

## Scholarship Practice Questions

### Question 1

NZS 2008

#### Armageddon

Universal gravitational constant =  $6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$

The volume of a sphere =  $\frac{4}{3}\pi r^3$

The movie "Armageddon" is based on an asteroid "the size of Texas", which is about to collide with the Earth. To protect the Earth, NASA proposes to land a drilling team on the asteroid, who will drill a hole to the centre and detonate a nuclear warhead there. This blast is supposed to split the asteroid into two equal pieces that will each move far enough sideways to safely miss the Earth. However, there is not much time and the explosion will take place only four hours before impact.

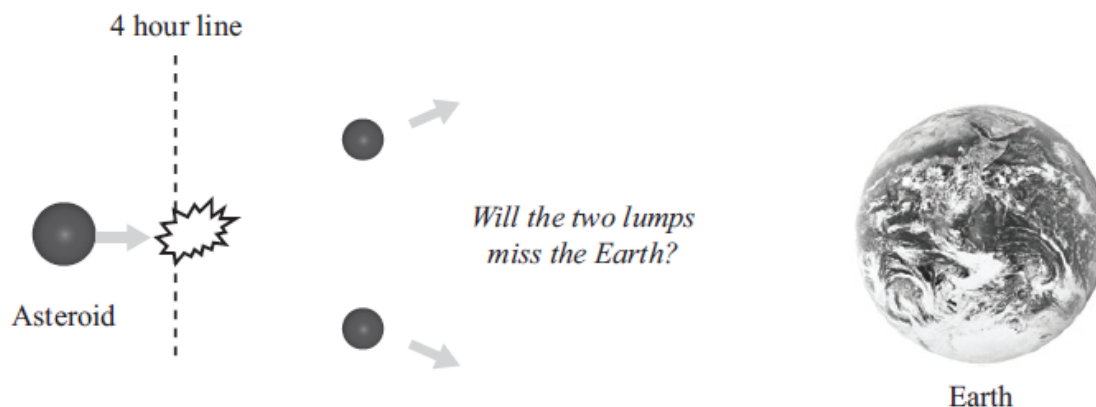
- (a) NASA scientists expect that the blast will not affect the motion of the centre of mass. Explain.
- (b) Using the information and diagram below, work out if the Earth will be saved. Ignore any gravitational attraction between the two lumps, and list any other assumptions you make during your calculation.

Width of Texas =  $1.45 \times 10^6 \text{ m}$

Average density of the asteroid =  $3000 \text{ kg m}^{-3}$

Energy released by the nuclear warhead =  $5 \times 10^{18} \text{ J}$

(this is equivalent to  $10^5$  Hiroshima bombs)



- (c) In reality the two pieces will gravitationally attract each other. Assuming the asteroid splits into two equal-sized spherical lumps, calculate the acceleration caused by the gravitational force of each sphere on the other. State the significance of the result.

### Question 2

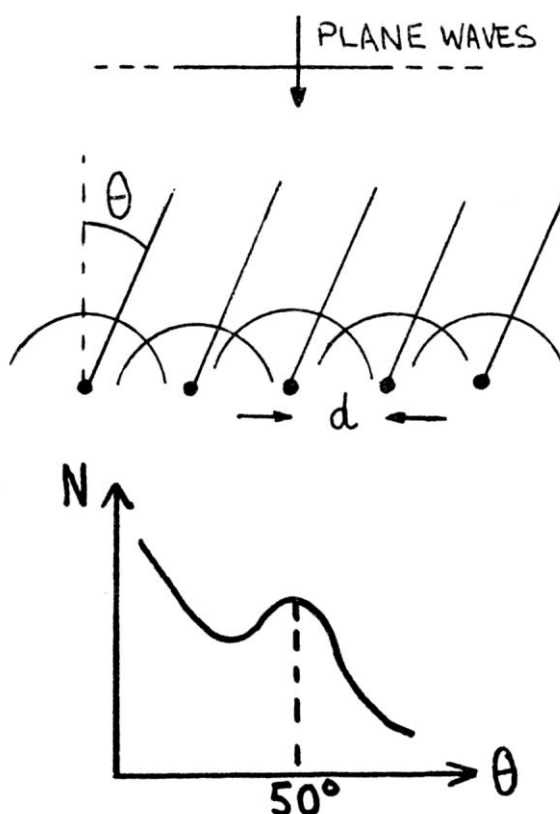
US74

Plane waves are incident normally on a regularly spaced set of scattering points.

