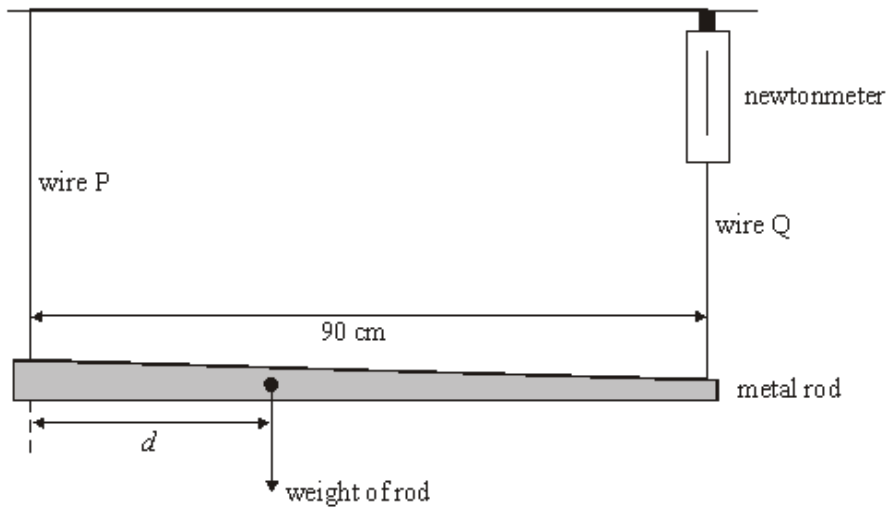**Q1.**   The figure below shows an apparatus used to locate the centre of gravity of a non-uniform metal rod.

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.

....

....

....

....

(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*.

....

....

....

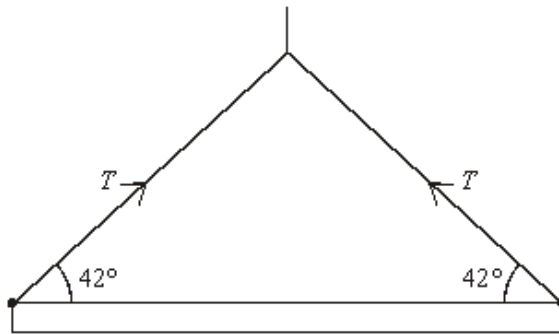**(3)**
(Total 5 marks)

Q2. 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.

   ....

   ....

(4)

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

(1)
(Total 5 marks)

Q3. (a) (i) State **two** vector quantities.

   vector quantity 1 ....

   vector quantity 2 ....

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

   scalar quantity 1 ....

   scalar quantity 2 ....

(2)

(b)   The helicopter shown in **Figure 1a** is moving horizontally through still air. The lift force from the helicopter's blades is labelled **A**.
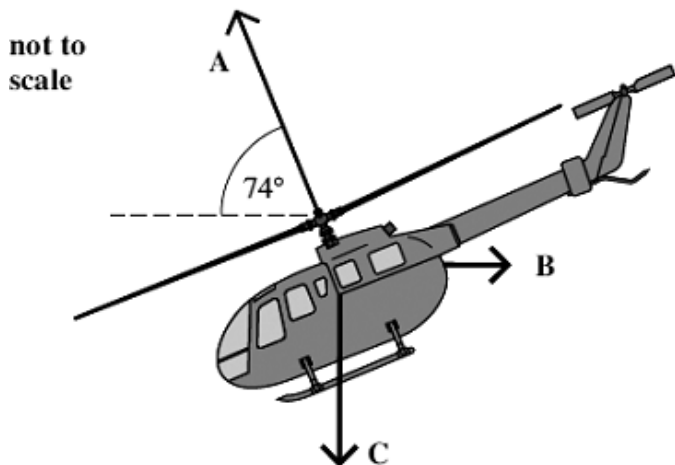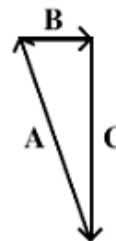
<div align="center">

Figure 1a   **Figure 1b**

</div>

(i)   Name the two forces **B** and **C** that also act on the helicopter.

B ....

C ....

