marks

Therefore $$|\boldsymbol{F}| = \sqrt{F_x^2 + F_y^2}$$ 1

$$= \sqrt{125^2 + 2\,235^2}\ \text{N}$$

$$\approx 2.2 \times 10^3\ \text{N (to 2 sig figs).}$$ 1

This is a huge force compared to that required to raise the centres of mass of the upper body and object with the spine nearly vertical, which would be of order $60\ \text{kg} \times 10\ \text{m s}^{-2} \approx 600\ \text{N}$. Lifting with a bent back places great strain on the lower back. But the torque due to the weight of the upper body dominates, which explains why attempting to pick up even a light load this way can result in injury. 2

Marks for working: 10

Checking

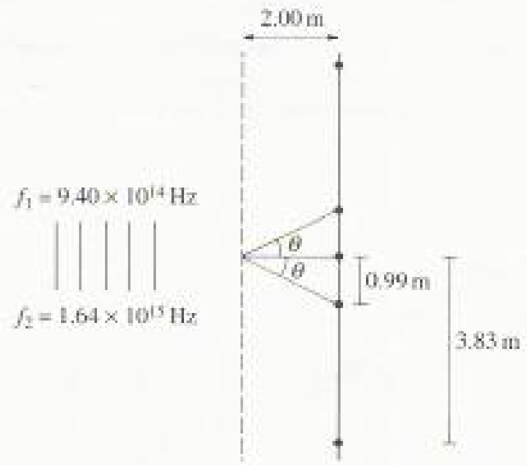
The greater the mass of the object the greater F_1, and hence the greater F_x and ultimately $|\boldsymbol{F}|$. This is in accordance with experience — it's more of a strain to pick up a heavy object than a light one. 1

Marks for checking: 1

Total for Q17: 16

Question 18

Preparation



1

Figure 4

Relevant equations and principles:

$c = f\lambda$

$d \sin \theta_n = n\lambda$ (grating equation) 2

Marks for preparation: 3

Working

The first laser beam has wavelength

$$\lambda_1 = \frac{c}{f} = \frac{3.00 \times 10^8\ \text{m s}^{-1}}{9.40 \times 10^{14}\ \text{Hz}} = 3.19 \times 10^{-7}\ \text{m}.$$ 1

The two spots closest to the central maximum correspond to first order diffraction ($n = 1$) at an angle θ_1, such that

$$\tan \theta_1 = \frac{0.99\ \text{m}}{2.00\ \text{m}} \quad \text{so} \quad \theta_1 = 26.3°.$$ 1

The grating equation then gives

$$d = \frac{\lambda_1}{\sin \theta_1} = \frac{3.19 \times 10^{-7}\ \text{m}}{\sin 26.3°} = 7.20 \times 10^{-7}\ \text{m}.$$ 1

The second laser beam has wavelength

$$\lambda_2 = \frac{c}{f} = \frac{3.00 \times 10^8\ \text{m s}^{-1}}{1.64 \times 10^{15}\ \text{Hz}} = 1.83 \times 10^{-7}\ \text{m}.$$ 1