used to view the pattern of bright and dark fringes formed by light from the two slits.



(a) (i) Explain qualitatively why these fringes are formed.

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(ii) Describe what is observed if one of the narrow slits is covered by an opaque object.

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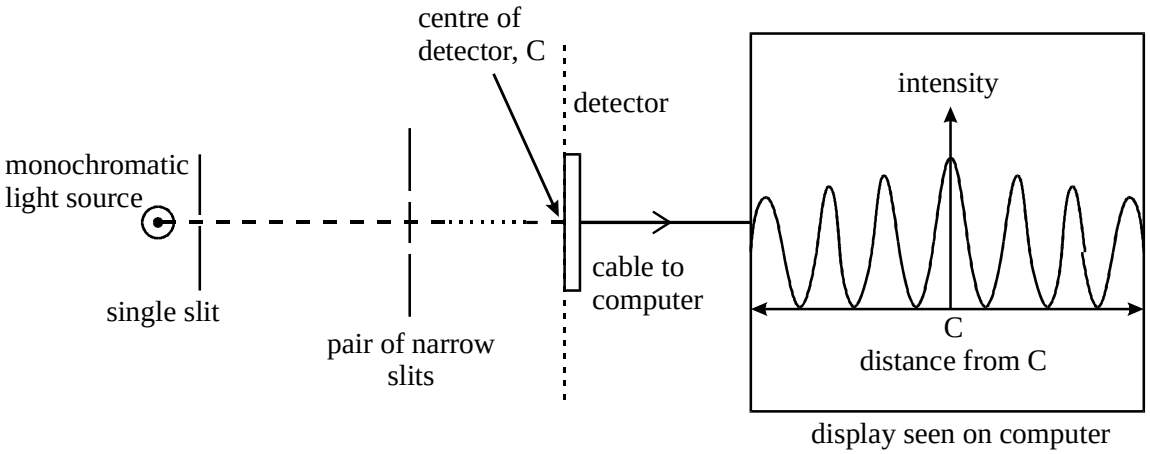
(8)

(b) The microscope is replaced by a fibre-optic detector linked to a computer. The detector consists of the flat end of many optical fibres fixed together along a line. The other end of each optical fibre is attached to a light-sensitive diode in a circuit connected to a computer. The signal to the computer from each diode is in proportion to the intensity of light incident on the diode. The computer display shows how the intensity of light at the detector varies along the line of the detector when both of the narrow slits are open.



(i) Describe and explain how the pattern on the display would change if the slit separation were increased.

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(ii) Each fibre consists of a core of refractive index 1.50 surrounded by cladding of refractive index 1.32. Calculate the critical angle at the core-cladding boundary.

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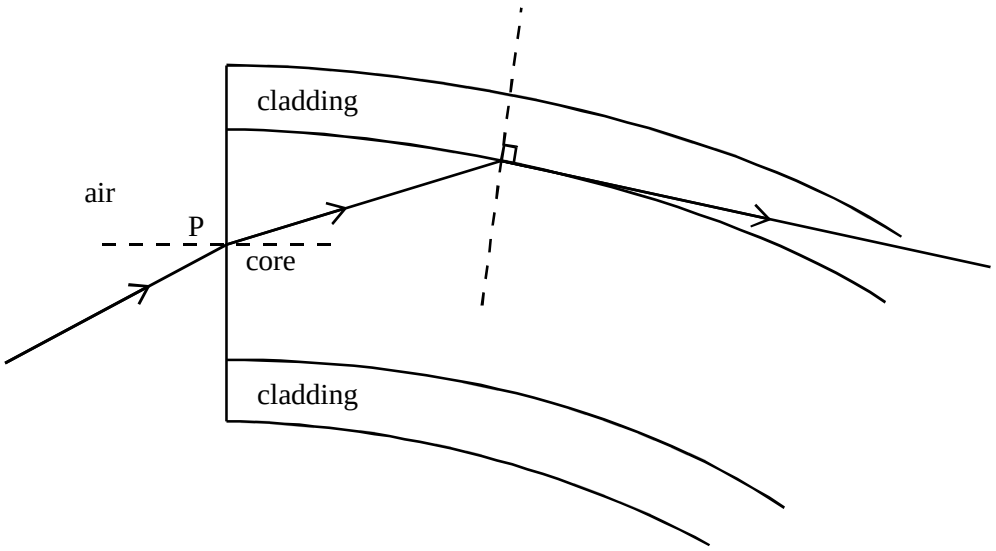
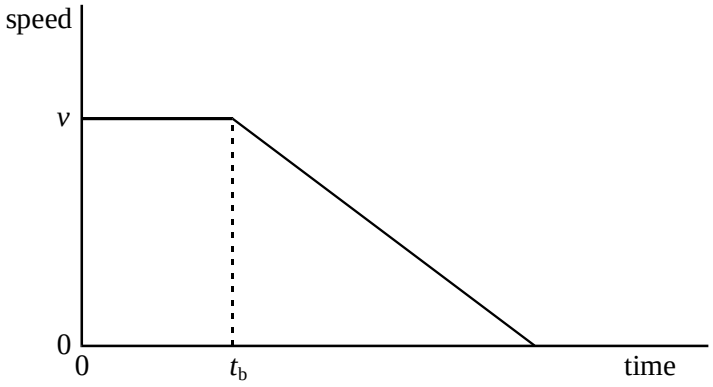
(iii) The diagram below shows a light ray entering an optical fibre at point P on the flat end of the fibre. The angle of incidence of this light ray at the core-cladding boundary is equal to the critical angle. On the diagram, sketch the path of another light ray from air, incident at the same point P, which is totally internally reflected at the core-cladding boundary.



(7)
(Total 15 marks)

55. The driver of a car sees an obstruction ahead and applies the brakes at time t_b later, bringing the car to a halt. The graph shows how the speed of the car varies with time.



The stopping distance, s, of the car which was travelling at speed v before the driver applied the brakes, can be represented by the equation

$$s = vt_b + \frac{v^2}{2a},$$

where a is the magnitude of the deceleration of the car (assumed constant).

(a) State what distance is represented by each of the terms

vt_b .....

$\frac{v^2}{2a}$ .....

(2)

(b) The table includes data on stopping distances of cars. Column C gives the total stopping distance for a car travelling at each of the speeds shown in column A.

column A	**column B**	**column C**	**column D**
speed v/km h^{-1}	speed v/m s^{-1}	stopping distance s/m	$\frac{s}{v}$/sec
32	8.9	12	
48		23	
64		36	
80		53	
96		73	
112		96	

(i) Complete column B,

(ii) In column D, calculate each of the corresponding values of $\frac{s}{v}$.

(2)

(c) The equation for s can be rearranged as $\frac{s}{v} = t_b + \frac{v}{2a}$.

From the data you have calculated, plot a suitable graph on the grid provided to verify this equation.

(Allow one sheet of graph paper)

(5)

(d) From your graph determine the value of

(i) t_b .....

(ii) the magnitude of the deceleration, a.

.....

.....

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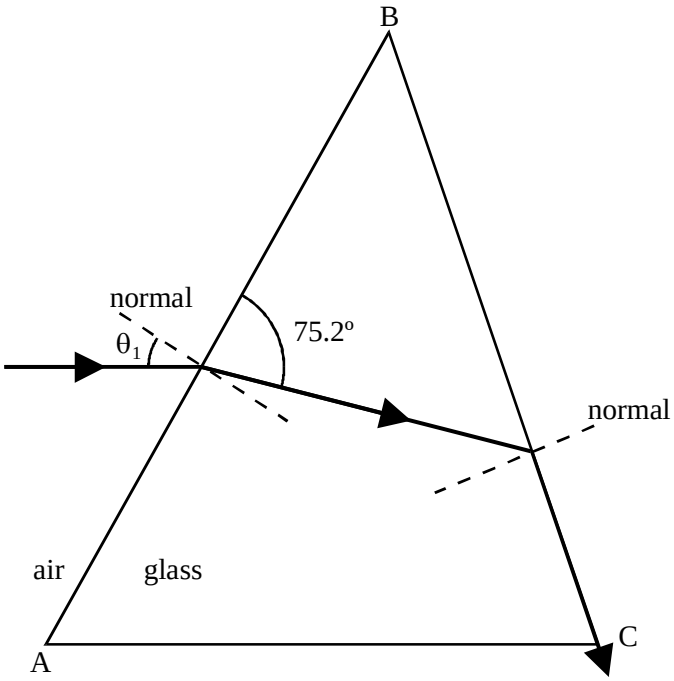
.....

.....

(4)

(Total 13 marks)

56. The diagram shows a ray of light passing from air into a glass prism at an angle of incidence θ_1 The light emerges from face BC as shown.
refractive index of the glass = 1.55



(a) (i) Mark the critical angle along the path of the ray with the symbol θ_c.

(ii) Calculate the critical angle, θ_c.

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.....

.....

(3)

(b) For the ray shown calculate the angle of incidence, θ_1.

.....

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.....

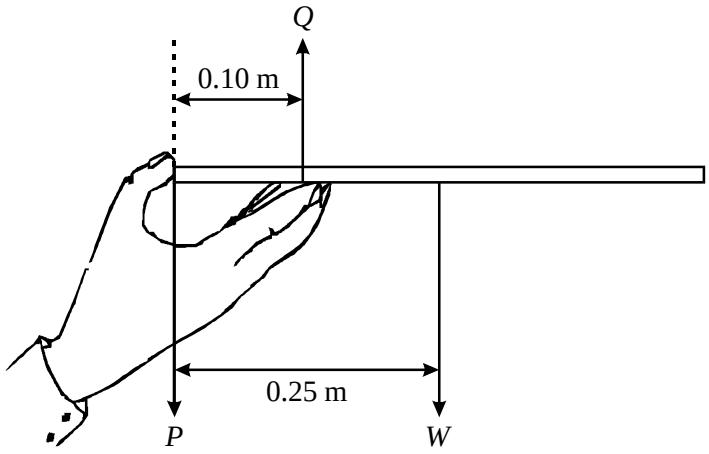
.....

(2)

(c) Without further calculations draw the path of another ray of light incident at the same point on the prism but with a smaller angle of incidence. The path should show the ray emerging from the prism into the air.

(3)
(Total 8 marks)

57. A waiter holds a tray horizontally in one hand between fingers and thumb as shown in the diagram.



P, *Q* and *W* are the three forces acting on the tray.

(a) (i) State **two** relationships between the forces that must be satisfied if the tray is to remain horizontal and in equilibrium.

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.....

(ii) If the mass of the tray is 0.12 kg, calculate the magnitude of the force *W*.

.....

.....

.....

(iii) Calculate the magnitudes of forces *P* and *Q*.

.....

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.....

(6)

(b) The waiter places a glass on the tray. State and explain where the glass should be positioned on the tray if the force, *P*, is to have the same value as in part (a).

.....

.....

.....

(2)

(Total 8 marks)

58. (a) A man jumps from a plane that is travelling horizontally at a speed of 70 m s^{-1}. If air resistance can be ignored, determine

(i) his horizontal velocity 2.0 s after jumping,

.....

(ii) his vertical velocity 2.0 s after jumping,

.....

.....

.....

(iii) the magnitude and direction of his resultant velocity 2.0 s after jumping.

.....

.....

.....

.....

.....

(5)

(b) After 2.0 s the man opens his parachute. Air resistance is no longer negligible. Explain in terms of Newton's laws of motion, why

(i) his velocity initially decreases,

.....

(ii) a terminal velocity is reached.

.....

.....

.....

.....

(4)
(Total 9 marks)

59. A material in the form of a wire, 3.0 m long and cross-sectional area = 2.8×10^{-7} m^2 is suspended from a support so that it hangs vertically. Different masses may be suspended from its lower end. The table shows the extension of the wire when it is subjected to an increasing load and then a decreasing load.

load/N	0	24	52	70	82	88	94	101	71	50	16	0
extension/mm	0	2.2	4.6	6.4	7.4	8.2	9.6	13.0	10.2	8.0	4.8	3.2

(a) Plot a graph of load (on *y* axis) against extension (on *x* axis) both for increasing and decreasing loads.

(Allow one sheet of graph paper)

(4)

(b) Explain what the shape of the graph tells us about the behaviour of the material in the wire. You may be awarded marks for the quality of written communication in your answer.

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.....

(4)

(c) Using the graph, determine a value of the Young modulus for the material of the wire.

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.....

(3)

(d) State how the graph can be used to estimate the energy stored during the loading process.

.....

.....

(1)

(Total 12 marks)

60. A uniform wooden beam of mass 35.0 kg and length 5.52 m is supported by two identical vertical steel cables **A** and **B** attached at either end, as shown in **Figure 1**.

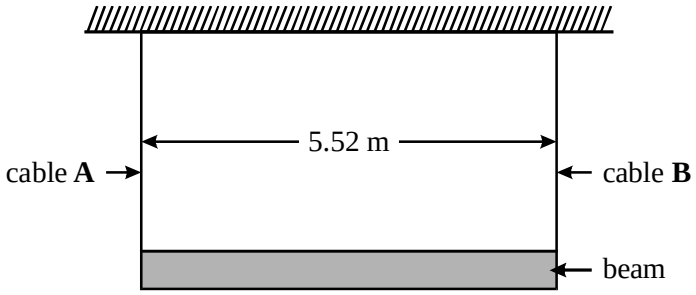

Figure 1

(a) Calculate

(i) the weight of the beam,

.....

(ii) the tension in each cable.

.....

.....

(2)

(b) Each unstretched cable has a diameter of 8.26 mm and a length 2.50 m. Calculate the extension of each cable when supporting the beam.

the Young modulus for steel = 2.10×10^{11} Pa

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(4)

(c) An object of mass 20.0 kg is hung from the beam 1.00 m from cable **A**, as shown in **Figure 2**.

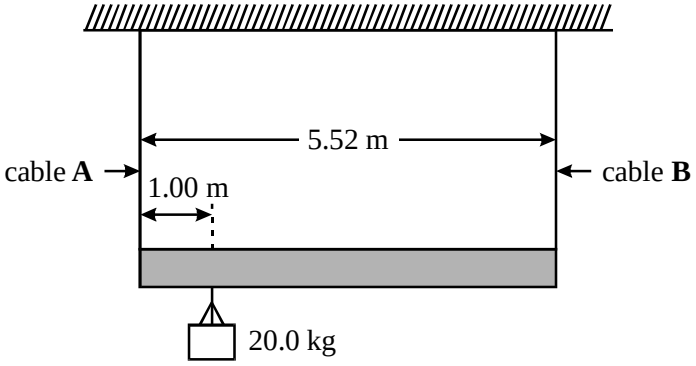

Figure 2

(i) Show that the new tension in cable **A** is 332 N.

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.....

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.....

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.....

(ii) Calculate the new tension in cable **B**.

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.....