(2)

(ii)   The force vectors are also shown arranged as a triangle in **Figure 1b**.

State and explain how **Figure 1b** shows that the helicopter is moving at a constant velocity.

....

....

....

....

....

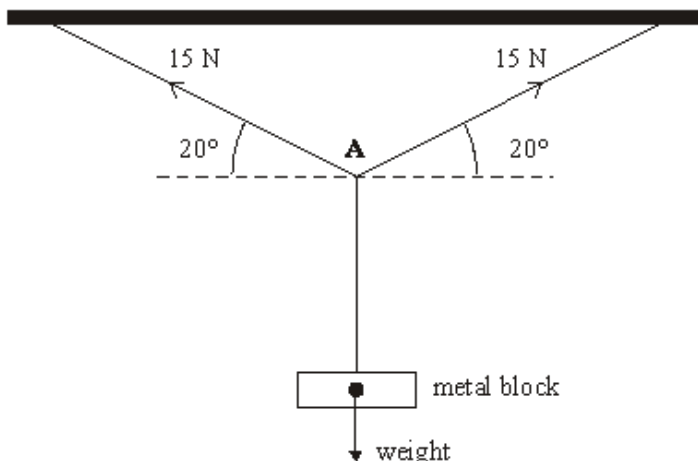(2)

(c)   The lift force, **A**, is 9.5 kN and acts at an angle of 74° to the horizontal.

Calculate the weight of the helicopter. Give your answer to an appropriate number of significant figures.

answer = ... N

(3)

(Total 9 marks)

Q4. 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.

```
                    ┌──────────────────────────────┐
                  15 N                            15 N
                    ↖                              ↗
              20°  ╱        A        ╲  20°
          ─ ─ ─ ─ ╱─ ─ ─ ─ ─ ─ ─ ─ ─╲─ ─ ─

                        │
                        │
                     ┌─────┐
                     │  ●  │  metal block
                     └─────┘
                        ↓ weight
```

(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.

....

....

....

....

....

....

(3)
(Total 6 marks)

Q5.   (a)   (i)   State the difference between a scalar quantity and a vector quantity.
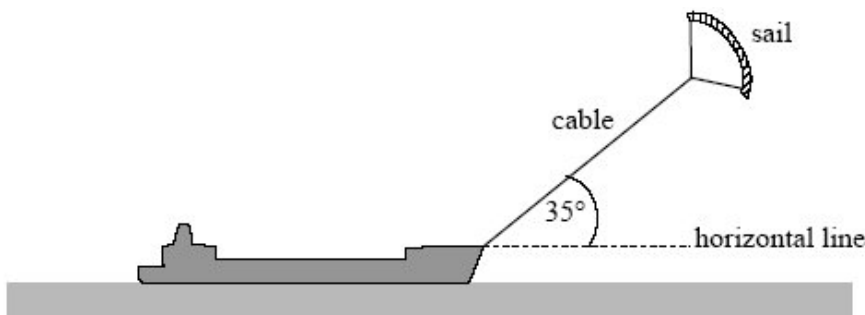
....

....

(1)

(ii)   State **two** examples of a scalar quantity and **two** examples of a vector quantity.

scalar quantities ....

vector quantities …..

(3)

(b)   The diagram below shows a ship fitted with a sail attached to a cable. The force of the
wind on the sail assists the driving force of the ship's propellors.

The cable exerts a steady force of 2.8 kN on the ship at an angle of 35° above a horizontal
line.

(i)   Calculate the horizontal and vertical components of this force.

horizontal component of force .... kN

vertical component of force .... kN

(2)

