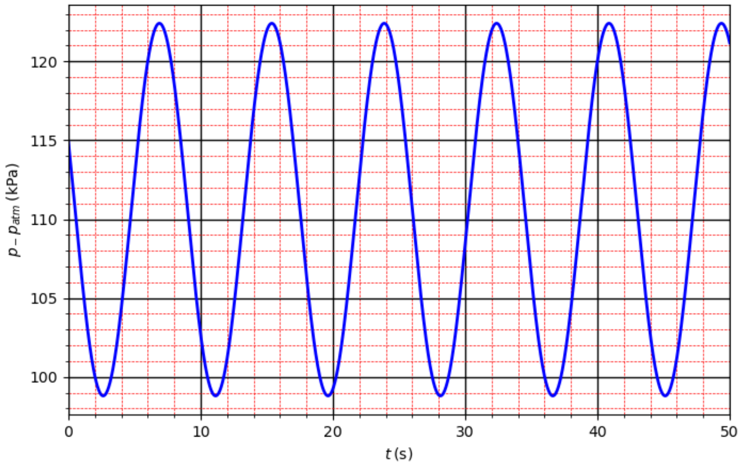
Q1.
An oil drilling platform is to be installed at a location where the mean water depth is 20 m. A design wave has been selected of height 8 m and period 13 s. Consider this wave to be regular and find:
(a) the wavelength and phase speed;
(b) the maximum horizontal acceleration at the surface, mid-depth and the bottom.

Q2. (Exam 2019 – part)
Regular-wave measurements are obtained from stationary sensors in different depths as listed in the table below. For each wave, identify the wave type (shallow-water, deep-water or intermediate) and speed of a wave crest in the wave direction (relative to the sensor).

Wave	Period T (s)	Depth h (m)	Current U (m s^{-1})
A	10	20	0
B	12	3	0
C	6	24	–0.8

Q3.
A pressure gauge is located on the seabed in water 15 m deep. It records a pressure which is periodic at a frequency of 0.1 Hz, and fluctuates over a range (minimum to maximum) of 9.5 kN m^{-2}. Estimate the wave height and wave length.

Q4.
A pressure transducer is located on the sea bed. It records a periodic pressure trace, part of which is shown below. Estimate the depth of water, wave height and wave length if:
(i) there is no current;
(ii) there is a current of 2 m s^{-1} in the direction of wave travel.
Take the density of seawater as 1025 kg m^{-3}.



Q5.
A pressure transducer is installed 2 m above the seabed in water depth of 22 m. Waves arriving from a distant storm result in time-varying pressure of amplitude 10 kPa and a period of 12 s. Assuming that the sea bed slope is gentle and that the depth contours are straight and parallel, estimate the wave height:

(a) nearshore at 8 m depth;
(b) at a deep-water location.

Q6.
Observations of the water particle motions at mid-depth beneath a sinusoidal wave in water of 1 m depth indicate an elliptical path with major semi-axis 0.1 m and minor semi-axis 0.05 m. Determine the wave height, period and wavelength.

Q7.
In water of depth 20 m a wave height of 2 m is measured by a stationary sensor. Calculate the wavelength and maximum particle speed for the following cases:

(a) an apparent period of 3 s and following current of 1 m s^{-1};
(b) an apparent period of 7 s and opposing current of 1 m s^{-1}.

Q8.
Deep-water waves approach a straight beach of uniform slope obliquely, In 6 m depth, waves have a height of 0.8 m, period 5.5 s and crests make an angle of 47° to the depth contours. Calculate the deep-water height H_0 and corresponding angle θ_0.

Q9.
A wave propagates normally toward a coastline over straight and parallel contours. The deep-water wavelength and height are 300 m and 2 m respectively.

(a) What are the wavelength, height and group velocity at depth of 30 m?
(b) What is the average energy per square metre of surface at the site of interest?
(c) How would wavelength, height and group velocity change at the 30-m depth if wave crests were oriented at 60° to the depth contours in deep water.

Q10. (Exam 2022)
A straight coastline borders a uniformly-sloping sea bed. Regular waves of wavelength 55 m and height 1.8 m are observed to cross the 9 m depth contour at an angle of 25° to the coastline-normal. Find:

(a) the wave period;
(b) the deep-water wavelength;
(c) the direction in deep water;
(d) the wave height in deep water.

