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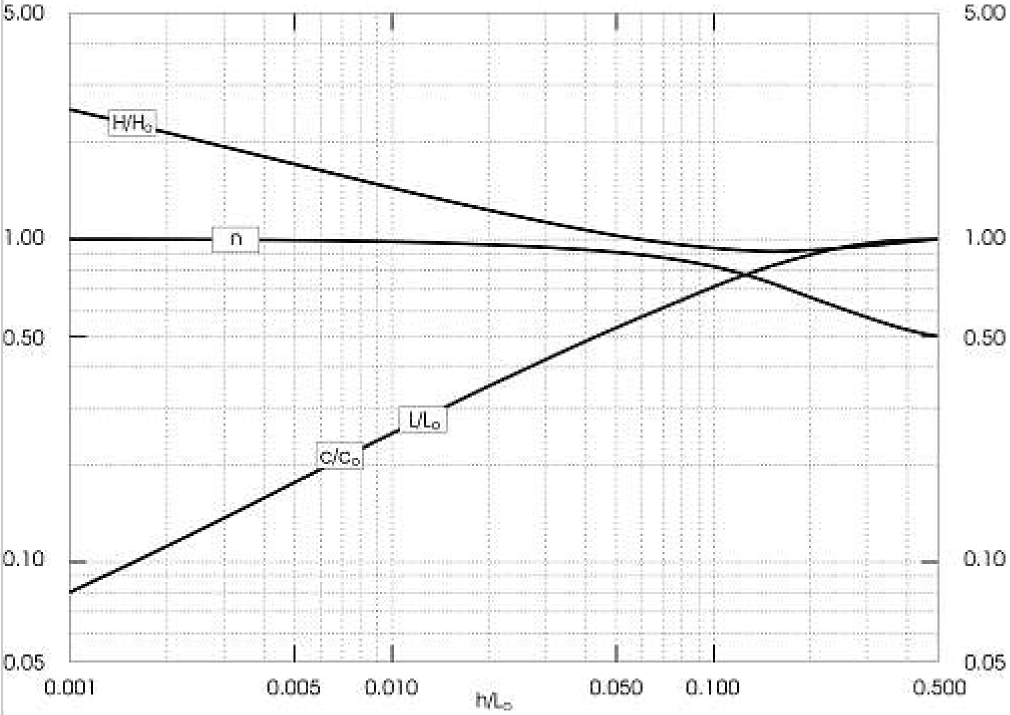
CIE4305 Coastal Dynamics I (2017-2018), ZHI LI, 3/3/18 at 11:33:11 AM CET

Question 1: *Score 1.5/2*

The term *H/H_0* in the below figure is the so-called shoaling factor.



This factor can be obtained from an energy balance.

An example of an energy balance is (with x the cross-shore and y the alongshore direction):

$$\underbrace{\frac{\partial E}{\partial t}}_{A} + \underbrace{\frac{\partial}{\partial x}\left(Ec_g\cos\theta\right)}_{B} + \underbrace{\frac{\partial}{\partial y}\left(Ec_g\sin\theta\right)}_{C} = \underbrace{-D_f}_{D} - \underbrace{D_w}_{E}$$

By assuming that some of the terms in the above equation are zero, we end up with an equation from which the shoaling coefficient can be derived.

Select these terms that should be set to zero.

Your response	Correct response
Choice 1: A Choice 4: D Choice 5: E	

Grade: 0.75/1.0

Total grade: 0.75×1/1 = 75%

Feedback:

For the pure occurrence of shoaling, a wave is considered which is normally incident with respect to alongshore uniform depth contours (otherwise, also refraction takes place). Further, it is to be assumed that dissipation is approximately zero, which is reasonable outside the breaker zone. Finally, stationary wave conditions are to be examined, so these do not change in time. Based on these considerations, you should be able to determine which terms are to be neglected in the energy balance if you are purely interested in shoaling.