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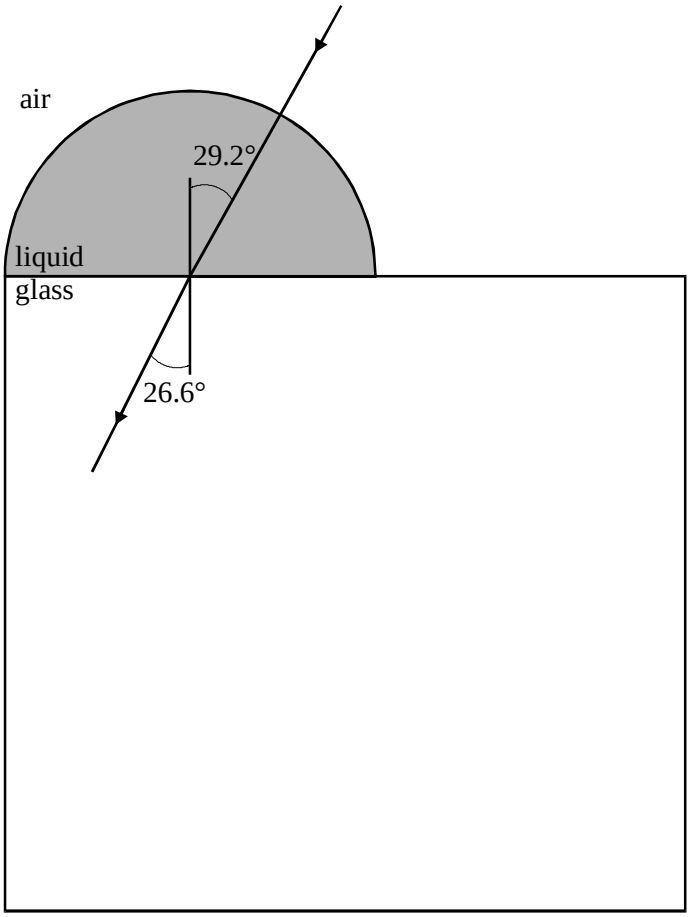
(6)
(Total 12 marks)

61. The diagram below shows a liquid droplet placed on a cube of glass. A ray of light from air, incident normally on to the droplet, continues in a straight line and is refracted at the liquid to glass boundary as shown.
refractive index of the glass = 1.45



(a) Calculate the speed of light

(i) in the glass,

.....

.....

.....

(ii) in the liquid droplet.

.....

.....

.....

.....

(3)

(b) Calculate the refractive index of the liquid.

.....

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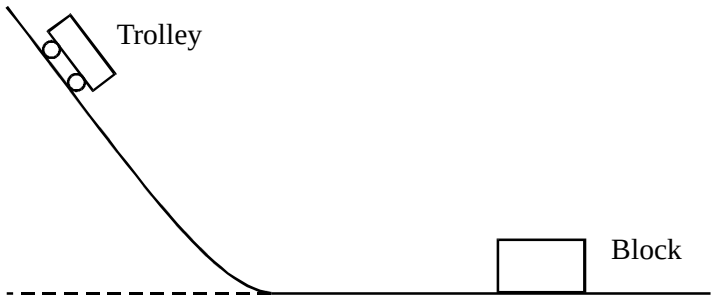
.....

(2)

(c) On the diagram above, complete the path of the ray showing it emerge from the glass cube into the air.
No further calculations are required.

(2)
(Total 7 marks)

62. The diagram represents an experiment that can be used to investigate stopping distances for a moving trolley.



The trolley is placed on the raised section of the track. When released it moves down the track and then travels along the horizontal section before colliding with the block. The trolley and block join and move together after the collision. The distance they move is measured.

(a) State the main energy changes taking place

(i) as the trolley descends,

.....

(ii) after the collision, as the trolley and block move together.

.....

(2)

(b) Describe how the speed of the trolley, just before it collides with the block may be measured experimentally.

You may be awarded marks for the quality of written communication in your answer.

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(3)

(c) State and explain how the speed of the trolley, prior to impact could be varied.

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(2)
(Total 7 marks)

63. An apple and a leaf fall from a tree at the same instant. Both apple and leaf start at the same height above the ground but the apple hits the ground first.

You may be awarded marks for the quality of written communication in your answer.

Use Newton's laws of motion to explain why

(i) the leaf accelerates at first then reaches a terminal velocity,

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.....

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.....

(ii) the apple hits the ground first.

.....

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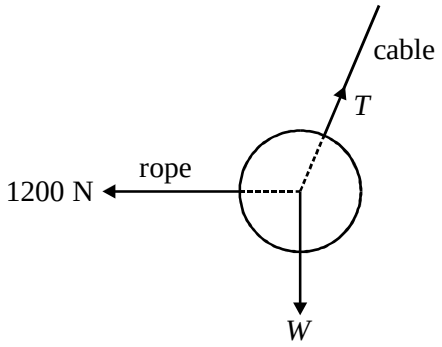
(Total 5 marks)

64. The diagram shows a 250 kg iron ball being used on a demolition site. The ball is suspended from a cable at point A, and is pulled into the position shown by a rope that is kept horizontal. The tension in the rope is 1200 N.



(a) In the position shown the ball is in equilibrium.

(i) What balances the force of the rope on the ball?

.....

(ii) What balances the weight of the ball?

.....

(2)

(b) Determine

(i) the magnitude of the vertical component of the tension in the cable,

.....

(ii) the magnitude of the horizontal component of the tension in the cable,

.....

.....

(iii) the magnitude of the tension in the cable,

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(iv) the angle the cable makes to the vertical.

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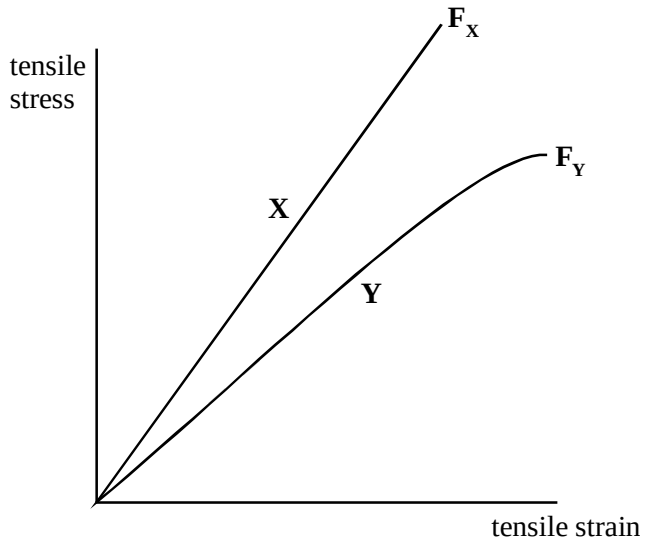
(6)
(Total 8 marks)

65. (a) The graph shows the variation of *tensile stress* with *tensile strain* for two wires **X** and **Y**, having the same dimensions, but made of different materials. The materials fracture at the points $\mathbf{F}_X$ and $\mathbf{F}_Y$ respectively.



You may be awarded marks for the quality of written communication provided in your answer to the following questions.

State, with a reason for each, which material, **X** or **Y**,

(i) obeys Hooke's law up to the point of fracture,

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(ii) is the weaker material,

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(iii) is ductile,

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(iv) has the greater elastic strain energy for a given tensile stress.

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(8)

(b) An elastic cord of unstretched length 160 mm has a cross-sectional area of 0.64 mm^2. The cord is stretched to a length of 190 mm. Assume that Hooke's law is obeyed for this range and that the cross-sectional area remains constant.

the Young modulus for the material of the cord = 2.0×10^7 Pa

(i) Calculate the tension in the cord at this extension.

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(ii) Calculate the energy stored in the cord at this extension.

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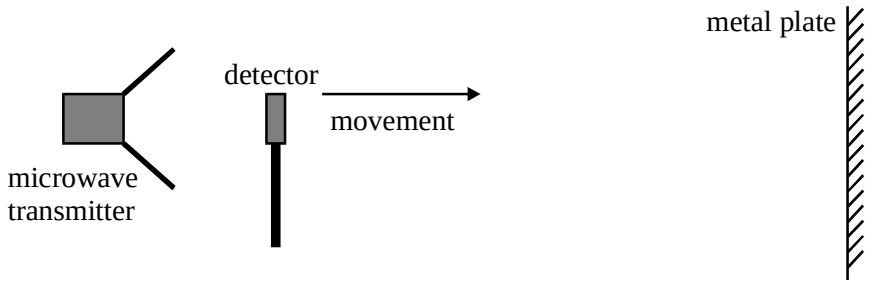
(5)
(Total 13 marks)

66.



A microwave transmitter directs waves towards a metal plate. When a microwave detector is moved along a line normal to the transmitter and the plate, it passes through a sequence of equally spaced maxima and minima of intensity.

(a) Explain how these maxima and minima are formed.

You may be awarded marks for the quality of written communication in your answer.

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(4)

(b) The detector is placed at a position where the intensity is a minimum. When it is moved a distance of 144 mm it passes through nine maxima and reaches the ninth minimum from the starting point.

Calculate

(i) the wavelength of the microwaves,

.....

.....

(ii) the frequency of the microwave transmitter.

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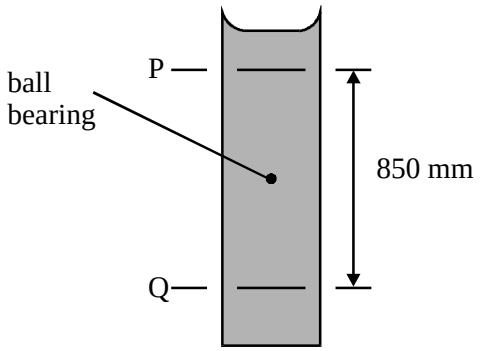
(3)
(Total 7 marks)

67. A student carried out an experiment to determine the terminal speed of various ball bearings as they fell through a viscous liquid. She did this by timing their fall between two marks, P and Q, which were 850 mm apart on a vertical glass tube.



You may be awarded marks for the quality of written communication in your answer.

(a) (i) Describe the motion of a ball bearing after being released from rest at the surface.

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(ii) In terms of the forces acting, explain why a ball bearing reaches a terminal speed under these conditions.

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(5)

(b) The student's results are shown in **columns A** and **B**. Complete **column C**.

column A	**column B**	**column C**	**column D**	**column E**
radius of ball bearing r / mm	time of fall / s (through 850 mm)	terminal speed v / mm s^{-1}	$\log_{10}(r$ / mm)	$\log_{10}(v$ / mm $s^{-1})$
1.62	32.0		0.210	
1.98	21.4		0.297	
2.21	17.2		0.344	
2.73	11.3		0.436	
3.40	7.2		0.531	
4.12	4.9		0.615	

(2)

(c) The relationship between v and r is known to be of the form

$$v = kr^n,$$

where n and k are constants.

(i) Enter the corresponding values for $\log_{10}(v$ / mm $s^{-1})$ in **column E** of the table in part (b).

(ii) Plot a graph of $\log_{10}(v$ / mm $s^{-1})$ on the y-axis, against $\log_{10}(r$ / mm) on the x-axis.

(Allow one sheet of graph paper)

(4)

(d) Use your graph to determine

(i) the constant n,

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(ii) the constant k.

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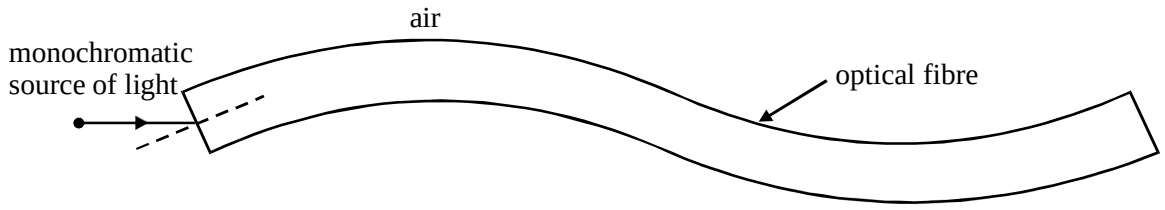
(5)

(Total 16 marks)

68. The diagram shows a ray of monochromatic light, in the plane of the paper, incident on the end face of an optical fibre.



(a) (i) Draw on the diagram the complete path followed by the incident ray, showing it entering into the fibre and emerging from the fibre at the far end.

(ii) State any changes that occur in the speed of the ray as it follows this path from the source. Calculations are not required.

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(4)

(b) (i) Calculate the critical angle for the optical fibre at the air boundary.

refractive index of the optical fibre glass = 1.57

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(ii) The optical fibre is now surrounded by cladding of refractive index 1.47. Calculate the critical angle at the core-cladding boundary.

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(iii) State **one** advantage of cladding an optical fibre.

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(6)
(Total 10 marks)

69. (a) (i) State what is meant by a scalar quantity.

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(ii) State **two** examples of scalar quantities.

example 1: .....

example 2: .....

(3)

(b) An object is acted upon by two forces at right angles to each other. One of the forces has a magnitude of 5.0 N and the resultant force produced on the object is 9.5 N.
Determine

(i) the magnitude of the other force,

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(ii) the angle between the resultant force and the 5.0 N force.

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(4)
(Total 7 marks)

70. A constant resultant horizontal force of 1.8×10^3 N acts on a car of mass 900 kg, initially at rest on a level road.

(a) Calculate

(i) the acceleration of the car,

.....

.....

(ii) the speed of the car after 8.0 s,

.....

.....

(iii) the momentum of the car after 8.0 s,

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.....

(iv) the distance travelled by the car in the first 8.0 s of its motion,

.....

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.....

(v) the work done by the resultant horizontal force during the first 8.0 s.

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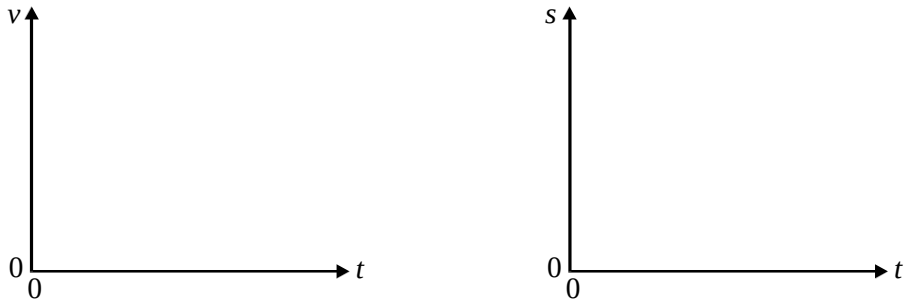
(9)

(b) On the axes below sketch the graphs for speed, *v*, and distance travelled, *s*, against time, *t*, for the first 8.0 s of the car's motion.



(2)

(c) In practice the resultant force on the car changes with time. Air resistance is one factor that affects the resultant force acting on the vehicle.
You may be awarded marks for the quality of written communication in your answer.

(i) Suggest, with a reason, how the resultant force on the car changes as its speed increases.

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(ii) Explain, using Newton's laws of motion, why the vehicle has a maximum speed.

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(5)
(Total 16 marks)

71. (a) State the principle of moments.

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(3)

(b) (i) Draw a labelled diagram of the apparatus you would use to verify the principle of moments.

(ii) Describe the procedure that would be used and state what measurements are taken.

You may be awarded marks for the quality of written communication in your answer.

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(iii) Explain how the results would be used to verify the principle of moments.

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(7)
(Total 10 marks)

72. (a) When a *tensile stress* is applied to a wire, a *tensile strain* is produced in the wire. State the meaning of

tensile stress, ...

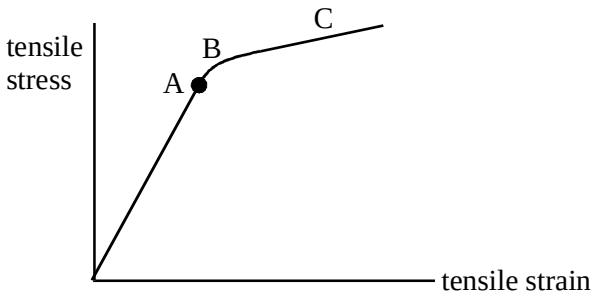
.....

tensile strain. .....

.....

(2)

(b) A long thin line metallic wire is suspended from a fixed support and hangs vertically. Weights are added to increase the load on the free end of the wire until the wire breaks. The graph below shows how the tensile strain in the wire increases as the tensile stress increases.