Q11.
Waves approach a beach of gentle slope orthogonally. Measurements at a location where the depth is 10 m indicate a wave height of 1 m and a period of 8 s.

(a) Calculate the wave height at 3 m depth.

(b) Estimate the breaking depth, h_b, and the corresponding breaking wave height, H_b, using a breaker depth index $\gamma_b = 0.78$, assuming it breaks as a shallow-water wave.

Q12.
A wave train has a narrow-band spectrum with a central frequency of 0.2 Hz. The wave height is found to exceed 2 m on average every 8 minutes.

(a) How often would you expect the wave height to exceed 3 m?

(b) What is the median wave height?

Q13.
A wave train has a narrow-band spectrum and a significant wave height of 2 m. Calculate:

(a) H_{rms};

(b) $H_{1/10}$;

(c) the probability that waves have a height between 4 m and 5 m.

Q14.
Consider an irregular wave field in deep water with significant wave height $H_s = 2.5$ m and peak period $T_p = 6$ s. The time variation of the surface elevation is to be simulate by the superposition of 6 regular wave components with frequencies

$$f_i = [0.75, 1.0, 1.25, 1.5, 1.75, 2.0] f_p$$

Use a Bretschneider spectrum to obtain:

(a) a suitable amplitude for each of these six regular wave components;

(b) the wavenumber of each regular wave component.

At one instant, all six wave components are found to be in phase.

(c) At this time obtain the crest height above SWL and the maximum particle velocity 5 m below the SWL.

Q15. Exam 2022 (part)

An irregular wavefield at a deep-water location is characterised by peak period of 9.1 s and significant wave height of 2.1 m. Assuming a Bretschneider spectrum, estimate the power density (in kW m^{-1}) associated with the frequency range 0.15 to 0.16 Hz of the irregular wave field.

Q16.

(a) Explain the concepts of "fetch-limited" and "duration-limited" waves.

(b) A 13.5 m s^{-1} wind acting over a fetch of 64 km lasts 3 hours. Estimate, from the JONSWAP curves, deep-water values of H_s and T_s. Are the waves fetch- or duration-limited?

Q17.

A long block-type caisson with rectangular section height and 10 m and breadth 4 m (in the direction of wave approach). Consider a design wave period of 6 s and incident wave height of 1.5 m. Assuming that the wave is wholly reflected by the breakwater and that it has porous foundation, use a piecewise-linear pressure distribution to estimate:

(a) the net horizontal wave-induced force per metre length of caisson;

(b) the wave-induced moment about the heel of the structure per metre length.

Some Previous Exam Questions (Other Questions can be found in the Notes)

Q18. (Exam 2021)

Monochromatic waves of frequency 0.1 Hz propagate toward a straight shoreline. Measured where the depth is 18 m they are found to have height 2.1 m and direction 25° to the shoreline normal.

(a) Find the period, wavelength, phase speed and wave power (per metre of crest) at the measurement location.

(b) Find the wave height and wave direction in water of depth 6 m.

(c) Using the Miche breaking criterion, and assuming that waves break in a region where the shallow-water approximation is valid, find the depth of water at which the waves break.

Q19. (Exam 2021)

(a) During a storm, wind blows at a constant 35 m s^{-1} over a fetch 150 km. Calculate the significant wave height and peak wave period using the JONSWAP curves if the storm duration is:
   (i) 4 hours;
   (ii) 8 hours.

(b) Narrow-banded waves with period 9 s and height $H_{\mathrm{rms}} = 1.8$ m are recorded in deep water by a wave buoy. Estimate how often a wave exceeding 3.0 m would be encountered:
   (i) at the wave buoy;
   (ii) when the waves have propagated into coastal waters of depth 10 m; (assume normal incidence to the coast).

Q20. (Exam 2020)

(a) Define the following terms for water waves:
   (i) refraction;
   (ii) diffraction;
   (iii) shoaling.

(b) Deep-water waves with a period of 12 s and height 3 m approach a coastline with wave crests making an angle of 20º to the depth contours. Find the wavelength, wave direction and wave height at depth 5 m.