Theory: section 5.2.2 (Shoaling)

Question 2: *Score 0/3*

Consider the following depth-averaged momentum balances in x- and y-direction:

$$\underbrace{\frac{\partial(\rho u h)}{\partial t}}_{A} + \underbrace{\frac{\partial(\rho u h)u}{\partial x}}_{B} + \underbrace{\frac{\partial(\rho u h)v}{\partial y}}_{C} = \underbrace{P_x}_{D} - \underbrace{\tau_{b,x}}_{E}$$

$$\underbrace{\frac{\partial(\rho v h)}{\partial t}}_{F} + \underbrace{\frac{\partial(\rho v h)u}{\partial x}}_{G} + \underbrace{\frac{\partial(\rho v h)v}{\partial y}}_{H} = \underbrace{P_y}_{I} - \underbrace{\tau_{b,y}}_{J}$$

The velocity components *u* and *v* are the depth-averaged velocity components in x- and y-direction, respectively.

Assume that the x-axis is perpendicular to the shoreline and the y-axis parallel to the shoreline.

Further, *h* is the instantaneous water depth and ρ is the water density.

The depth-integrated pressure force and bed shear stress are indicated by *P* and τ_b respectively, with the subscripts *x* and *y* denoting their direction.

When these equations are averaged over the wave motion, wave forces appear that are responsible for mean water level variations and wave-driven currents.

Select the term(s) in the above momentum equations from which the wave force originates that is responsible for driving a longshore current along a coastline with straight and parallel depth-contours.

Your response	Correct response
Choice 1: A Choice 4: D Choice 7: G Choice 9: I Choice 10: J	

Grade: 0/1.0

Total grade: 0.0×1/1 = 0%

Feedback:

The cross-shore gradient of the radiation shear stress S_{yx} acts as the driving force of the longshore current. First ask yourself whether this term can be found in the upper or lower equation. Now locate the driving force. You are looking for a term that describes cross-shore changes in y-momentum that is being tranfered in x-direction.

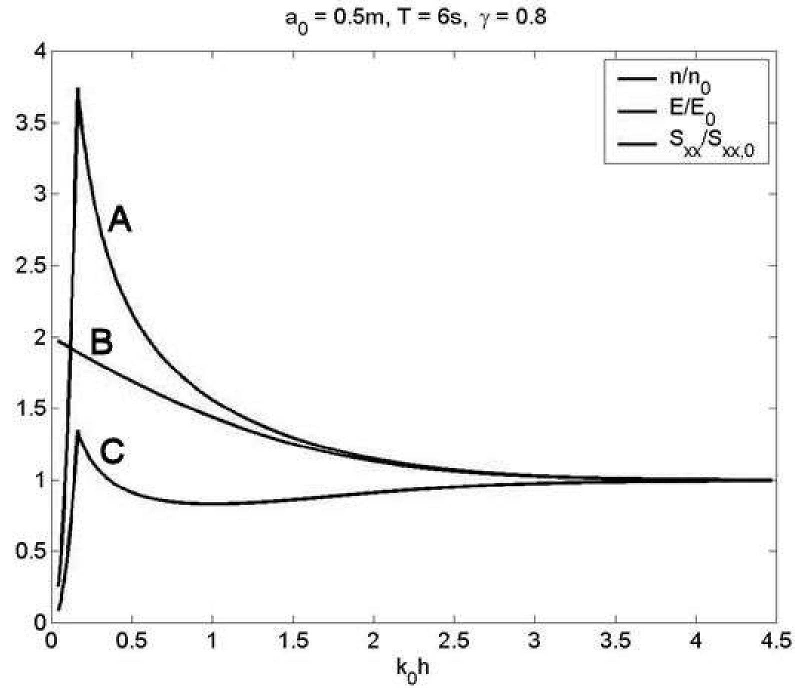
Note that only the driving term(s) are asked for and not the balancing forces that counteract the driving forces. There are two candidates for the balancing forces: a hydraulic pressure gradient and bed shear stresses (can you locatie these terms?). In this case, a hydraulic pressure gradient cannot develop in the alongshore direction (unbounded, uniform situation). The driving force will therefore be counteracted by bed shear stresses in alongshore direction. These develop when a longshore current is generated.