(ii)   The ship is moving at a constant velocity of 8.3 m s^{-1} and the horizontal component
of the force of the cable on the ship acts in the direction in which the ship is moving.
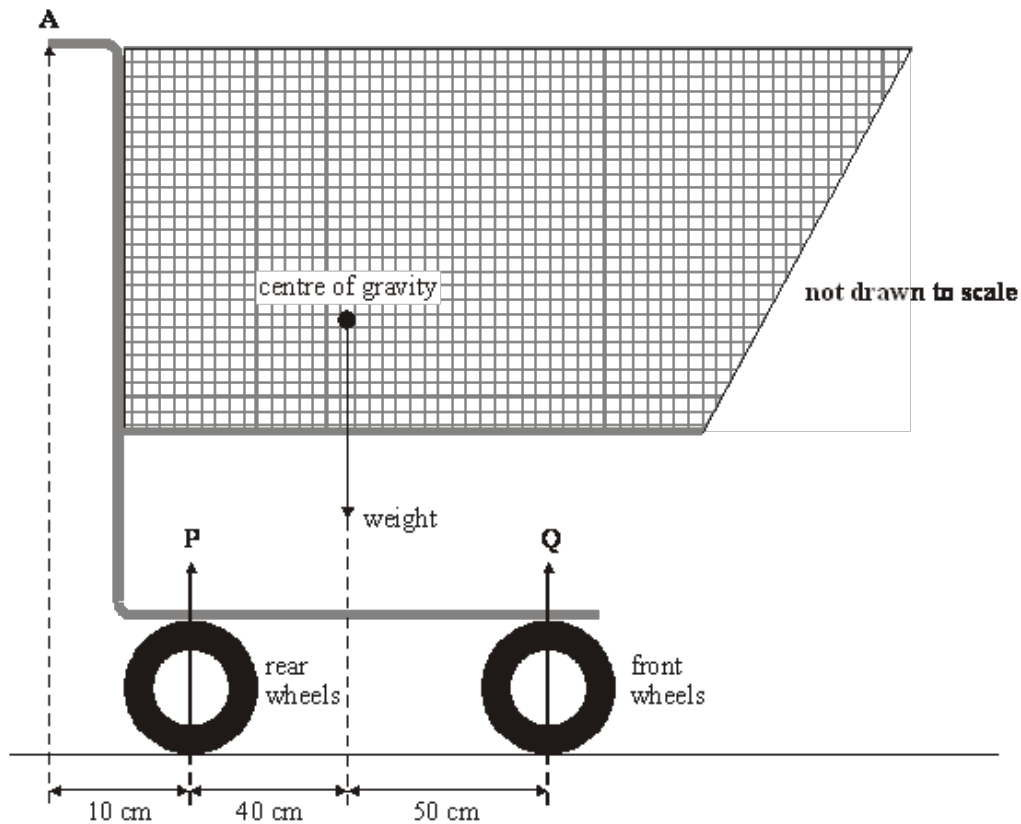Calculate the power provided by the wind to this ship, stating an appropriate unit.

Answer ....

(3)

(c)   The cable has a diameter of 0.014 m. Calculate the tensile stress in the cable when it
       exerts a force of 2.8 kN on the ship, stating an appropriate unit.
       Assume the weight of the cable is negligible.

Answer ....

(5)
(Total 14 marks)

Q6.   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.

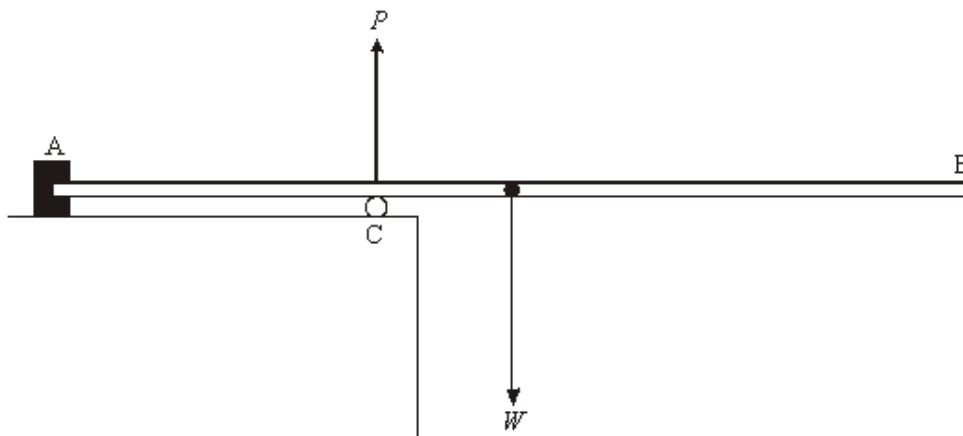...