(c) If the beach slope is 1 in 20, use the breaker height and breaker depth indices to estimate wave height and water depth at breaking.

Q21. (Exam 2020)

(a) In the context of ocean waves, what is meant by:
   (i) "narrow-banded sea state";
   (ii) "significant wave height" (either definition will be accepted);
   (iii) "energy spectrum";
   (iv) "duration-limited".

(b) In a narrow-banded sea state, waves with period 10 s and height $H_{\rm rms} = 2.5$ m are recorded off an estuary.
   (i) In one hour, how many waves are expected to exceed a height of 3.5 m?
   (ii) Estimate how often a wave exceeding height 5 m would be recorded.
   (iii) Assuming deep-water behaviour, what are the wavelength, celerity and group velocity of such waves?

(c) During a storm, wind blows at a constant 20 m s^{-1} over a fetch of 100 km for 6 hours. Determine whether the sea state is fetch- or duration-limited and calculate the significant wave height and peak period using the JONSWAP curves.

Q22. (Exam 2019)
A caisson-type breakwater is to be installed in water depth of 12 m running North to South along a coastline with shallow angle bed slope. Waves are measured in 100 m depth at a location offshore from the deployment site.

(a) Wind-generated irregular waves are measured and approximated by a regular wave with period 7 s, height 1.8 m and heading 90^o (due East).
  (i) Explain two types of breaking wave, identifying the type of bed slope on which each typically occurs.
  (ii) Calculate the height of these waves when propagated to the intended structure depth.
  (iii) Estimate the overturning moment due to wave-induced force on the vertical face of a caisson-type breakwater. Accompany your answer with a sketch of the pressure distribution on the structure.

(b) At a later time, measurements at the same offshore location indicate that swell waves occur *with* the wind-generated waves and are described by a second regular wave with period 13 s, height 1.3 m and heading 120^o.
  (i) Show that the energy from these waves would be expected to reach the shore at an earlier time than the wind-waves in part (a).
  (ii) Determine the wave heading and height at the intended structure depth and hence the caisson height required to avoid overtopping due to a combination of wind and swell waves.

Q23. (Exam 2018)
A sensor fixed 2 m above a flat bed records time-varying velocity. Mean water depth is 8 m. Measurements in the absence of current indicate that horizontal velocity varies sinusoidally with amplitude 0.34 m s^{-1} and period 5 s:

(a) Provide an annotated sketch showing depth variation of hydrodynamic pressure that would be expected for the following wave types:
  (i) shallow-water wave;
  (ii) deep-water wave.

(b) Calculate the non-dimensional wavenumber (kh) and identify the wave type.

(c) Use the expression for velocity potential to obtain:
  (i) an expression for the amplitude of horizontal velocity at mean water line;
  (ii) the wave height;
  (iii) maximum horizontal acceleration of particles at the bed.

Q24. (Exam 2018)

Waves propagate towards a straight shoreline. The wave heading is equal to the angle formed between wave crests and the bed contours. The bed slope is less than 1 in 100. Waves are measured from a fixed sensor in water depth of 35 m.

Measured conditions are approximated as regular waves with period 9 s and amplitude 0.8 m.

(a) State the meaning of the term "significant wave height" and determine the value of this parameter for an irregular wave with equivalent energy period to this regular wave.

(b) State the meaning of the term "shoaling" and explain the range of depths over which linear theory can be used to predict this behaviour.

(c) Estimate the wavelength and wave power per metre width of crest if the measurements are obtained whilst mean flow velocity is:
- (i) negligible;
- (ii) 0.50 m s^{-1} against the wave direction.

(d) If there is no current and the measured wave heading is 25°, calculate the wave heading and wave power per metre width of crest at 5 m depth. State your assumptions.

Q25. (Exam 2017)

A sensor fixed 1.5 m above a flat sea-bed records time-varying pressure. Mean water depth is 24 m. Pressure variation due to propagating waves is measured in the absence of current and found to vary sinusoidally with amplitude 1.22 kN m^{-2} and period 6 s.

(a) Determine the wavelength and speed of this wave.

(b) Use the expression for velocity potential to obtain:
- (i) an expression for dynamic pressure;
- (ii) the wave height;
- (iii) maximum horizontal velocity of a particle.