Theory: section 5.5.5 (Alongshore balance: longshore current)

Question 3: *Score 1/2*

For regular waves normally incident to an alongshore uniform coast, the below picture shows the cross-shore distribution of n (the ratio between group and phase velocity), the shore-normal radiation stress S_{xx} and the wave energy E. All quantities are normalized by their offshore value.

The subscript '0' refers to deep water conditions.



Indicate which line in the picture corresponds to which term below:

n/n_0:

Your response	Correct response
B	

Grade: 1/1.0

$S_{xx}/S_{xx,0}$:

Your response	Correct response
C	

Grade: 0/1.0

Total grade: 1.0×1/2 + 0.0×1/2 = 50% + 0%

Feedback:

In deep water, the wave group velocity equals approximately half of the phase velocity. The ratio between the group velocity and the higher phase velocity, *n*, equals thus 0.5 in deep water. In shallow water, the phase velocity approximates the group velocity and *n* becomes hence equal to 1. So, in deep water n/n0 should equal 1 and it gradually increases to a value of 2 in shallow water.

Related to the wave energy, one should take two processes into account: shoaling and dissipation of energy. Due to **shoaling**, E/E0 will first become slightly smaller than 1 after which it becomes larger than 1 if the depth reduces further. This behaviour can be understood from the underlying relations. As long as the waves are not breaking, *E*n*c* can be assumed to be constant. As the depth reduces, *n* will increase and *c* will decrease, but the shape of these functions is different (see the figure in section 5.2.2, Shoaling), such that *nc* decreases (and thus E increases) after a first initial increase that leads to a slight decrease of *E* (see also Fig 7.1 from the lecture notes of Ocean Waves). Finally E/E0 will get to zero by wave breaking (**dissipation**).

The above is enough to answer the question. To understand the behavior of *Sxx*: if waves are propagating in cross-shore direction and in the situation of an alongshore uniform coast, using linear theory, the following expression for the radiation stress *Sxx* can be derived:

$$S_{\mathrm{XX}} = \left(2\,n - \frac{1}{2}\right)E$$

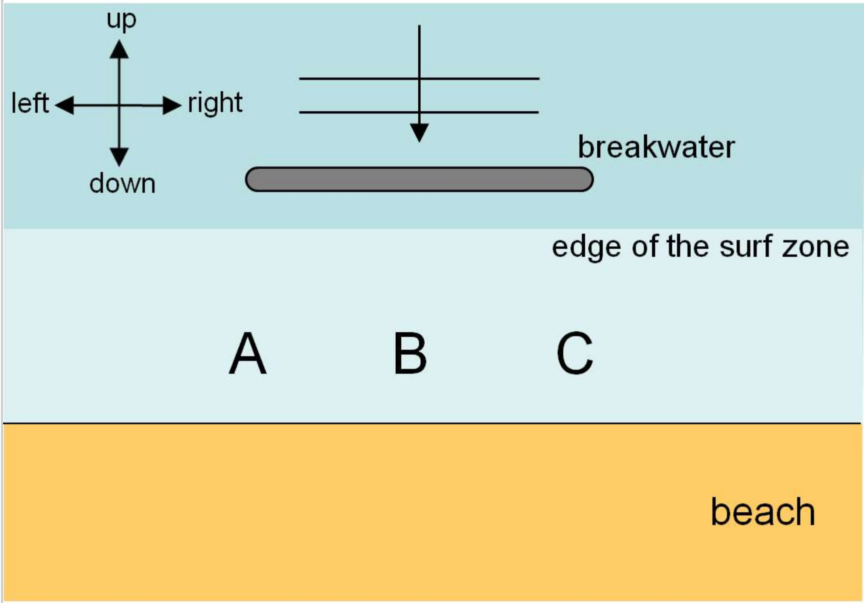
which reduces to 0.5 E in deep water (n = 0.5) and 1.5 E in shallow water (n=1). However, we are not interested in the absolute value of *Sxx*, but in the value relative to *Sxx,0*. It can be shown that this function increases monotonically from deep water until the breaking point.