With reference to the graph, describe the behaviour of the wire as the load on the free end is increased. To assist with your answer refer to the point A, and regions B and C.

You may be awarded marks for the quality of written communication in your answer.

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(5)
(Total 7 marks)

73. (a) Define the *density* of a material.

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(1)

(b) Brass, an alloy of copper and zinc, consists of 70% **by volume** of copper and 30% **by volume** of zinc.

density of copper $= 8.9 \times 10^3$ kg m^{-3}
density of zinc $= 7.1 \times 10^3$ kg m^{-3}

(i) Determine the mass of copper and the mass of zinc required to make a rod of brass of volume 0.80×10^{-3} m^3.

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(ii) Calculate the density of brass.

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(4)
(Total 5 marks)

74. (a) State the conditions that are necessary for the formation of a stationary wave.

You may be awarded marks for the quality of written communication provided in your answer.

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(2)

(b)

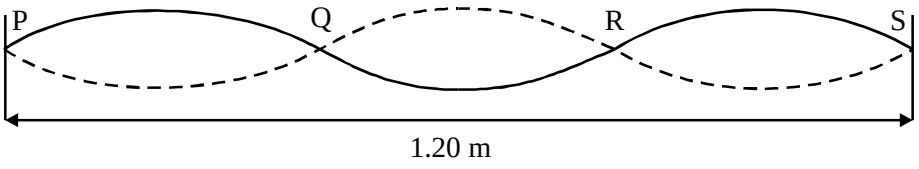

Figure 1

The diagram represents a stationary wave on a stretched string. The continuous line shows the position of the string at a particular instant when the displacement is a maximum. P and S are the fixed ends of the string. Q and R are the positions of the nodes. The speed of waves on the string is 200 m s^{-1}.

(i) State the wavelength of the waves on the string.

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(ii) Calculate the frequency of vibration.

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(iii) Draw on the diagram the position of the string 3.0 ms later than the position shown. Explain below how you arrive at your answer.

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(5)
(Total 7 marks)

75. **Figure 1** shows a cross-section through a rectangular light-emitting diode (LED). When current passes through the LED, light is emitted from the semiconductor material at P and passes through the transparent material and into the air at Q.

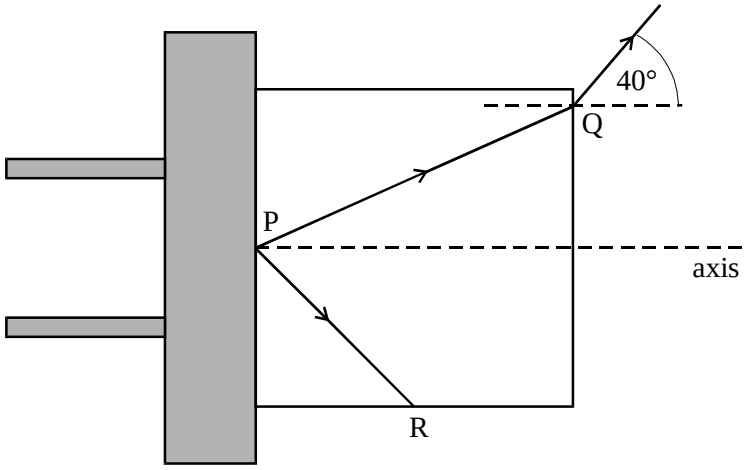

Figure 1

(a) (i) The refractive index of the transparent material of the LED is 1.5. Calculate the critical angle of this material when the LED is in air.

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(ii) **Figure 1** shows a light ray PQ incident on the surface at Q. Calculate the angle of incidence of this light ray at Q if the angle of refraction is 40°.

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(iii) **Figure 1** also shows a second light ray PR incident at R at an angle of incidence of 45°. Use **Figure 1** to explain why this light ray cannot escape into the air.

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(7)

(b) The LED in part (a) is used to send pulses of light down two straight optical fibres of the same refractive index as the transparent material of the LED. The fibres are placed end-on with the LED, as shown in **Figure 2**. Optical fibre 1 is positioned at Q and the other at S directly opposite P.

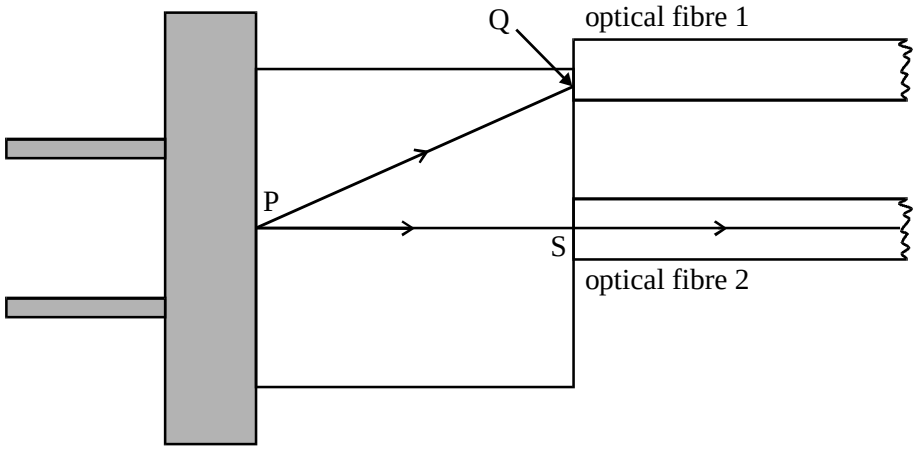

Figure 2

(i) Continue the path of the light ray PQ into and along the optical fibre.

(ii) Compare the times taken for pulses of light to travel along the same length of each fibre.

Give a reason for your answer.

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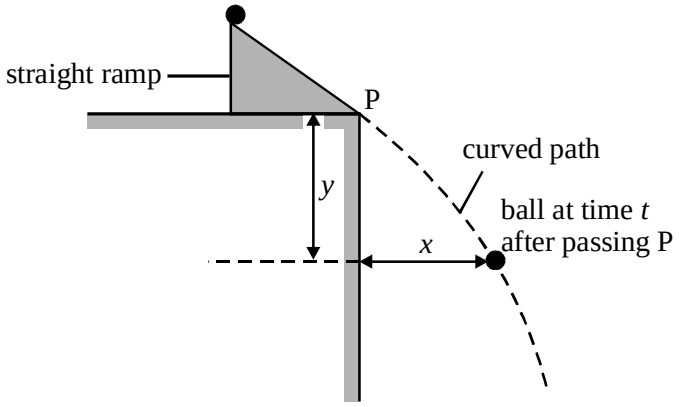
(3)
(Total 10 marks)

76. While investigating projectile motion, a student used stroboscopic photography to determine the position of a steel ball at regular intervals as it fell under gravity. With the stroboscope flashing 20 times per second, the ball was released from rest at the top of an inclined track, and left the foot of the track at P, as shown in the diagram below.



For each of the images on the photograph, the student calculated the horizontal distance, *x*, and the vertical distance, *y*, covered by the ball at time *t* after passing P. Both distances were measured from point P. He recorded his results for the distances *x* and *y* in the table.

image	*x*/cm	*y*/cm	*t*/s	(y/t)/cm s^{-1}
1	11.6	9.3	0.05	
2	22.0	21.0	0.10	
3	32.4	35.0	0.15	
4	44.2	51.8	0.20	
5	54.8	71.0	0.25	
6	66.0	92.2	0.30	

(a) Using two sets of measurements from the table, calculate the horizontal component of velocity of the ball. Give a reason for your choice of measurements.

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(2)

(b) The student worked out that the variables *y* and *t* in the experiment could be represented by

$$\frac{y}{t} = u + kt$$

where *u* and *k* are constants.

(i) Complete the table above.

(ii) Use the data in the table to plot a suitable graph to confirm the equation.

(Allow one sheet pf graph paper)

(iii) Use your graph to find the values of u and k.

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.....

(9)

(c) State the physical significance of

u .....

.....

k .....

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(2)

(d) Calculate the magnitude of the velocity of the ball at point P.

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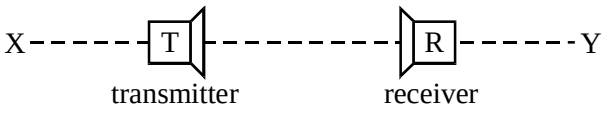
(2)
(Total 15 marks)

77. (a) The diagram below shows an arrangement used to investigate the properties of microwaves.



When the transmitter T was rotated through 90° about the straight line XY, the receiver signal decreased to zero. Explain why this happened and state the property of microwaves responsible for this effect.

You may be awarded marks for the quality of written communication in your answer.

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(3)

(b) A microwave oven produces microwaves of wavelength 0.12 m in air.

(i) Calculate the frequency of these microwaves.

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(ii) In a certain oven, explain why food heated in a fixed position in this oven would be uncooked at certain points if stationary waves were allowed to form.

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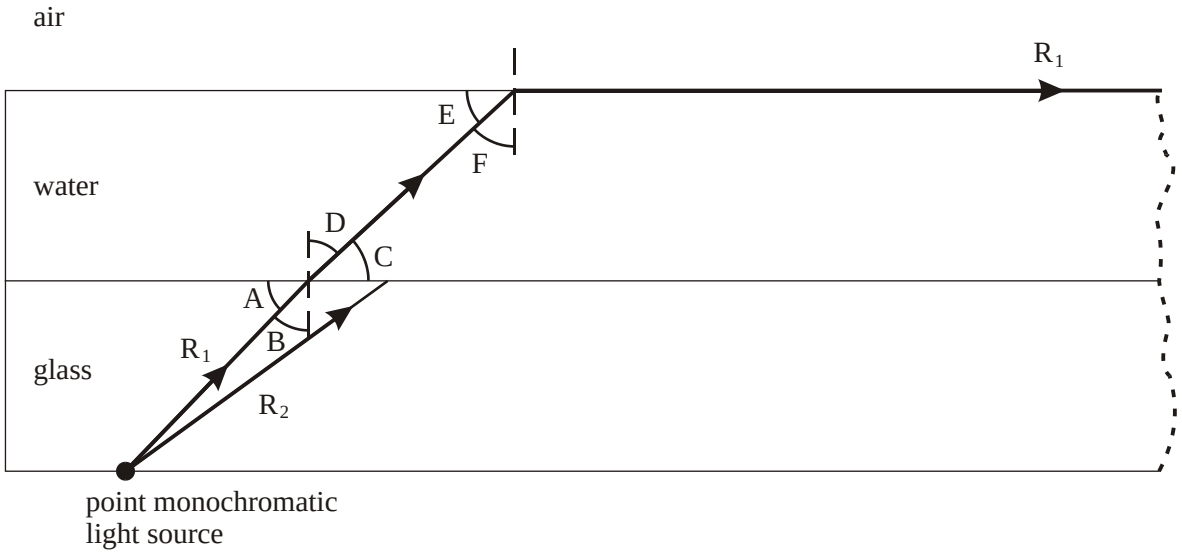
(3)
(Total 6 marks)

78. The diagram shows a cross-sectional view of the base of a glass tank containing water. A point monochromatic light source is in contact with the base and ray, R_1, from the source has been drawn up to the point where it emerges along the surface of the water.



(a) (i) Which angle, A to F, is a critical angle?

.....

(ii) Explain how the path of R_1 demonstrates that the refractive index of glass is greater than the refractive index of water.

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(2)

(b) Using the following information

A = 47.1°

B = 42.9°

C = E = 41.2°

D = F = 48.8°

calculate

(i) the refractive index of water,

.....

.....

.....

(ii) the ratio, $\frac{\text{speed of light in water}}{\text{speed of light in glass}}$.

.....

.....

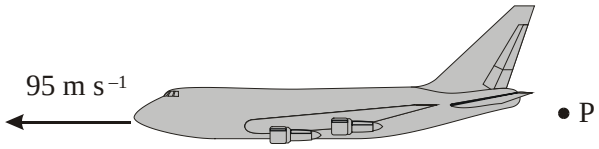
.....

(5)

(c) Ray R_2 emerges from the source a few degrees away from ray R_1 as shown.
Draw on the diagram above the continuation of ray R_2.
Where possible show the ray being refracted.

(2)
(Total 9 marks)

79. The aeroplane shown in the diagram below is travelling horizontally at 95 m s^{-1}. It has to drop a crate of emergency supplies.
The air resistance acting on the crate may be neglected.



(a) (i) The crate is released from the aircraft at point **P** and lands at point **Q**. Sketch the path followed by the crate between **P** and **Q** as seen from the ground.

(ii) Explain why the horizontal component of the crate's velocity remains constant while it is moving through the air.

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(3)

(b) (i) To avoid damage to the crate, the maximum vertical component of the crate's velocity on landing should be 32 m s^{-1}. Show that the maximum height from which the crate can be dropped is approximately 52 m.

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(ii) Calculate the time taken for the crate to reach the ground if the crate is dropped from a height of 52 m.

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(iii) If **R** is a point on the ground directly below **P**, calculate the horizontal distance **QR**.

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(6)

(c) In practice air resistance is **not** negligible. State and explain the effect this has on the maximum height from which the crate can be dropped.

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(2)

(Total 11 marks)

80. (a) Define the moment of a force.

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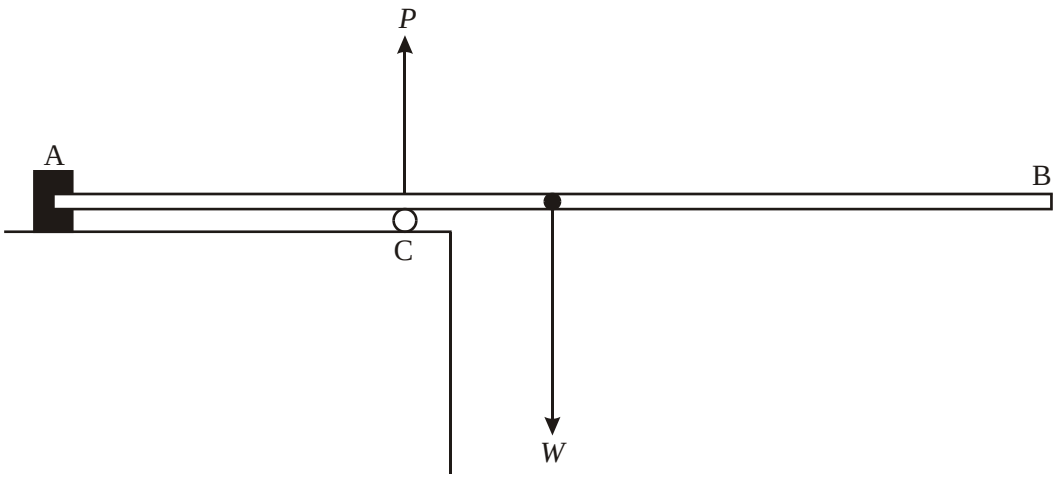
(2)

(b) The diagram shows a uniform diving board of weight, *W*, that is fixed at A. The diving board is supported by a cylinder at C, that exerts an upward force, *P*, on the board.



(i) By considering moments about A, explain why the force *P* must be greater than the weight of the board, *W*.

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(ii) State and explain what would be the effect on the force *P* of a girl walking along the board from A to B.

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(4)
(Total 6 marks)

81. A skydiver of mass 70 kg, jumps from a stationary balloon and reaches a speed of 45 m s^{-1} after falling a distance of 150 m.

(a) Calculate the skydiver's

(i) loss of gravitational potential energy,

.....

.....

(ii) gain in kinetic energy.

.....

.....