....

....

....

(3)
(Total 10 marks)

Q7. (a) Define the moment of a force.

....

....

(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*.

....

....

....

....

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

....

....

....

....

(4)
(Total 6 marks)

Q8.   The figure below shows a motorcycle and rider. The motorcycle is in contact with the road at **A** and **B**.
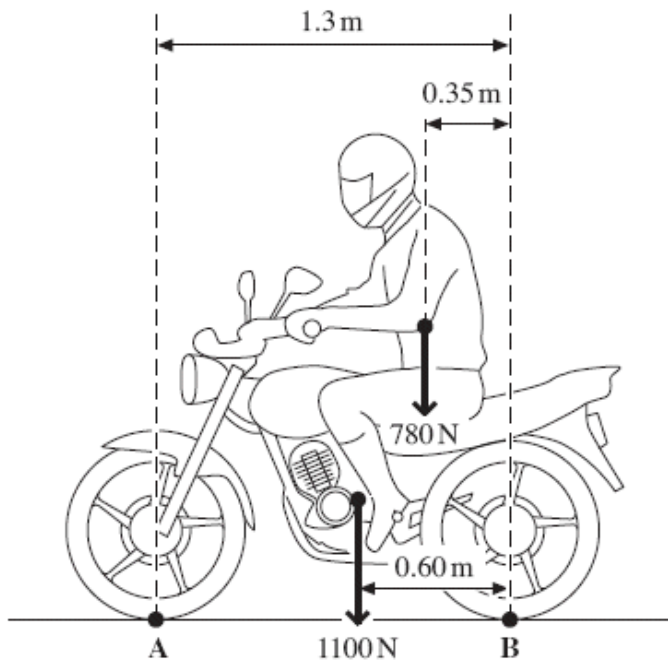
The motorcycle has a weight of 1100 N and the rider's weight is 780 N.

(a)   State the Principle of Moments.

....

....

....

(2)

(b)   Calculate the moment of the rider's weight about **B**. Give an appropriate unit.

answer = ...

(2)

(c) By taking the moments about **B**, calculate the vertical force that the road exerts on the front tyre at **A**. State your answer to an appropriate number of significant figures.

answer = ... N

(4)

(d) Calculate the vertical force that the road exerts on the rear tyre at **B**.

answer = ... N

(1)

(e) The maximum power of the motorcycle is 7.5 kW and it has a maximum speed of 26 m s^{-1}, when travelling on a level road.

Calculate the total horizontal resistive force for this speed.

answer = ... N

(2)
(Total 11 marks)

Q9. The diagram below shows a dockside crane that is used to lift a container of mass 22000 kg from a cargo ship onto the quayside. The container is lifted by four identical 'lifting' cables attached to the top corners of the container.
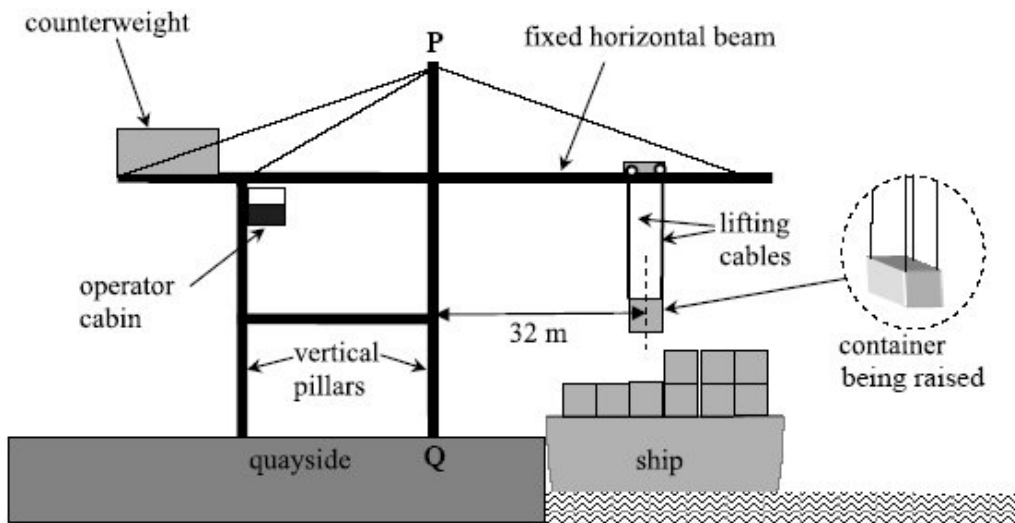
(a) When the container is being raised, its centre of mass is at a horizontal distance 32 m from the nearest vertical pillar **PQ** of the crane's supporting frame.