- (a) If the waves scattered backward interfere constructively in a direction making an angle  $\theta$  with the normal, show that  $n\lambda = d \sin \theta$ , where  $d$  is the spacing of the sources.

The atoms in the surface of a nickel crystal are regularly spaced,  $d$  being  $2.15 \times 10^{-10} \text{ m}$ .

- (b) Assuming the atoms behave as the scattering points in (a) above, calculate the wavelength of the waves which gave a first order maximum at  $\theta = 50^\circ$ .



In 1927, Davisson and Germer fired a beam of low energy electrons normally at a nickel crystal surface, and measured the number scattered  $N$  for different angles  $\theta$ . The results are illustrated on the figure.

(c) In view of these results and (b) above, how might these electrons be described?

Davisson and Germer were in fact following up an idea of de Broglie, who had suggested in 1924

that a particle of momentum  $p$  should have an associated wavelength  $\lambda = \frac{h}{p}$  where  $h$  is Planck's

constant. To test this idea it will be necessary to calculate  $p$ .

(d) If  $m$  is the mass of the electron,  $e$  its charge and  $V$  the voltage through which the electrons were accelerated, show that

(i)  $E_K = eV$  and

(ii)  $p = \sqrt{2meV}$

(e) Given  $e = 1.60 \times 10^{-19}$  C,  $m = 9.11 \times 10^{-31}$  kg,  $h = 6.63 \times 10^{-34}$  Js, and that the accelerating voltage  $V$  was 54 V, calculate the predicted wavelength.

Did the idea stand up to this experimental test?

### Question 3

UES79

A mass of 1 kg slides along the  $x$ -axis on a horizontal sheet of ice (neglect friction) with a speed of  $5 \text{ ms}^{-1}$ , and another mass of 3 kg slides along the  $y$ -axis with a speed of  $4 \text{ ms}^{-1}$ .

- What are the  $x$  and  $y$  components of the total momentum?
- What are the  $x$  and  $y$  velocity components of the centre of mass?
- What is the total kinetic energy?

The masses collide and stick together.

- What is now the total kinetic energy?
- Determine the  $x$  and  $y$  velocity components of the combined mass.
- What were the velocity components of the masses relative to the centre of mass before the collision?
- What was the total kinetic energy relative to the centre of mass before the collision?

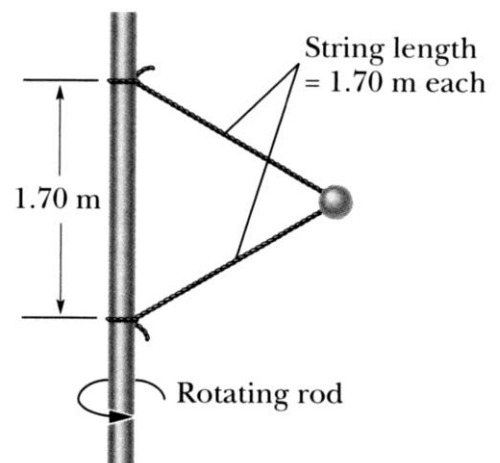
### Question 4

As shown in the diagram, light strings connect a 1.34 kg ball to a vertical rotating rod. The strings are attached to the rod and are taut. The tension in the upper string is 35 N.

(a) Draw a free-body diagram for the ball.

What are

- the tension in the lower string,
- the total force on the ball,
- the speed of the ball?