(4)

(b) The difference between the loss of gravitational potential energy and the gain in kinetic energy is equal to the work done against air resistance. Use this fact to calculate

(i) the work done against air resistance,

.....

.....

(ii) the average force due to air resistance acting on the skydiver.

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(3)
(Total 7 marks)

82. (a) State *Hooke's law* for a material in the form of a wire.

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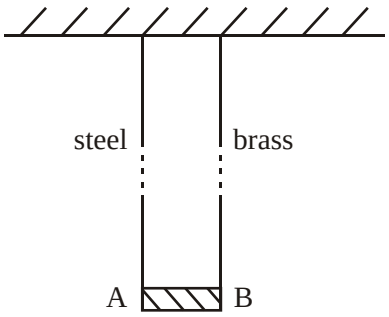
.....

(2)

(b) A rigid bar AB of negligible mass, is suspended horizontally from two long, vertical wires as shown in the diagram. One wire is made of steel and the other of brass. The wires are fixed at their upper end to a rigid horizontal surface. Each wire is 2.5 m long but they have different cross-sectional areas.



When a mass of 16 kg is suspended from the centre of AB, the bar remains horizontal.

the Young modulus for steel = 2.0×10^{11} Pa
the Young modulus for brass = 1.0×10^{11} Pa

(i) What is the tension in each wire?

.....

(ii) If the cross-sectional area of the steel wire is 2.8×10^{-7} m^2, calculate the extension of the steel wire.

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(iii) Calculate the cross-sectional area of the brass wire.

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(iv) Calculate the energy stored in the steel wire.

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(7)

(c) The brass wire is replaced by a steel wire of the same dimensions as the brass wire. The same mass is suspended from the midpoint of AB.

(i) Which end of the bar is lower?

.....

(ii) Calculate the vertical distance between the ends of the bar.

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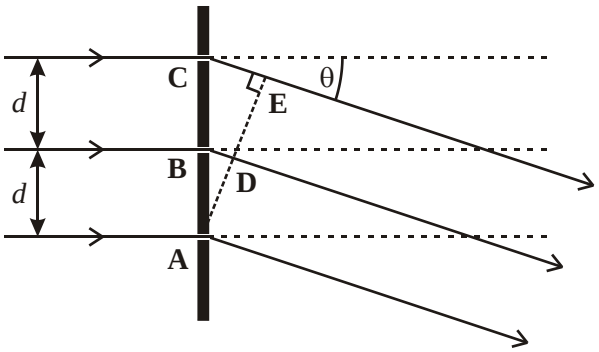
.....

(2)
(Total 11 marks)

83. The diagram below shows a section of a diffraction grating. Monochromatic light of wavelength λ is incident normally on its surface. Light waves diffracted through angle θ form the **second** order image after passing through a converging lens (not shown). **A**, **B** and **C** are adjacent slits on the grating.



(a) (i) State the phase difference between the waves at **A** and **D**.

.....

(ii) State the path length between **C** and **E** in terms of λ.

.....

(iii) Use your results to show that, for the second order image,
$2\lambda = d \sin \theta$,
where d is the distance between adjacent slits.

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(3)

(b) A diffraction grating has 4.5×10^5 lines m^{-1}. It is being used to investigate the line spectrum of hydrogen, which contains a visible blue-green line of wavelength 486 nm. Determine the highest order diffracted image that could be produced for this spectral line by this grating.

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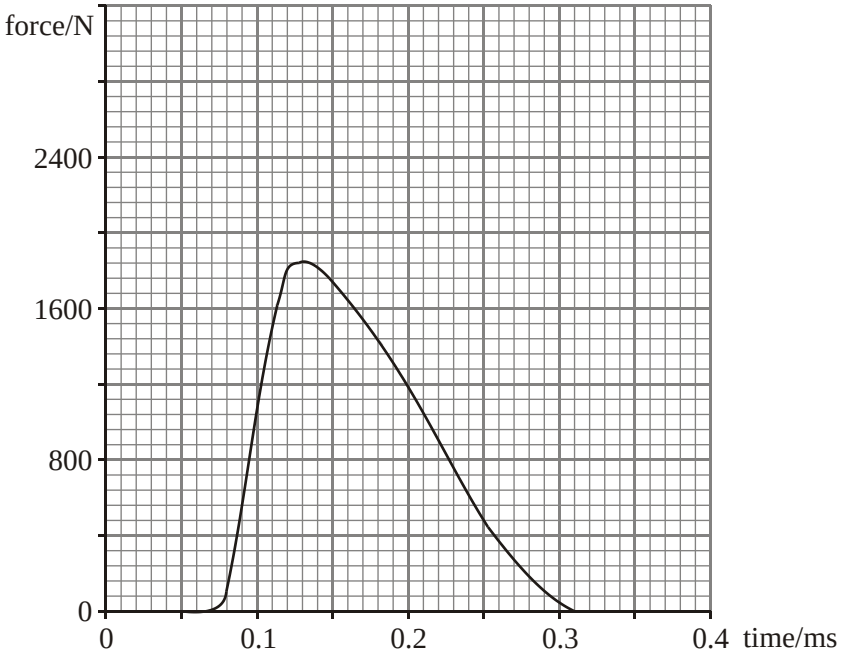
(2)
(Total 5 marks)

84. The diagram below shows how the impact force on the heel of a runner's foot varies with time during an impact when the runner is wearing cushioned sports shoes.



(a) Estimate the maximum stress on the cartilage pad in the knee joint as a result of this force acting on the cartilage pad over a contact area of 550 mm^2.

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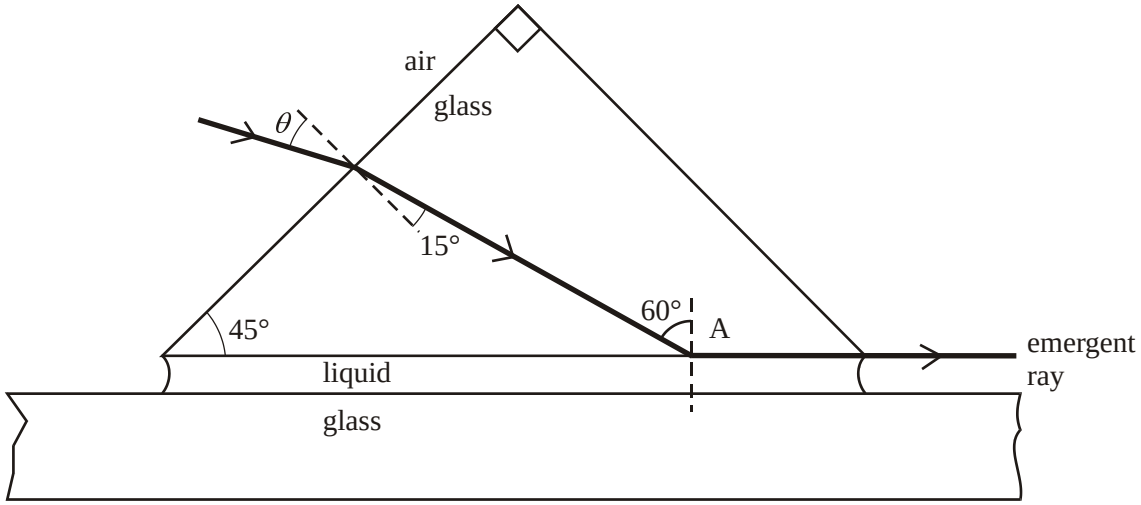
(4)

(b) On the diagram above, sketch the graph of force against time you would expect to see if a sports shoe with less cushioning had been used.

(3)
(Total 7 marks)

85. The diagram, which is not to scale, shows the cross-section of a 45° right angled glass prism supported by a film of liquid on a glass table. A ray of monochromatic light is incident on the prism at an angle of incidence θ and emerges along the glass - liquid boundary as shown.

refractive index of glass = 1.5



(a) Calculate the speed of light in the glass.

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(2)

(b) Determine

(i) the angle of incidence, θ,

.....

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.....

(ii) the refractive index of the liquid.

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(5)

(c) The liquid is now changed to one with a lower refractive index. Draw a possible path for the ray beyond the point A and into the air.

(2)
(Total 9 marks)

86. (a) State the difference between vector and scalar quantities.

.....

.....

(1)

(b) State **one** example of a vector quantity (other than force) and **one** example of a scalar quantity.

vector quantity .....

scalar quantity .....

(2)

(c) A 12.0 N force and a 8.0 N force act on a body of mass 6.5 kg at the same time.
For this body, calculate

(i) the maximum resultant acceleration that it could experience,

.....

.....

(ii) the minimum resultant acceleration that it could experience.

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.....

(4)
(Total 7 marks)

87. A packing case is being lifted vertically at a constant speed by a cable attached to a crane.
The packing case has a mass of 640 kg.

(a) With reference to one of Newton's laws of motion, explain why the tension, *T*, in the cable must be equal to the weight of the packing case.

You may be awarded marks for the quality of written communication in your answer.

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(3)

(b) The packing case is lifted through a vertical height of 8.0 m in 4.5 s.

Calculate

(i) the work done on the packing case,

.....

.....

(ii) the power output of the crane in this situation.

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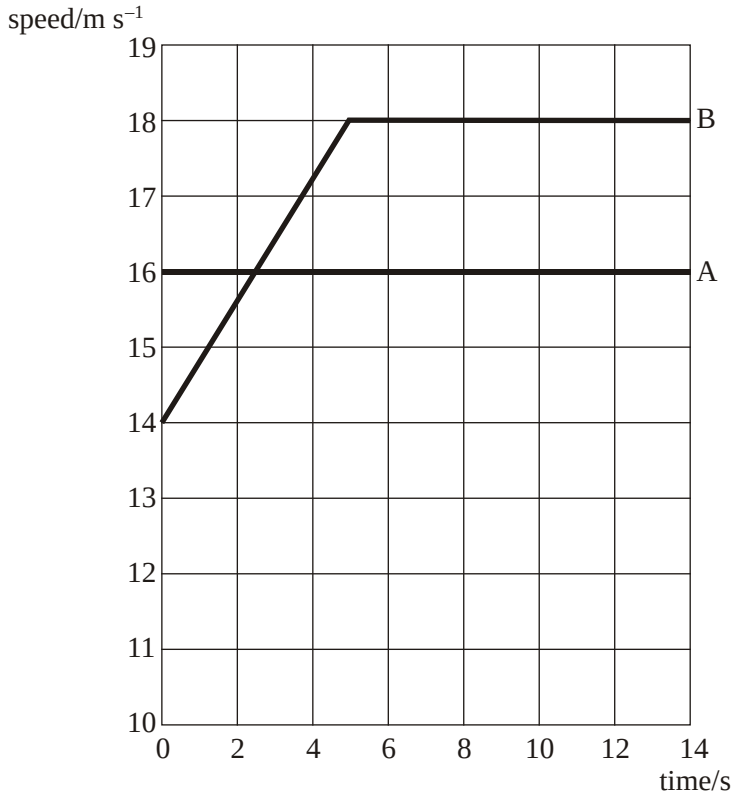
(3)
(Total 6 marks)

88. The graph represents the motion of two cars, A and B, as they move along a straight, horizontal road.



(a) Describe the motion of each car as shown on the graph.

(i) car A: .....

.....

(ii) car B: .....

.....

(3)

(b) Calculate the distance travelled by each car during the first 5.0 s.

(i) car A: .....

.....

.....

(ii) car B: .....

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(4)

(c) At time t = 0, the two cars are level. Explain why car A is at its maximum distance ahead of B at t = 2.5 s

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(3)
(Total 10 marks)

89. (a) Define the moment of a force about a point.

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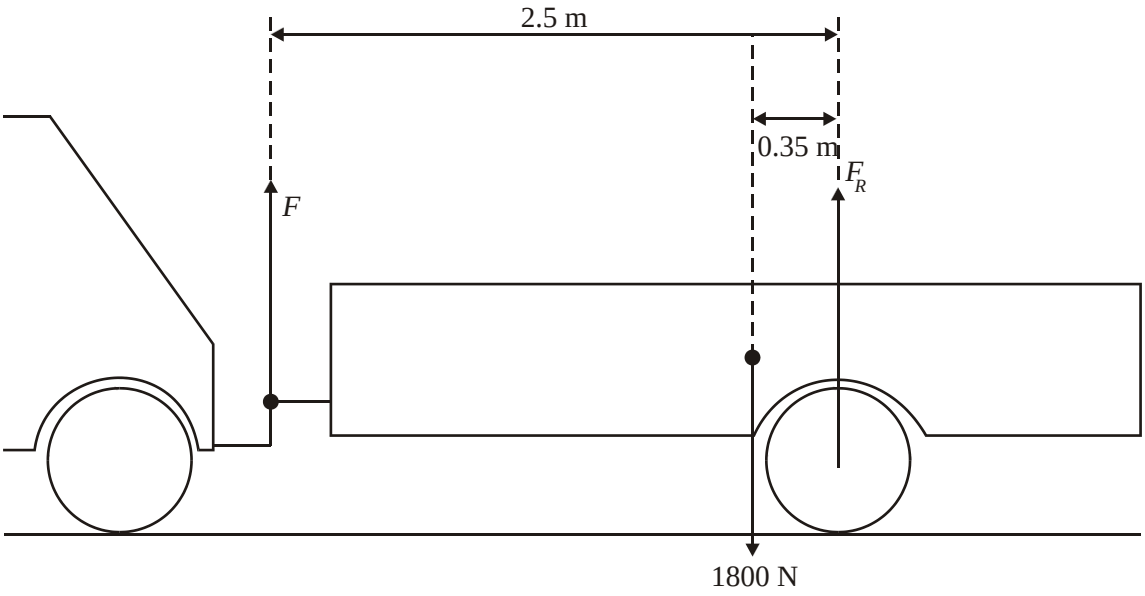
(2)

(b) The diagram shows a trailer attached to the towbar of a stationary car. The weight of the trailer is 1800 N and is shown acting through its *centre of gravity*.
F is the force exerted by the towbar on the trailer. F_R is the **total** normal reaction force experienced by the trailer. When stationary all forces acting on the trailer are vertical.



(i) Explain what is meant by centre of gravity.

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.....

(ii) Calculate the force, *F*, exerted by the towbar on the trailer.

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(3)

(iii) Calculate F_R.

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(2)

(c) The car starts to move forwards. State and explain what happens to the magnitude and direction of force, *F*.

You may be awarded marks for the quality of written communication in your answer.

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(3)
(Total 10 marks)

90. (a) When determining the Young modulus for the material of a wire, a *tensile stress* is applied to the wire and the *tensile strain* is measured.

(i) State the meaning of

tensile stress .....

.....

tensile strain .....

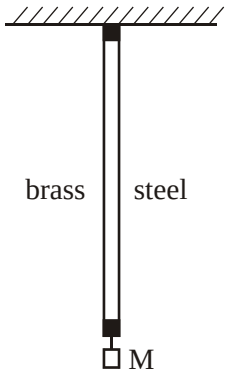
.....

(ii) Define the Young modulus .....

.....

(3)

(b) The diagram below shows two wires, one made of steel and the other of brass, firmly clamped together at their ends. The wires have the same unstretched length and the same cross-sectional area.
One of the clamped ends is fixed to a horizontal support and a mass M is suspended from the other end, so that the wires hang vertically.



(i) Since the wires are clamped together the extension of each wire will be the same.
If E_S is the Young modulus for steel and E_B the Young modulus for brass, show that

$$\frac{E_S}{E_B} = \frac{F_S}{F_B},$$

where F_S and F_B are the respective forces in the steel and brass wire.