(i) Assume the tension in each of the four lifting cables is the same. Calculate the tension in each cable when the container is lifted at constant velocity.

answer .... N

(2)

(ii) Calculate the moment of the container's weight about the point **Q** on the quayside, stating an appropriate unit.

answer ....

(3)

(iii) Describe and explain one feature of the crane that prevents it from toppling over when it is lifting a container.

....

....

....

....

....

(2)

(b)   Each cable has an area of cross–section of $3.8 \times 10^{-4} \, m^2$.

  (i)   Calculate the tensile stress in each cable, stating an appropriate unit.

answer ....

(3)

  (ii)   Just before the container shown in the diagram above was raised from the ship, the length of each lifting cable was 25 m. Show that each cable extended by 17 mm when the container was raised from the ship.

Young modulus of steel = $2.1 \times 10^{11} \, Pa$

(2)
(Total 12 marks)

Q10.   (a)   Define the moment of a force about a point.

....

....

....

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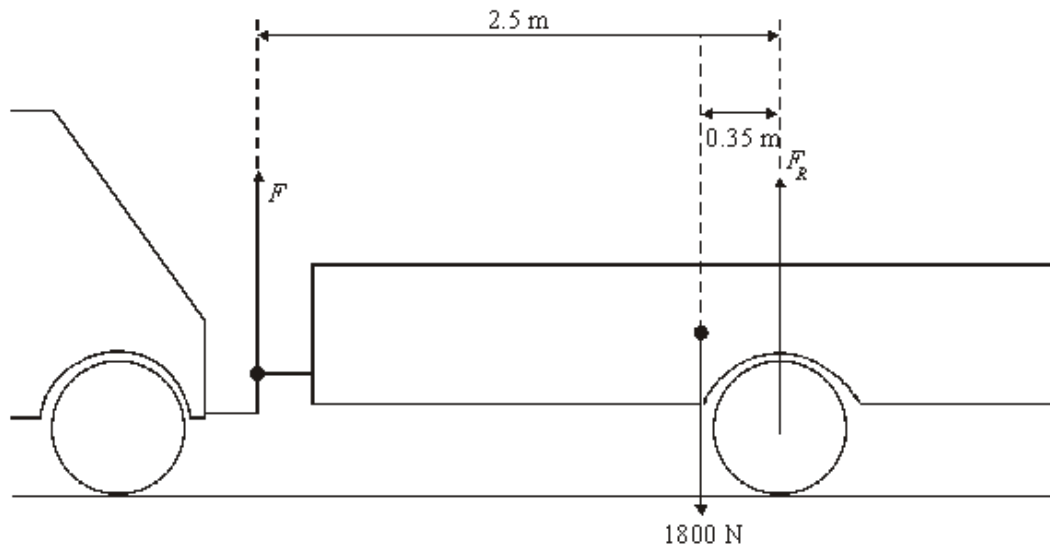
(i)   Explain what is meant by centre of gravity.

....

....

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

....

....

....

(3)

(iii) Calculate F_R.

....

....

....

(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.

....

....

....

....

....

....