(c) In the context of linear wave theory, explain the physical meaning of the terms *kinematic boundary condition* and *dynamic boundary condition*.

(d) Determine the wave period that would result in the same absolute period if this were recorded in the presence of a uniform flow of 0.6 m s^{-1} in the wave direction.

Q26. (Exam 2016)
Waves propagate in constant water depth of 1.2 m. Vertical acceleration is measured at the surface by a stationary sensor and found to fluctuate with period of 1.5 s.

(a) For this wave type, sketch particle trajectories near still water line, mid-depth and the bed.

(b) Derive an expression for the vertical acceleration of a particle at depth z. Hence calculate wavelength, wave height and power density if vertical acceleration is 0.88 m s^{-2} at the free surface.

(c) Determine the wavelength that would generate the same absolute period if waves propagate over an opposing uniform flow of speed $U = 0.3 \text{ m s}^{-1}$.

(d) Explain the characteristics of spilling breakers. Using the Miche criterion, estimate the maximum height of deep-water waves of period 1 s prior to the onset of breaking.

Q27. (Exam 2016 – part)
A breakwater is located in 4 m water depth parallel to the coastline and comprises a rectangular cross-section with base width 3 m. Consider incident waves with period 5.5 s and height 0.75 m.

(a) Determine the period and wavelength of the wave in deep water that would cause these conditions at the breakwater.

(b) Sketch the depth variation of hydrostatic and hydrodynamic pressure on the breakwater. State values of hydrodynamic pressure at wave crest, still water line and seabed.

(c) Calculate the wave induced overturning moment about the heel of the breakwater. State the moment as per metre width of wave crest.

Q28. (Exam 2015 – part)
A velocity sensor is located 3 m above the bed in a water depth of 23 m.

(a) Determine the largest values of wavelength and period that could be considered as deepwater conditions.

(b) For a wave period of 9 s:
  (i) Calculate the wavenumber and wavelength.
  (ii) Starting with an expression given on the formula sheet, derive an expression for the amplitude of horizontal particle velocity at depth z. Hence calculate the wave height if horizontal velocity of 0.31 m s^{-1} is measured at the sensor.
  (iii) Calculate the horizontal particle velocity at $z = 0$ and compare to the wave speed.

Q29. (Exam 2015 – part)
Irregular waves characterised by $H_s = 1.5$ m occur at a deep-water location after a wind speed of 14 m s^{-1} has persisted for 6 hours. Determine whether these conditions are duration-limited.

Q30. (Exam 2014)
Wave conditions are often measured using either a floating accelerometer, located at the surface, or by a pressure sensor, located near the bed. Both measurement approaches are employed to measure waves in a water depth of 20 m.

(a) In the context of linear wave theory, explain the physical meaning of each of the following expressions:
 (i) kinematic boundary condition;
 (ii) dynamic boundary condition.

(b) For one sample, time variation of total pressure (kN m^{-2}) is described by:

$$p(t) = 191 + 6.47\cos(\frac{2\pi t}{8})$$

 (i) Obtain the wavelength and speed.
 (ii) Starting with expressions given on the datasheet, derive an equation for dynamic pressure and hence calculate the wave height.

(c) At a later time, regular waves occur with period less than 5 s.
 (i) Explain why a near-bed pressure measurement would be insufficient to determine wave height.
 (ii) Starting with the velocity potential equation, derive an equation for the amplitude of horizontal acceleration at $z = 0$.

Q31. (Exam 2014 – part)
Waves propagate onto a long straight coastline. Consider the x-axis to be normal to the coastline and the y-axis parallel to the coastline. Waves propagate at an angle θ to the x-axis.

(a) Starting with the irrotationality condition for the wavenumber vector:

$$\frac{\partial k_y}{\partial x} - \frac{\partial k_x}{\partial y} = 0$$

derive Snell's law for wave refraction.

(b) A wave with period 7 s and height 1.2 m crosses the 28 m depth contour at angle $\theta = 35°$. Determine the direction, height and power per metre width of wave crest at the 5 m depth contour.

(c) Consider an incident wave with period 7 s, height 2.8 m and angle $\theta = 0°$ in 5 m depth, with a beach slope of 1 in 40. Use the breaker height and breaker depth indices to determine wave height and water depth at breaking.