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(ii) The mass M produces a total force of 15 N. Show that the magnitude of the force F_S = 10 N.

the Young modulus for steel = 2.0×10^{11} Pa
the Young modulus for brass = 1.0×10^{11} Pa

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(iii) The cross-sectional area of each wire is 1.4×10^{-6} m^2 and the unstretched length is 1.5 m. Determine the extension produced in either wire.

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(6)
(Total 9 marks)

91. (a) State the characteristic features of

(i) longitudinal waves,

.....

.....

(ii) transverse waves.

.....

.....

(3)

(b) Daylight passes horizontally through a fixed polarising filter **P**. An observer views the light emerging through a second polarising filter **Q**, which may be rotated in a vertical plane about point **X** as shown in **Figure 1**.

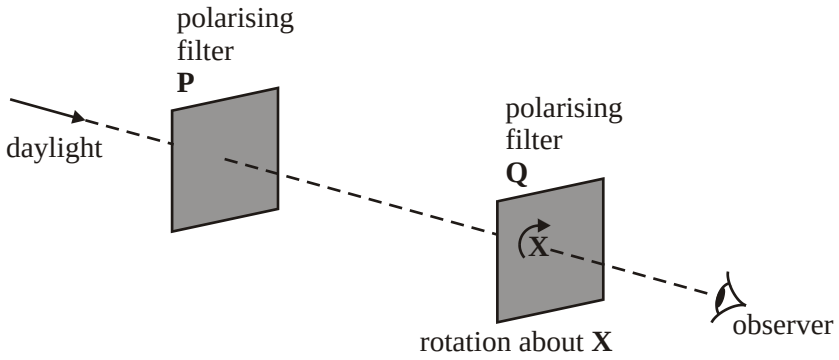

Figure 1

Describe what the observer would see as **Q** is rotated slowly through 360°.

You may be awarded marks for the quality of written communication provided in your answer.

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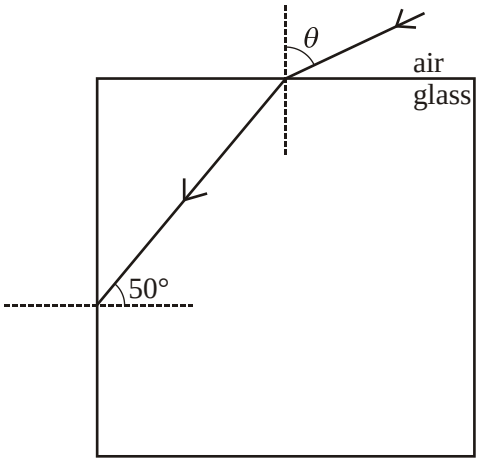
(2)
(Total 5 marks)

92. The diagram shows a cube of glass. A ray of light, incident at the centre of a face of the cube, at an angle of incidence θ, goes on to meet another face at an angle of incidence of 50°, as shown in the figure bellow

critical angle at the glass-air boundary = 45°



(a) Draw on the diagram the continuation of the path of the ray, showing it passing through the glass and out into the air.

(3)

(b) Show that the refractive index of the glass is 1.41

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(2)

(c) Calculate the angle of incidence, θ.

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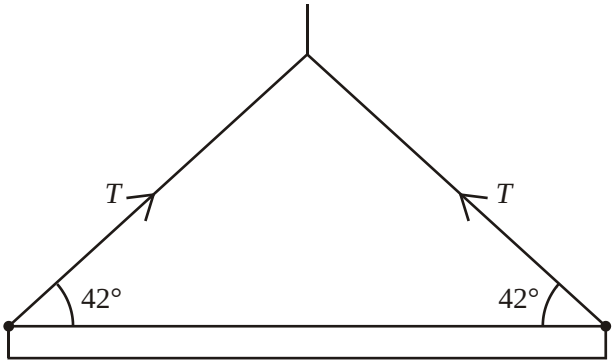
(3)
(Total 8 marks)

93. The figure below shows a uniform steel girder being held horizontally by a crane. Two cables are attached to the ends of the girder and the tension in each of these cables is *T*.



(a) If the tension, *T*, in each cable is 850 N, calculate

(i) the horizontal component of the tension in each cable,

.....

.....

(ii) the vertical component of the tension in each cable,

.....

.....

(iii) the weight of the girder.

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(4)

(b) On the figure draw an arrow to show the line of action of the weight of the girder.

(1)

(Total 5 marks)

94. (a) Explain why a raindrop falling vertically through still air reaches a constant velocity. You may be awarded marks for the quality of written communication in your answer.

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(4)

(b) A raindrop falls at a constant vertical velocity of 1.8 m s^{-1} in still air. The mass of the raindrop is 7.2×10^{-9} kg.

Calculate

(i) the kinetic energy of the raindrop,

.....

.....

(ii) the work done on the raindrop as it falls through a vertical distance of 4.5 m.

.....

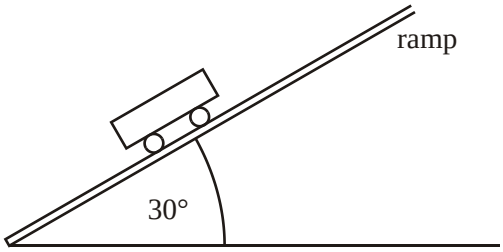
.....

(4)

(c) The raindrop in part (b) now falls through air in which a horizontal wind is blowing. If the velocity of the wind is 1.4 m s^{-1}, use a scale diagram or calculation to determine the magnitude and direction of the resultant velocity of the raindrop.

(3)
(Total 11 marks)

95. A fairground ride ends with the car moving up a ramp at a slope of 30° to the horizontal as shown in the figure below.



(a) The car and its passengers have a total weight of 7.2×10^3 N. Show that the component of the weight parallel to the ramp is 3.6×10^3 N.

.....

.....

(1)

(b) Calculate the deceleration of the car assuming the only force causing the car to decelerate is that calculated in part (a).

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.....

(2)

(c) The car enters at the bottom of the ramp at 18 m s^{-1}. Calculate the minimum length of the ramp for the car to stop before it reaches the end. The length of the car should be neglected.

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(2)

(d) Explain why the stopping distance is, in practice, shorter than the value calculated in part (c).

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(2)

(Total 7 marks)

96. (a) State *Hooke's law* for a material in the form of a wire and state the conditions under which this law applies.

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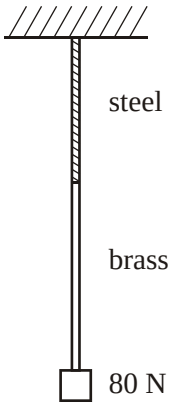
(2)

(b) A length of steel wire and a length of brass wire are joined together. This combination is suspended from a fixed support and a force of 80 N is applied at the bottom end, as shown in the figure below.



Each wire has a cross-sectional area of 2.4×10^{-6} m^2.

length of the steel wire = 0.80 m
length of the brass wire = 1.40 m
the Young modulus for steel = 2.0×10^{11} Pa
the Young modulus for brass = 1.0×10^{11} Pa

(i) Calculate the total extension produced when the force of 80 N is applied.

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(ii) Show that the mass of the combination wire = 4.4×10^{-2} kg.

density of steel = 7.9×10^3 kg m^{-3}
density of brass = 8.5×10^3 kg m^{-3}

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(7)

(c) A single brass wire has the same mass and the same cross-sectional area as the combination wire described in part (b). Calculate its length.

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(2)
(Total 11 marks)

97. (a) State what is meant by *coherent sources* of light.

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(2)

(b)

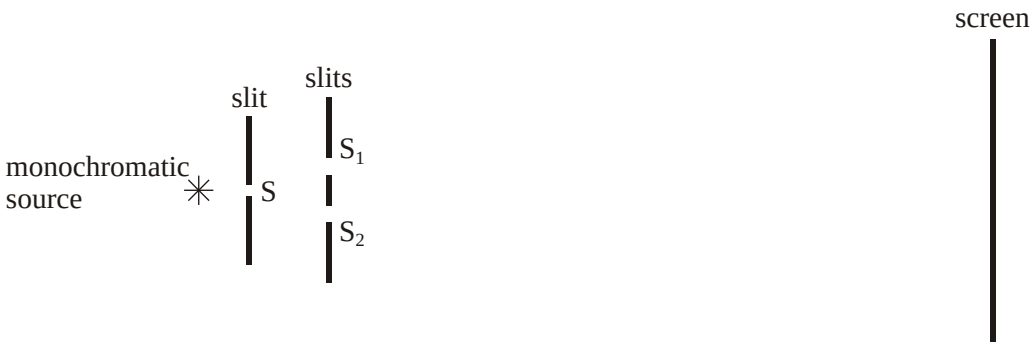

Figure 1

Young's fringes are produced on the screen from the monochromatic source by the arrangement shown in **Figure 1**.

You may be awarded marks for the quality of written communication in your answers.

(i) Explain why slit S should be narrow.

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.....

.....

.....

(ii) Why do slits S_1 and S_2 act as coherent sources?

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(4)

(c) The pattern on the screen may be represented as a graph of intensity against position on the screen. The central fringe is shown on the graph in **Figure 2**. Complete this graph to represent the rest of the pattern by drawing on **Figure 2**.

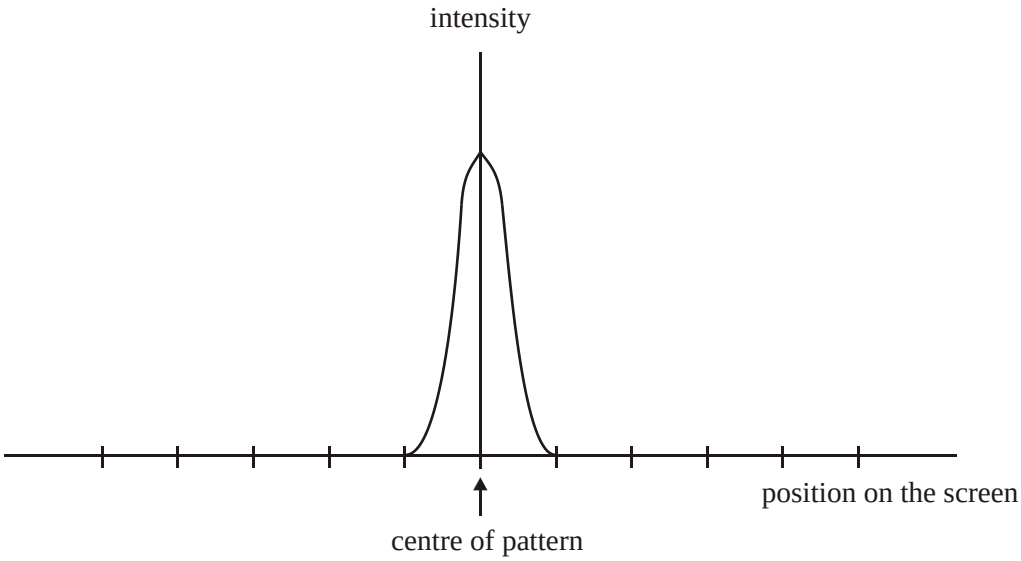
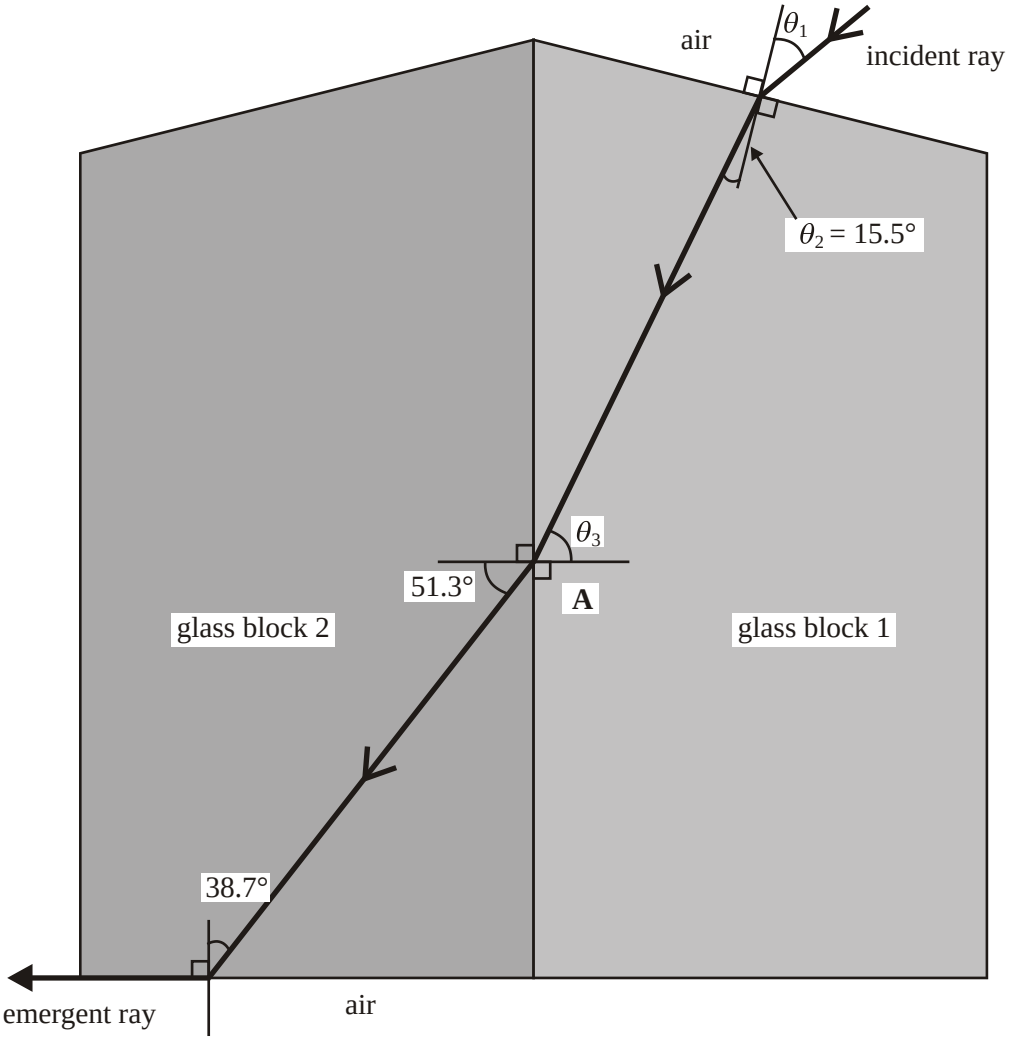


Figure 2

(2)
(Total 8 marks)

98. The figure below shows a ray of light passing from air into glass at the top face of glass block 1 and emerging along the bottom face of glass block 2.

refractive index of the glass in block 1 = 1.45



(a) Calculate

(i) the incident angle θ_1,

.....

.....

.....

(ii) the refractive index of the glass in block 2,

.....

.....

(iii) the angle θ_3 by considering the refraction at point **A**.

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(7)

(b) In which of the two blocks of glass will the speed of light be greater?

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Explain your reasoning.

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(2)

(c) Using a ruler, draw the path of a ray partially reflected at **A** on the figure above. Continue the ray to show it emerging into the air. No calculations are expected.