(3)
(Total 10 marks)

M1.   (a)   resultant force zero **(1)**
            resultant torque about any point zero **(1)**

2

      (b)   (i)   force due to wire P = 5.0 - 2.0 = 3.0 N **(1)**

            (ii)   (moments give) 5.0 × d = 2.0 × 0.90 **(1)**
                  d = 0.36 m **(1)**

3

[5]

M2.   (a)   (i)   horizontal component = 850 × cos 42 **(1)**
                  = 630 N **(1)** (632 N)

            (ii)   vertical component = 850 × sin 42 = 570 N **(1)** (569 N)
                  (if mixed up sin and cos then CE in (ii))

            (iii)   weight of girder = 2 × 570 = 1100 N **(1)** (1142 N)
                  (use of 569 N gives weight = 1138 N)
                  (allow C.E. for value of vertical component in (ii))

4

      (b)   arrow drawn vertically downwards at centre of girder **(1)**

1

[5]

M3.   (a)   (i)   two from: velocity, acceleration, force etc ✓

1

            (ii)   two from: speed, distance, mass etc ✓

1

      (b)   (i)   B: drag / air resistance ✓

                  C: weight ✓

2

            (ii)   closed triangle (of vectors) ✓

                  so forces are in **equilibrium / resultant force is zero / forces balance**
                  (so moving at constant velocity) ✓

2

(c) W = 9500 sin 74 ✓

    = 9100 ✓ (9132)

    2 sf ✓

                  3

                  [9]

M4.   (a)   (i)   (horizontal) force = zero **(1)**

        (ii)   (vertical) force = 2 × 15 sin 20 **(1)**

                = 10(.3) N **(1)**

                  3

    (b)   (i)   weight (of block) = 10(.3) N **(1)**

             (allow C.E. for value from (a) (ii))

        (ii)   resultant force must be zero **(1)**

             with reference to an appropriate law of motion **(1)**

                  3

                  [6]

M5.   (a)   (i)   vector has direction **and** a scalar does not **(1)**

        (ii)   scalar examples; any two e.g. speed, mass, energy, time, power

             vector examples; any two e.g. displacement, velocity,
             acceleration, force or weight

             (1)(1)(1) for 4 correct, **(1)(1)** for 3 correct, **(1)** for 2 correct

                  4

    (b)   (i)   horizontal component (= 2.8 cos 35) = 2.3 (kN) (2293.6) **(1)**

             vertical component (= 2.8 sin 35) = 1.6(kN) (1606.0) **(1)**

        (ii)   power = force × velocity **or** 2.3 kN × 8.3 m s^{-1} **(1)** (ecf from (b) (i))

             = 1.9 × 10^4 (19037 or 19100) **(1)** ecf

             W (or J s^{-1}) **(1)** (or 19 W (or kJ s^{-1}))

                  5

(c) (area of cross–section of cable =) π × (½ 0.014)^2 **(1)**

= 1.5(4) × 10^{-4} (m^2) (1)

stress (=F/A) = $\dfrac{2800\,N}{1.54 \times 10^{-4}\,m^2}$

(allow ecf here if attempt to calculate area) **(1)**

= 1.8(2) × 10^7 **(1)** ecf

Pa (or N m^{-2}) **(1)**

QWC	descriptor	mark range
good-excellent	The candidate provides a comprehensive and coherent description which includes all the necessary measurements in a logical order. The description should show awareness of the need to use a range of standard masses. In addition, the use of the measurements is explained clearly, including an outline of a graphical method to find the mass of the rock sample, or calculation using two or more standard masses and averaging. For 6 marks there must be a description of how to make accurate measurements.	**5-6**
modest-adequate	The candidate's description includes the necessary measurements using one standard mass as well as the rock sample. The description may not be presented in a logical order and they show little consideration in relation to making the measurements accurately. A clear explanation is provided of how to find the mass of the rock sample from their measurements, including correct use of Hooke's law through calculations or inadequate graphical method.	**3-4**
poor-limited	The candidate knows the necessary measurements to be made using a standard mass and the rock sample. The explanation of how to find the mass of the rock sample may be sketchy.	**1-2**

5

[14]

M6.   (a) the point (in a body) **(1)**

where the weight (or gravity) of the object appears to act

[or resultant torque zero] **(1)**

2

(b) (i) $P \times 0.90 = 160 \times 0.50$ **(1)**
$P = 89$ N (88.9 N)

   (ii) $Q = (160 - 89) = 71$ N **(1)**
(allow C.E. for value of *P* from (i))