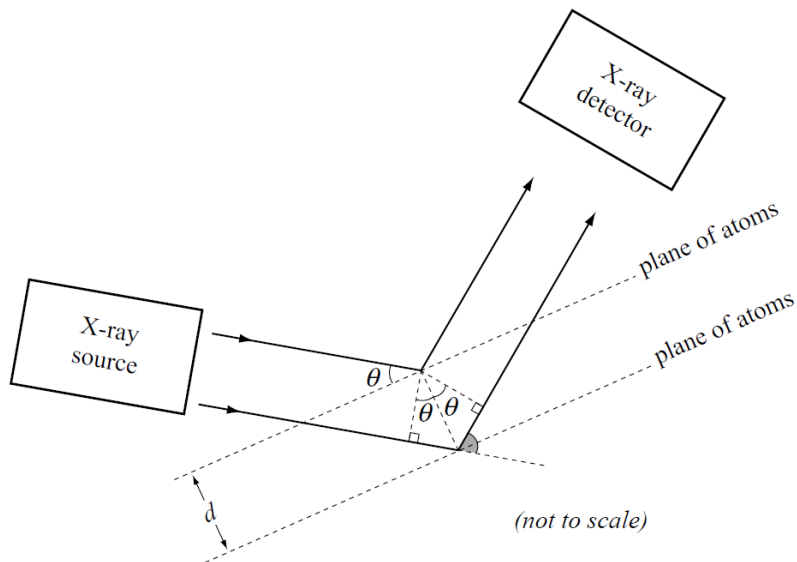
### Question 5

NZS04

#### Bragg's Law

- (a) State the necessary conditions for interference fringes to be produced by two sources of light at a distance  $d$  apart.

The regularly spaced atoms in a crystalline solid can be used to produce interference effects. The diagram shows how incident X-rays are reflected such that there is a path difference between the reflections from adjacent planes of atoms. The distance between each plane is  $d$ .



- (b) Using your knowledge of the necessary conditions for constructive interference of the rays, derive Bragg's Law:

$$m\lambda = 2d \sin \theta \quad m = 1, 2, 3 \dots$$

- (c) In one particular crystalline solid, a third order X-ray diffraction maximum is observed when the shaded angle equals  $29.2^\circ$ . The wavelength of the X-rays is  $1.27 \times 10^{-10}$  m.

Calculate the interplanar distance  $d$ .

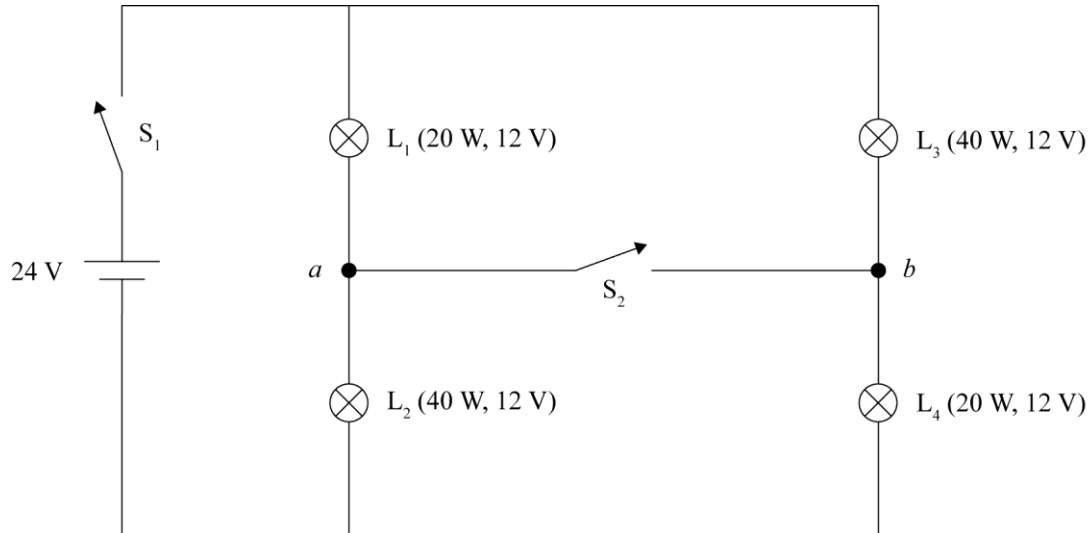
- (d) Given the value of  $d$  calculated above, comment on why X-rays rather than visible light are used for diffraction experiments with crystals.

### Question 6

NZS05

### DC Circuits

David and John buy four electric lightbulbs from the hardware store. Two of them are labelled 20 W, 12 V and the other two are labelled 40 W, 12 V. They set up the following circuit.



- When switches  $S_1$  and  $S_2$  are closed, what is the current through the branch  $ab$  and in what direction is it?
- Switch  $S_2$  is now opened. Explain how the intensities of bulbs  $L_1$  and  $L_2$  change.
- David and John wish to calculate the potential difference between points  $a$  and  $b$ ,  $V_{ab}$ , when switch  $S_2$  is open. What additional information would they require in order to make this calculation?