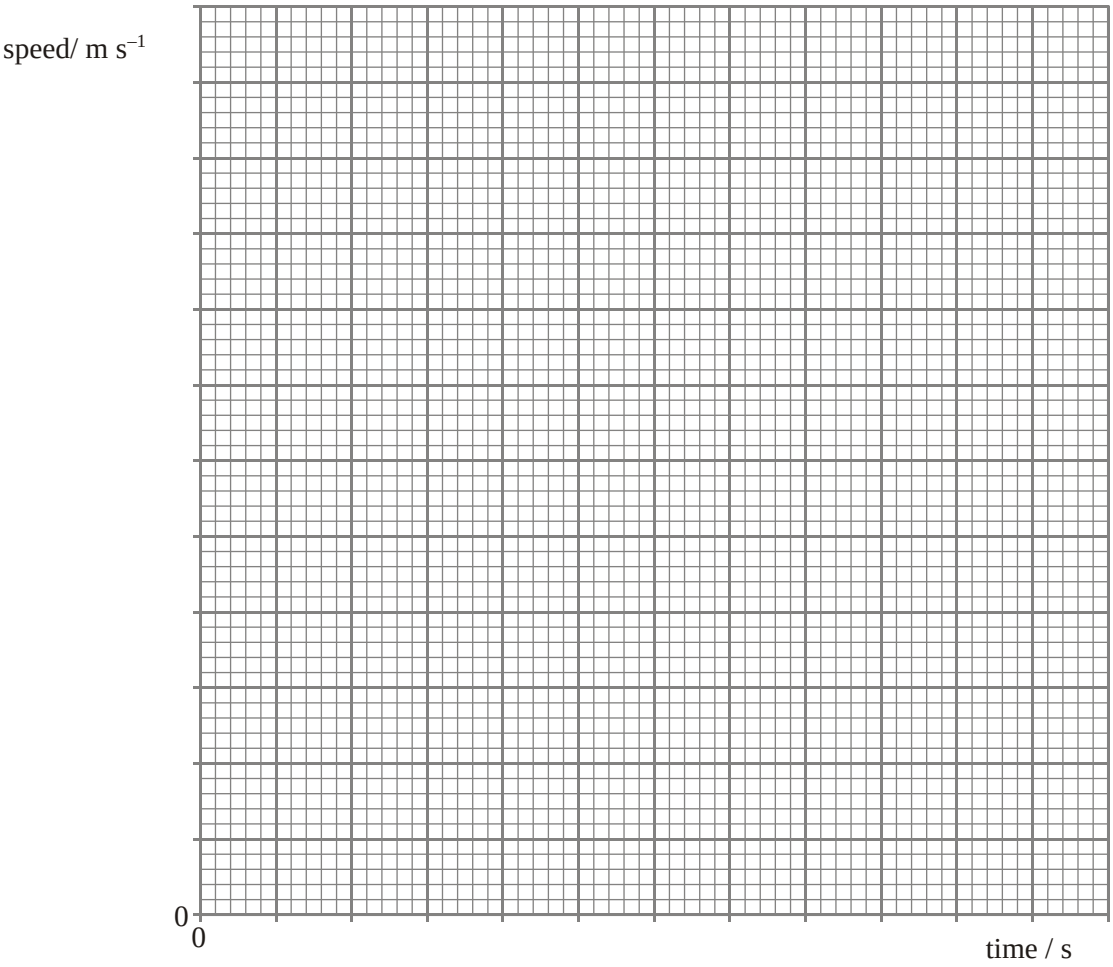
(2)

(Total 11 marks)

99. A car accelerates from rest to a speed of 26 m s^{-1}. The table shows how the speed of the car varies over the first 30 seconds of motion.

time/ s	0	5.0	10.0	15.0	20.0	25.0	30.0
speed/ m s^{-1}	0	16.5	22.5	24.5	25.5	26.0	26.0

(a) Draw a graph of speed against time on the grid provided.



(3)

(b) Calculate the average acceleration of the car over the first 25 s.

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(2)

(c) Use your graph to estimate the distance travelled by the car in the first 25 s.

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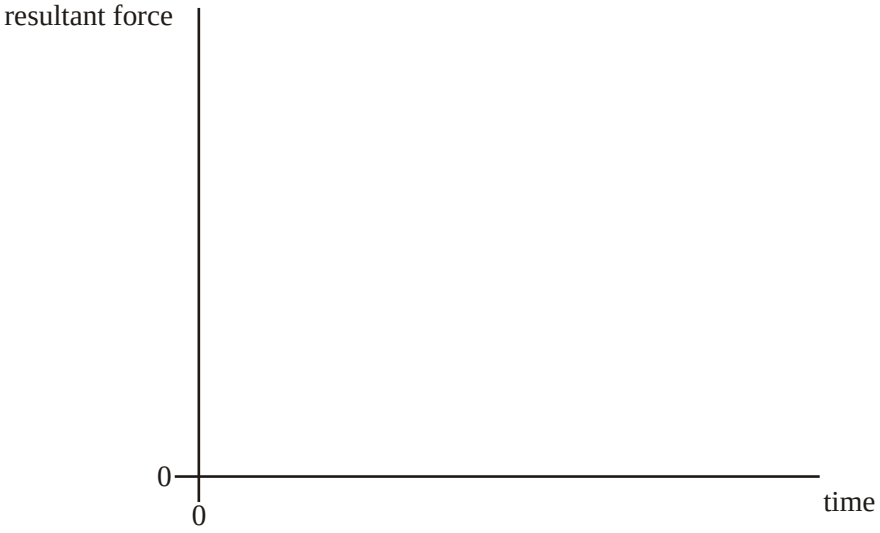
(2)

(d) Using the axes below, sketch a graph to show how the resultant force acting on the car varies over the first 30 s of motion.



(2)

(e) Explain the shape of the graph you have sketched in part (d), with reference to the graph you plotted in part (a).

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(2)

(Total 11 marks)

100. The figure below shows apparatus that can be used to investigate energy changes.

The trolley and the mass are joined by an inextensible string. In an experiment to investigate energy changes, the trolley is initially held at rest, and is then released so that the mass falls vertically to the ground.

You may be awarded marks for the quality of written communication in your answer.

(a) (i) State the energy changes of the falling mass.

.....

.....

(ii) Describe the energy changes that take place in this system.

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(4)

(b) State what measurements would need to be made to investigate the *conservation of energy*.

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(2)

(c) Describe how the measurements in part (b) would be used to investigate the conservation of energy.

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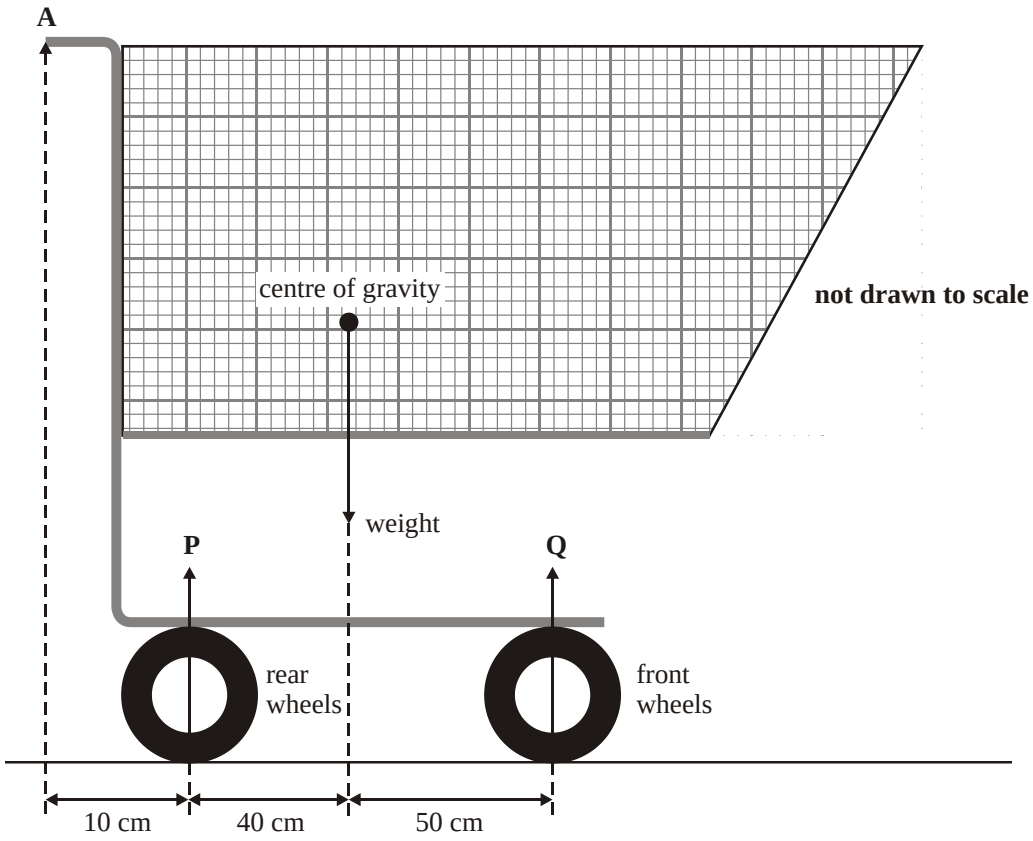
(4)
(Total 10 marks)

101. The figure below shows a supermarket trolley.



The weight of the trolley and its contents is 160 N.

(a) Explain what is meant by centre of gravity.

.....

.....

(2)

(b) **P** and **Q** are the resultant forces that the ground exerts on the rear wheels and front wheels respectively. Calculate the magnitude of

(i) force **P**,

.....

.....

.....

(ii) force **Q**.

.....

.....

(3)

(c) Calculate the minimum force that needs to be applied vertically at **A** to lift the front wheels off the ground.

.....

.....

.....

(2)

(d) State and explain, without calculation, how the minimum force that needs to be applied vertically at **A** to lift the rear wheels off the ground compares to the force you calculated in part (c).

You may be awarded marks for the quality of written communication in your answer.

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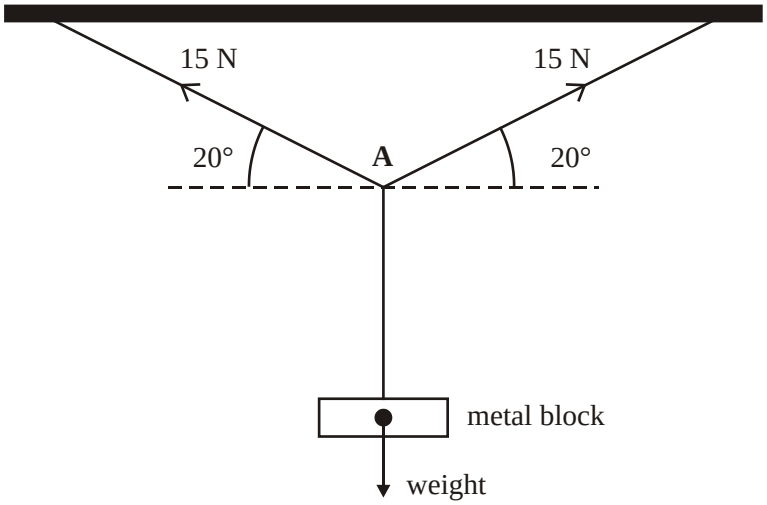
(3)
(Total 10 marks)

102. The figure below shows a stationary metal block hanging from the middle of a stretched wire which is suspended from a horizontal beam. The tension in each half of the wire is 15 N.



(a) Calculate for the wire at **A**,

(i) the resultant horizontal component of the tension forces,

.....

.....

(ii) the resultant vertical component of the tension forces.

.....

.....

(3)

(b) (i) State the weight of the metal block.

.....

(ii) Explain how you arrived at your answer, with reference to an appropriate law of motion.

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(3)
(Total 6 marks)

103. (a) When a *tensile stress* is applied to a wire, a *tensile strain* is produced in the wire.
State the meaning of

tensile stress, ...

.....

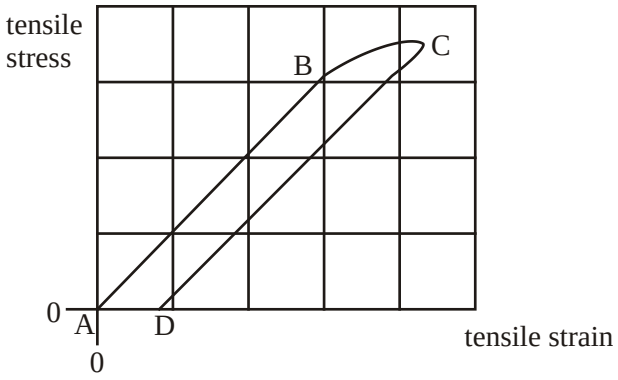
tensile strain. .....

.....

(2)

(b) A long, thin metal wire is suspended from a fixed support and hangs vertically.
Masses are suspended from its lower end.

As the load on the lower end is increased from zero to a certain value, and then decreased again to zero, the variation of the resulting tensile strain with the applied tensile stress is shown in the graph.



(i) Describe the behaviour of the wire during this process. Refer to the points A, B, C and D in your answer.
You may be awarded marks for the quality of written communication in your answer.

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(ii) State, with a reason, whether the material of the wire is ductile or brittle.

.....

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(iii) What does AD represent?

.....

(iv) State how the Young modulus for the material may be obtained from the graph.

.....

(v) State how the energy per unit volume stored in the wire during the loading process may be estimated from the graph.

.....

(9)

(c) The wire described in part (b) has an unstretched length of 3.0 m and cross-sectional area 2.8×10^{-7} m^2. At a certain stage between the points A and B on the graph, the wire supports a load of 75 N. Calculate the extension produced in the wire by this load.
the Young modulus for the material of the wire = 2.1×10^{11} Pa

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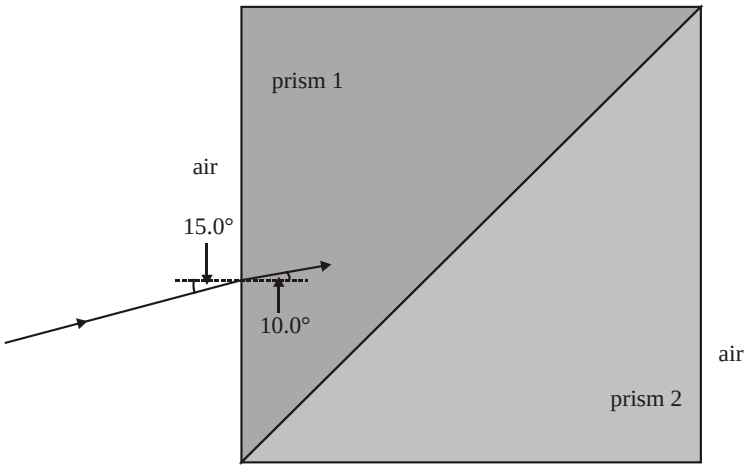
(2)
(Total 13 marks)

104. A ray of light passes from air into a glass prism as shown in **Figure 1**.

Figure 1



(a) Confirm, by calculation, that the refractive index of the glass from which the prism was made is 1.49.