                           3

(c)   (minimum) force $\times 0.10 = 160 \times 0.40$ **(1)**

force $= 640$ N **(1)**

                           2

(d)   force is less **(1)**

because distance to pivot is larger **(1)**

smaller force gives large enough moment (1)

                           3
                                 [10]

M7.   (a)   product of the force and the **perpendicular distance (1)**
reference to a point/pivot **(1)**

                           2

(b) (i)   since *W* is at a greater distance from A **(1)**
then *W* must be less than *P* if moments are to be equal **(1)**

    (ii)   *P* must increase **(1)**
since moment of girl's weight increases as she moves from A to B **(1)**
correct statement about how P changes
(e.g. P minimum at A, maximum at B, or P increases in a
linear fashion) **(1)**

                           max 4
                                 [6]

M8.   (a)   (sum of) clockwise moment**s** (about a point) =(sum of) anticlockwise
moment**s (1)**

(for a system) in equilibrium **(1)**
accept balanced not stationary

                           2

(b) $(780 \times 0.35 =)$ 270 (Nm) **(1)** (273)

Nm (1) or newton metre(s) accept Newton metre(s)
(not J, nm or nM, Nms, etc)

                           2

(c)   (b) + (1100 × 0.60) **(1)**

(=) F_A × 1.3 **(1)** (F_A = 660 + 273/1.3 gets both marks)

(= 933/1.3) = 720 (N) **(1)** (717.7 or 715 for use of 930)
            ecf (b)

2 sf only (1)
            independent mark

4

(d)   (780 + 1100 – (c)) = 1200 **(1)** (1162 N)
            ecf (c)

1

(e) $\left(F = \dfrac{P}{v}\right) = \dfrac{7.5(\times 10^3)}{26}$ **(1)**

            must be arranged in this form

= 290 (N) **(1)** (288.46)

2

[11]

M9.   (a)   (i)   weight of container (= mg = 22000 × 9.8(1)) = 2.16×10^5 (N) **(1)**

                tension (= ¼ *mg*) = (5.39) 5.4×10^4 (N) or divide a weight by 4 **(1)**

        (ii)   moment (= force × distance) = 22000 *g* × 32 **(1)** ecf weight in (a) (i)

                = 6.9 or 7.0×10^6 **(1) N m** or correct base units **(1)** not J, nm, NM

        (iii)   the counterweight **(1)**

                provides a (sufficiently large) anticlockwise moment (about Q)
                or moment in opposite direction (to that of the container to
                prevent the crane toppling clockwise) **(1)**

                or
                left hand pillar pulls (down) **(1)**
                and provides anticlockwise moment

                or
                the centre of mass of the crane('s frame and the counterweight)
                is between the two pillars **(1)**

                which prevents the crane toppling **clockwise**/to right **(1)**

7

(b) (i) (tensile) stress $(= \dfrac{\text{tension}}{\text{csa}}) = \dfrac{5.4 \times 10^4}{3.8 \times 10^{-4}}$ ecf (a) (i) **(1)**

= 1.4(2) × 10⁸ **(1) Pa** (or N m⁻²) **(1)**

(ii) extension = $\dfrac{\text{length} \times \text{stress}}{E}$ or $\dfrac{FL}{EA}$ **(1)**

$= \dfrac{25 \times 1.4 \times 10^8}{2.1 \times 10^{11}}$ and (= 1.7 × 10⁻² m) = 17 (mm) **(1)**

5

[12]

M10. (a) (moment) force × perpendicular **(1)** distance (from the point) **(1)**

2

(b) (i) the point in a body where the resultant torque is zero
[or where the (resultant) force of gravity acts or where the weight
acts through] **(1)**

(ii) $F \times 2.5 = 1800 \times 0.35$ **(1)**
$F = 250$ N **(1)**   (252 N)

(iii) $F_R = (1800 - 252)$ **(1)**
= 1500 N **(1)**   (1548) N
[use of $F = 250$ N gives $F_R = 1550$ N or 1600 N)
(allow C.E. for incorrect value of F from (ii))

5

(c) force must have a horizontal component **(1)**
F (therefore) increases in magnitude **(1)**
and act at an angle (to the vertical) towards the car **(1)**

3
QWC 1

[10]