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(1)

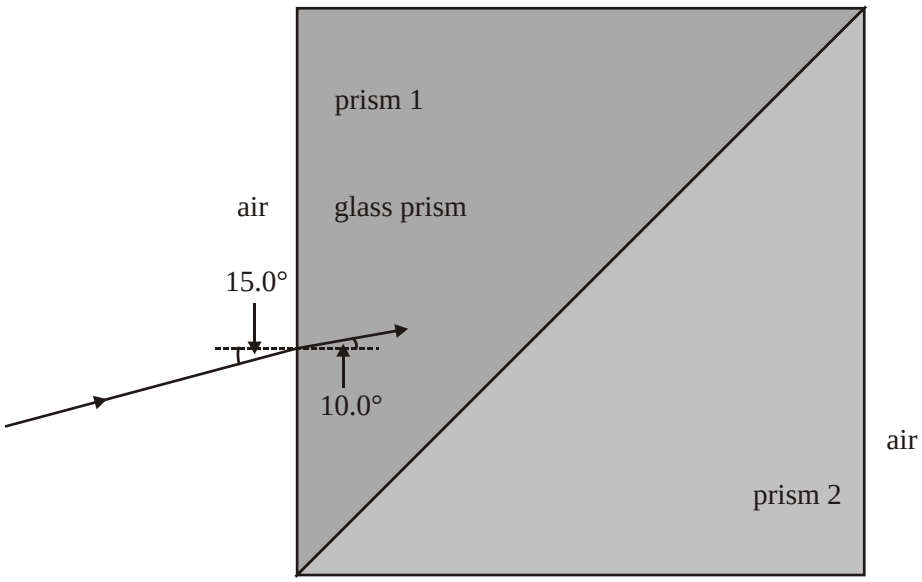
(b) On **Figure 1**, draw the continuation of the path of the ray of light until it emerges back into the air. Write on **Figure 1** the values of the angles between the ray and any normals you have drawn.

the critical angle from glass to air is less than 45°

(2)

(c) A second prism, prism 2, made from transparent material of refractive index 1.37 is placed firmly against the original prism, prism 1, to form a cube as shown in **Figure 2**.

Figure 2



(i) The ray strikes the boundary between the prisms. Calculate the angle of refraction of the ray in prism 2.

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(ii) Calculate the speed of light in prism 2.

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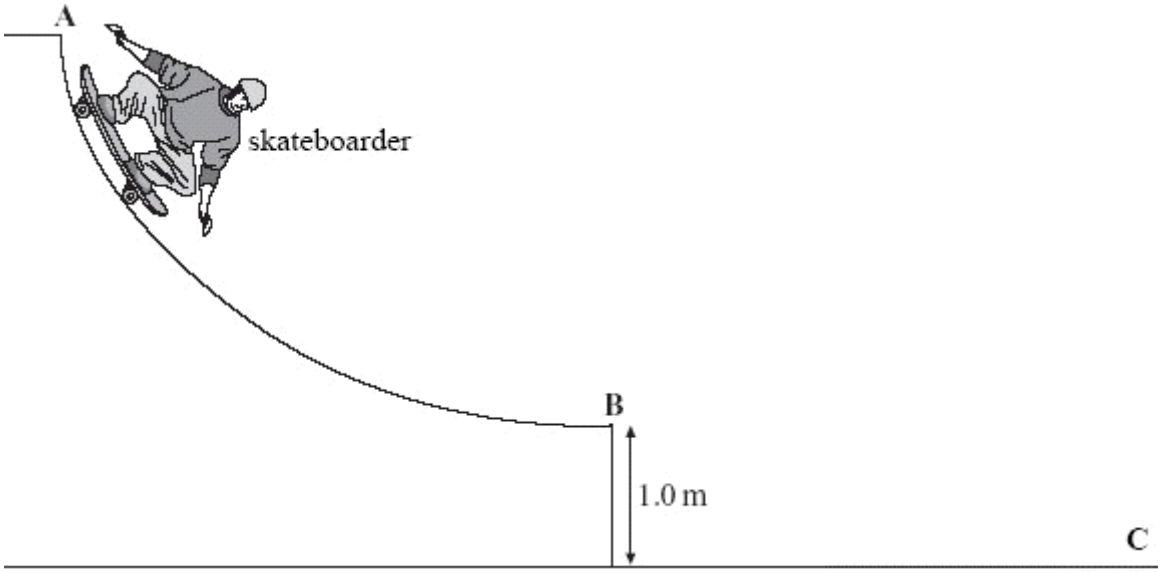
(iii) Draw a path the ray could follow to emerge from prism 2 into the air.

(7)
(Total 10 marks)

105. The figure below shows a skateboarder descending a ramp.



The skateboarder starts from rest at the top of the ramp at **A** and leaves the ramp at **B** horizontally with a velocity *v*.

(a) State the energy changes that take place as the skateboarder moves from **A** to **B**.

.....

.....

(2)

(b) In going from **A** to **B** the skateboarder's centre of gravity descends a vertical height of 1.5 m. Calculate the horizontal velocity, *v*, stating an assumption that you make.

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(3)

(c) Explain why the acceleration decreases as the skateboarder moves from **A** to **B**.

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(2)

(d) After leaving the ramp at **B** the skateboarder lands on the ground at **C** 0.42 s later.

Calculate for the skateboarder

(i) the horizontal distance travelled between **B** and **C**,

.....

.....

(ii) the vertical component of the velocity immediately before impact at **C**,

.....

.....

.....

(iii) the magnitude of the resultant velocity immediately before impact at **C**.

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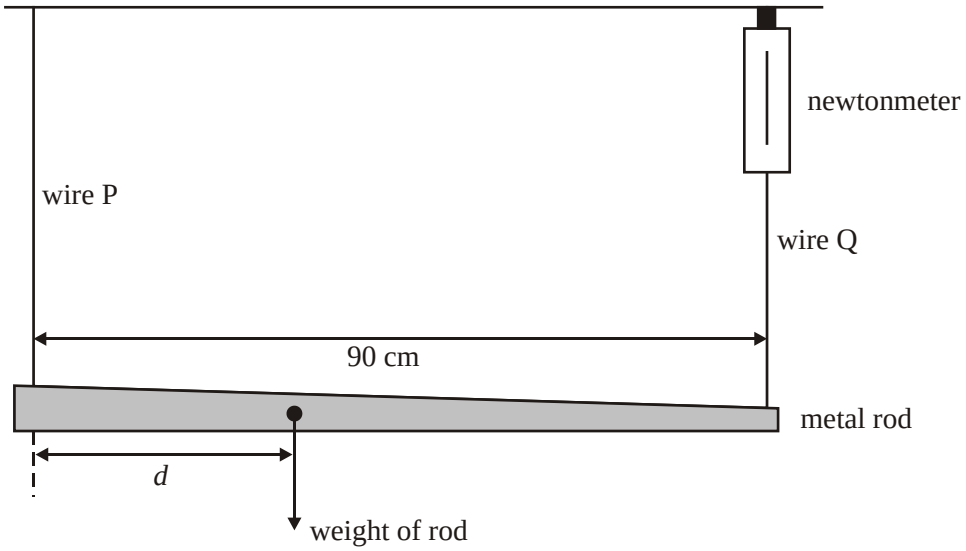
(5)
(Total 12 marks)

106. The figure below shows an apparatus used to locate the centre of gravity of a non-uniform metal rod.



The rod is supported horizontally by two wires, P and Q and is in equilibrium.

(a) State **two** conditions that must be satisfied for the rod to be in equilibrium.

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(2)

(b) Wire Q is attached to a newtonmeter so that the force the wire exerts on the rod can be measured. The reading on the newtonmeter is 2.0 N and the weight of the rod is 5.0 N.
Calculate

(i) the force that wire P exerts on the rod,

.....

(ii) the distance *d*.

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.....

(3)
(Total 5 marks)

107. A supertanker of mass 4.0×10^8 kg, cruising at an initial speed of 4.5 m s^{-1}, takes one hour to come to rest.

(a) Assuming that the force slowing the tanker down is constant, calculate

(i) the deceleration of the tanker,

.....

.....

(ii) the distance travelled by the tanker while slowing to a stop.

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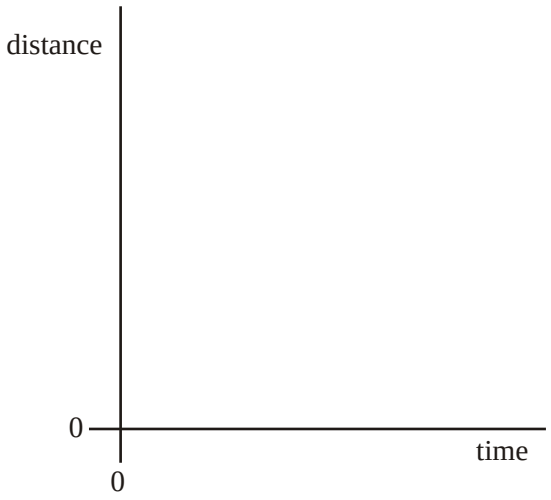
.....

(4)

(b) Sketch, using the axes below, a distance-time graph representing the motion of the tanker until it stops.



(2)

(c) Explain the shape of the graph you have sketched in part (b).

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(2)
(Total 8 marks)

108. (a) (i) Describe the behaviour of a wire that obeys Hooke's law.

.....

.....

(ii) Explain what is meant by the elastic limit of the wire.

.....

.....

(iii) Define the Young modulus of a material and state the unit in which it is measured.

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(5)

(b) A student is required to carry out an experiment and draw a suitable graph in order to obtain a value for the Young modulus of a material in the form of a wire.
A long, uniform wire is suspended vertically and a weight, sufficient to make the wire taut, is fixed to the free end. The student increases the load gradually by adding known weights. As each weight is added, the extension of the wire is measured accurately.

(i) What other quantities must be measured before the value of the Young modulus can be obtained?

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(ii) Explain how the student may obtain a value of the Young modulus.

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(iii) How would a value for the elastic energy stored in the wire be found from the results?

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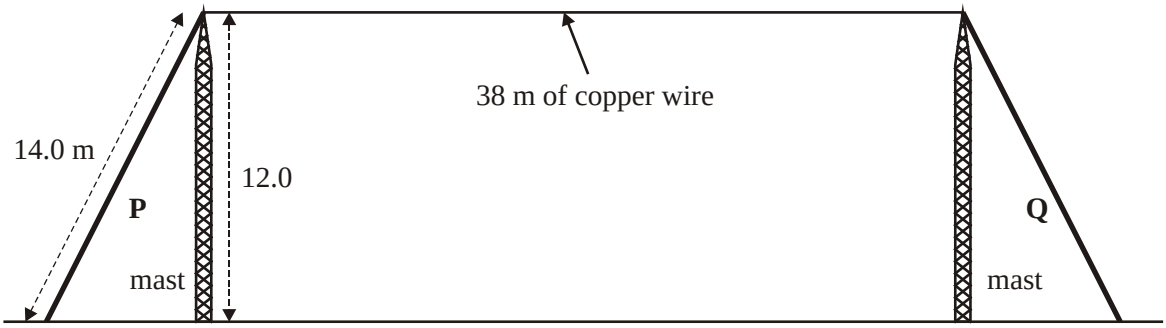
(6)
(Total 11 marks)

109. An aerial system consists of a horizontal copper wire of length 38 m supported between two masts, as shown in the figure below. The wire transmits electromagnetic waves when an alternating potential is applied to it at one end.



(a) The wavelength of the radiation transmitted from the wire is twice the length of the copper wire. Calculate the frequency of the transmitted radiation.

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(1)

(b) The ends of the copper wire are fixed to masts of height 12.0 m. The masts are held in a vertical position by cables, labelled **P** and **Q**, as shown in the figure above.

(i) **P** has a length of 14.0 m and the tension in it is 110 N. Calculate the tension in the copper wire.

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(ii) The copper wire has a diameter of 4.0 mm. Calculate the stress in the copper wire.

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(iii) Discuss whether the wire is in danger of breaking if it is stretched further due to movement of the top of the masts in strong winds.

breaking stress of copper = 3.0×10^8 Pa

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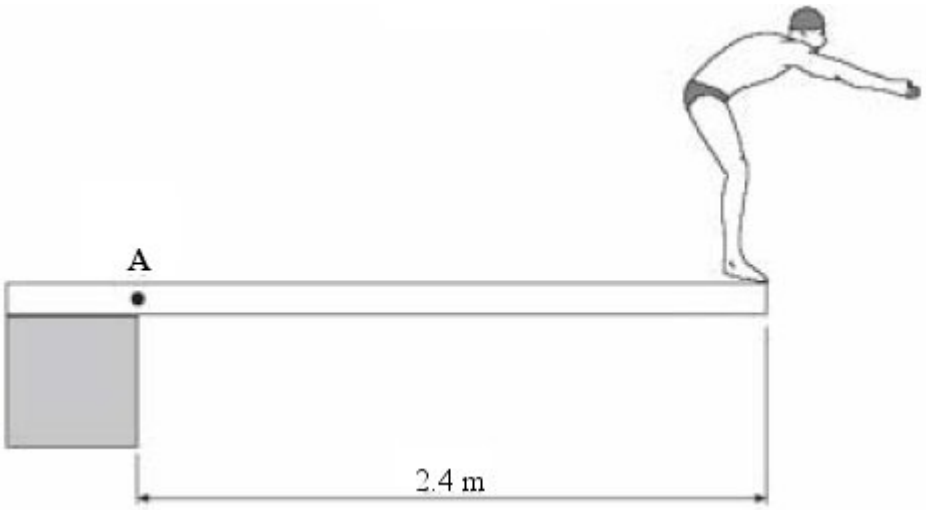
(7)
(Total 8 marks)

110. The diagram below shows a swimmer standing at the end of a diving board above a swimming pool. The mass of the swimmer is 72 kg and the horizontal distance between point A and his centre of mass is 2.4 m.



(a) Calculate the moment of the swimmer's weight about point A.

Gravitational field strength of the Earth, g = 9.8 N kg^{-1}.

Moment .....

(3)

(b) The swimmer dives off the diving board and his centre of mass falls through 3.2 m before he reaches the water. Calculate the swimmer's vertical speed as he enters the water. Neglect air resistance.

Gravitational field strength of the Earth, $g = 9.8 \text{ N kg}^{-1}$

Speed .....

(3)

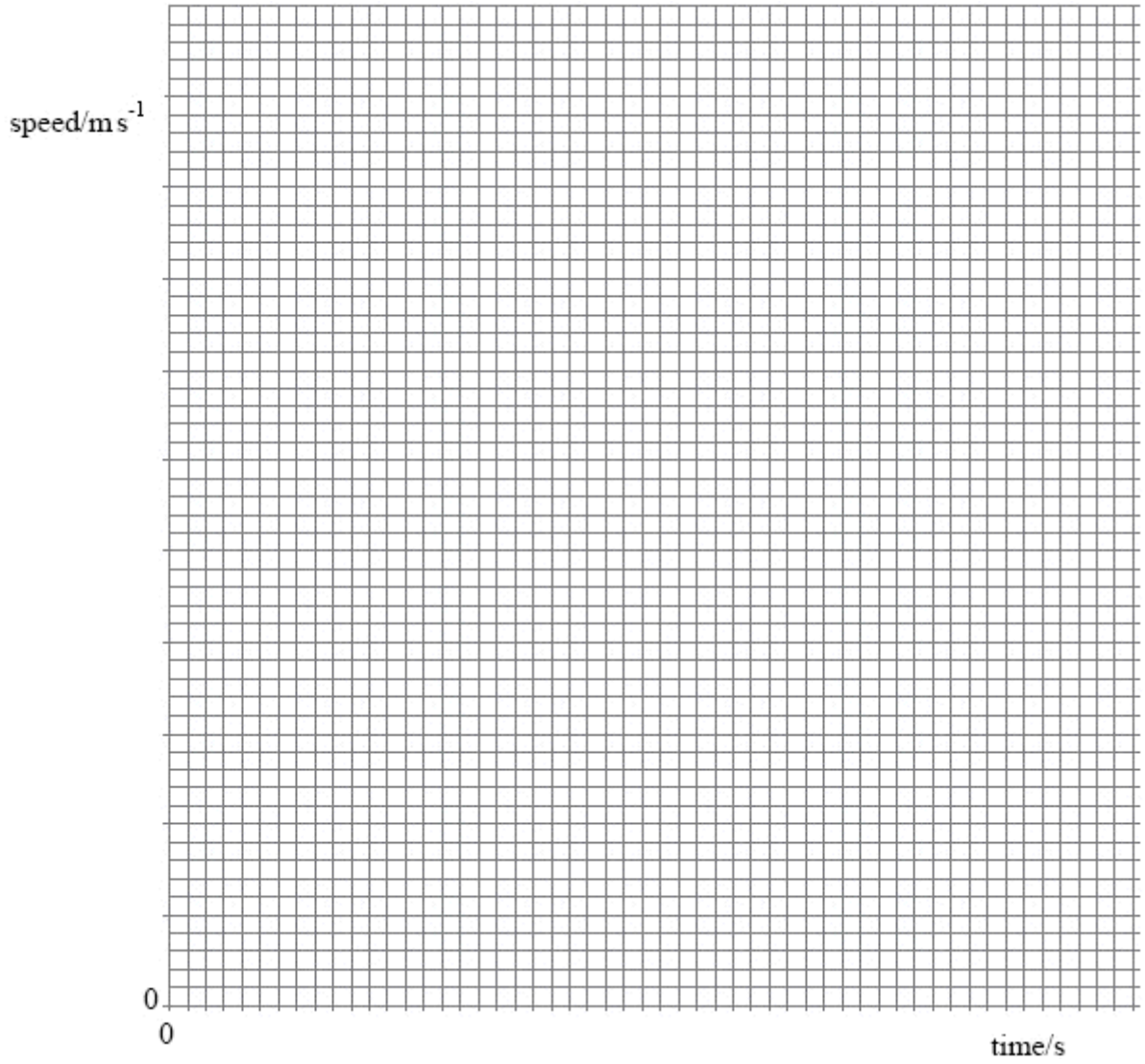
(c) The water brings the diver to rest when his centre of mass is 1.6 m below the surface of the water. Calculate the average total upward force acting on the diver which brings his vertical velocity to zero.

(3)
(Total 9 marks)

111. A car accelerates from rest to a speed of 26 m s^{-1}. The table shows how the speed of the car varies over the first 30 seconds of motion.

time/s	0	5.0	10.0	15.0	20.0	25.0	30.0
speed/m s^{-1}	0	16.5	22.5	24.5	25.5	26.0	26.0

(a) Draw a graph of speed against time on the grid below.



(5)

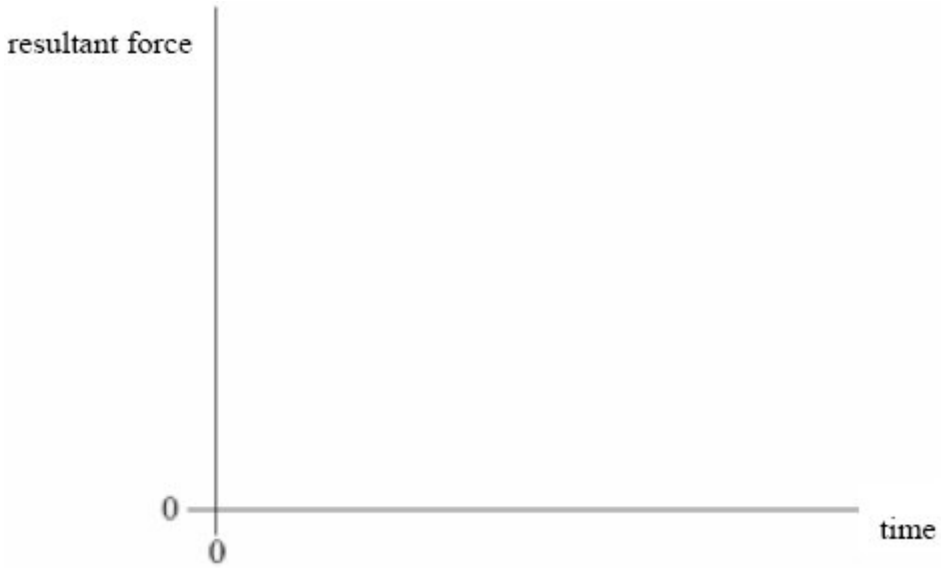
(b) Calculate the average acceleration of the car over the first 25 s.

(2)

(c) Use your graph to estimate the distance travelled by the car in the first 25 s.

(2)

(d) Using the axes below, sketch a graph to show how the resultant force acting on the car varies over the first 30 s of motion.



(3)

(e) Explain the shape of the graph you have sketched in part (d), with reference to the graph you plotted in part (a).

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(2)
(Total 14 marks)

112. (a) (i) Describe the behaviour of a wire that obeys Hooke's law.

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(ii) Explain what is meant by the elastic limit of the wire.

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(iii) Define the Young modulus of a material and state the unit in which it is measured.

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(5)

(b) A student is required to carry out an experiment and draw a suitable graph in order to obtain a value for the Young modulus of a material in the form of a wire. A long, uniform wire is suspended vertically and a weight, sufficient to make the wire taut, is fixed to the free end. The student increases the load gradually by adding known weights. As each weight is added, the extension of the wire is measured accurately.

(i) What other quantities must be measured before the value of the Young modulus can be obtained?

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(ii) Explain how the student may obtain a value of the Young modulus.

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(iii) How would a value for the elastic energy stored in the wire be found from the results?

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(6)

(Total 11 marks)

113. (a) State **two** requirements for two light sources to be coherent.

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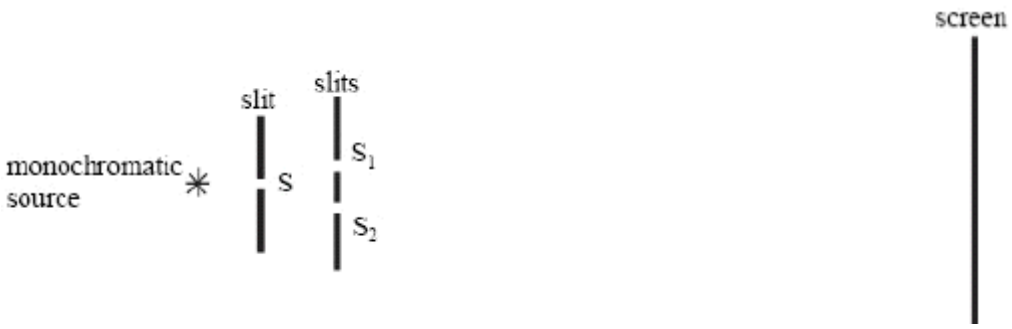
(2)

(b) **Figure 1**



Young's fringes are produced on the screen from the monochromatic source by the arrangement shown in **Figure 1**.
Explain how this arrangement produces interference fringes on the screen. In your answer, explain why slit S should be narrow and why slits S_1 and S_2 act as coherent sources.
The quality of your written answer will be assessed in this question.

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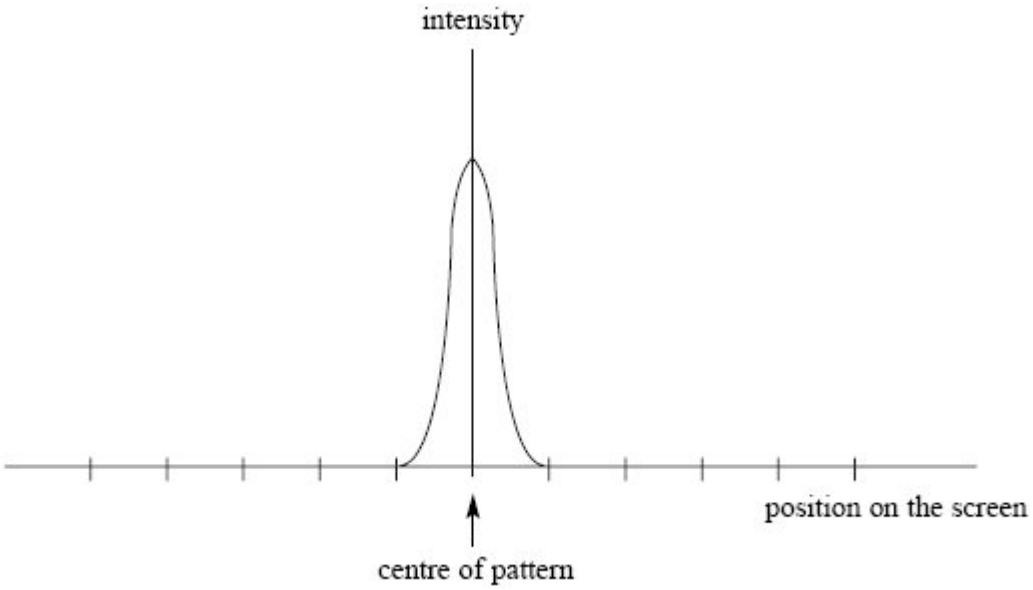
(6)

(c) The pattern on the screen may be represented as a graph of intensity against position on the screen. The central fringe is shown on the graph in **Figure 2**. Complete this graph to represent the rest of the pattern by drawing on **Figure 2**.

Figure 2



(2)
(Total 10 marks)

114. (a) State and explain **two** physical properties of the light produced by a laser which makes it different from the light produced by a filament lamp.

Property 1 .....

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Property 2 .....

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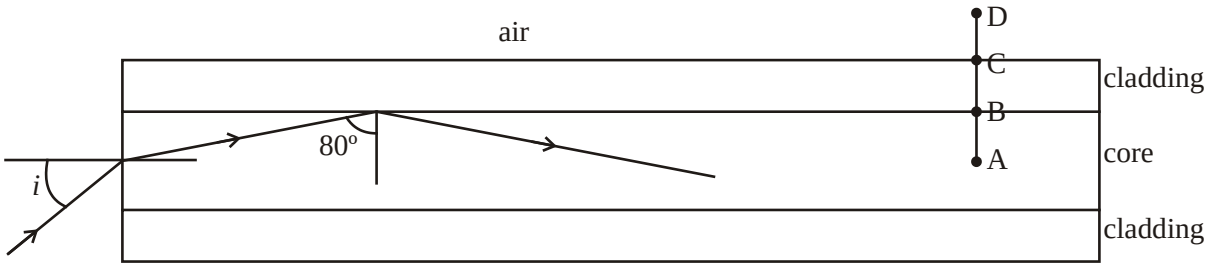
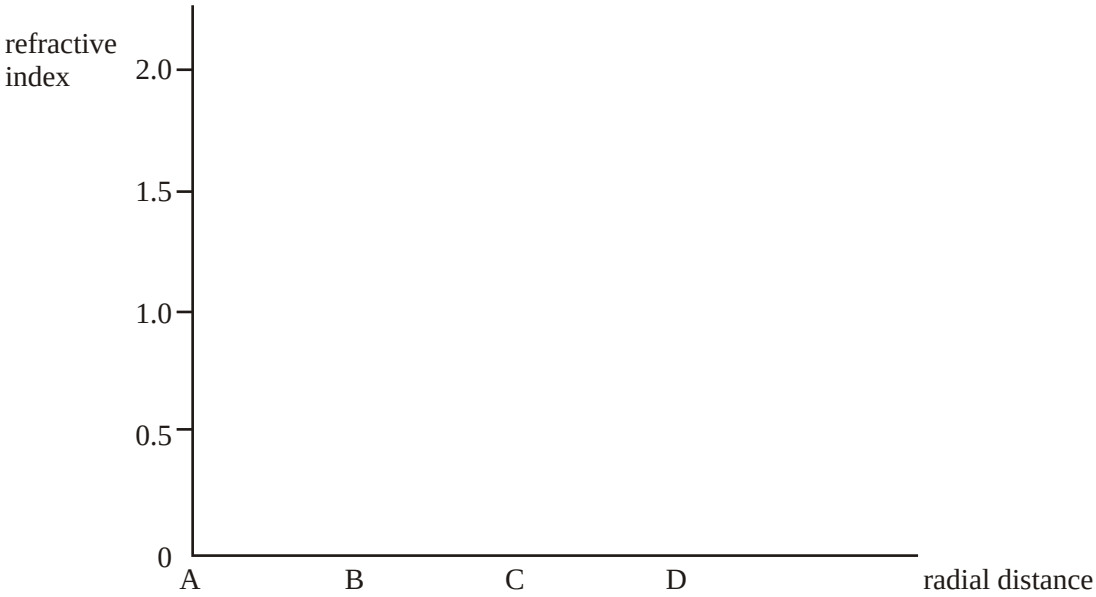
(4)

(b) The diagram below shows a cross-section through an optical fibre used for transmitting information. A laser beam, carrying digital data, is incident on the end of the core of the fibre at an angle of incidence *i*.
The core is made from glass of refractive index 1.5.



(i) Complete the graph below to show how the refractive index changes with radial distance along the line ABCD in the diagram, above.



(ii) Calculate the value of the angle of incidence, *i*, shown in the diagram.

Angle of incidence, *i* .....

(iii) Explain how the glass cladding around the optical fibre's core improves the security of data being transmitted through it and give a reason why this is important.

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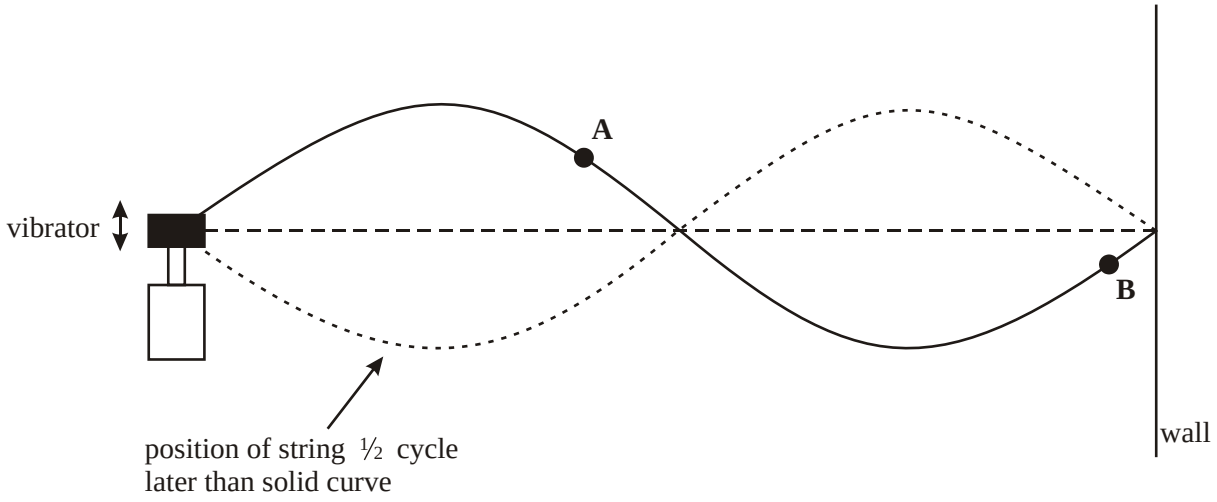
(8)
(Total 12 marks)

115. **Figure 1** shows a stretched string driven by a vibrator. The right-hand end of a string is fixed to a wall. A stationary wave is produced on the string; the string vibrates in two loops.

Figure 1



(a) State the physical conditions that are necessary for a stationary wave to form on the string.

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(3)

(b) State how you know that the wave on the string is transverse.

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(1)

(c) Compare the *amplitude* and *phase* of the oscillations of points **A** and **B** on the string.

Amplitude .....

Phase .....

(2)

(d) The length of the string is 1.2 m and the speed of the transverse wave on the string is 6.2 m s^{-1}. Calculate the vibration frequency of the vibrator.

Vibration frequency .....

(4)

(e) The frequency of the vibrator is tripled.

(i) Sketch the new shape of the stationary wave on **Figure 2**.

Figure 2

(ii) Show on your diagram three points, P, Q and R that oscillate in phase.

(2)

(Total 12 marks)