Theory: sections 3.5.3 (Wave groups), 5.2.2 (Shoaling) and 5.5.2 (Radiation stress)

Question 4: *Score 1/1*

Consider an emerged breakwater as in the below figure (top-view).

Wave incidence is normal to the coast.



In wich nearshore position(s) is the set-up largest?

Your response	Correct response

Choice 1: A Choice 3: C	

Grade: 3/3.0

What are the directions that best describe the current pattern at positions A, B and C?

Current pattern at position A is orientated

Your response	Correct response
to the right	

Grade: 1/1.0

Current pattern at position B is orientated

Your response	Correct response
up	

Grade: 1/1.0

Current pattern at position C is orientated

Your response	Correct response
to the left	

Grade: 1/1.0

Total grade: 1.0×3/6 + 1.0×1/6 + 1.0×1/6 + 1.0×1/6 = 50% + 17% + 17% + 17%

Feedback:

The breakwater blocks part of the waves. Due to diffraction, still some of the wave energy can propagate to point B. However, as the energy spreads out by diffraction, the wave height and thus set-up will be the smallest at point B.

The difference in water level elevation causes a net current (from higher to lower water elevations). As the set-up in the nearshore points A and C is larger than the set-up in point B, the nearshore flow will be directed from both A and C towards point B. Continuity requires the flow in point B to be directed towards the breakwater, from which it will return again in the direction of the tips of the breakwater.

Theory: sections 5.2.4 (Diffraction) and 5.5.7 (3D effects)

Question 5: *Score 0/1*

The non-dimensional fall velocity is defined as: $\frac{H_b}{w_s T}$

A larger value of the non-dimensional fall velocity may be indicative for:

Your response	Correct response
plunging breakers	

Grade: 0/1.0

Total grade: 0.0×1/1 = 0%

Feedback:

The Iribarren parameter represents the ratio of the slope steepness and the wave steepness. Spilling breakers are usually found along flat beaches (small Iribarren number), these waves begin breaking at a relatively great distance from the shore and break gradually. There is very little reflection of wave energy back towards the sea. At these relatively flat beaches, generally fine sediments are found.

The opposite is the case for relatively large Iribarren numbers. Now the wave steepness is relatively small relative to the profile steepness. The breakers become more plunging and surging and the sediment is generally coarser.

A comparable ratio is the dimensionless fall velocity parameter. The smaller this number, the smaller the relative wave steepness. Now, the wave steepness is not expressed relative to the profile steepness but, analoguously, to the fall velocity (and hence relative to the sediment grain size). In Section 4.4.2 we have already seen that the profile steepness is often proportional to the grain size.

Theory: section 5.2.5 (Wave breaking, subsection "Effect of bed slope on breaking process")

Question 6: *Score 1.2/3*

Radiation stresses are defined as:

$$S_{xx} = \underbrace{\overline{\int_{-h_0}^{\eta} (\rho u_x)\, u_x dz}}_{A} + \underbrace{\overline{\int_{-h_0}^{\eta} p_{wave} dz}}_{B}$$

$$S_{xy} = \underbrace{\overline{\int_{-h_0}^{\eta} (\rho u_x)\, u_y dz}}_{C} + \underbrace{\overline{\int_{-h_0}^{\eta} \tau_{xy} dz}}_{D}$$

$$S_{yx} = \underbrace{\overline{\int_{-h_0}^{\eta} (\rho u_y)\, u_x dz}}_{E} + \underbrace{\overline{\int_{-h_0}^{\eta} \tau_{yx} dz}}_{F}$$

$$S_{yy} = \underbrace{\overline{\int_{-h_0}^{\eta} (\rho u_y)\, u_y dz}}_{G} + \underbrace{\overline{\int_{-h_0}^{\eta} p_{wave} dz}}_{H}$$

Now assume that waves are obliquely incident to an alongshore uniform coast.

The *x*-direction is taken as the wave propagation direction and the *y*-direction as the along-crest direction.

Check all the terms that are zero.

Your response	Correct response
Choice 4: D Choice 6: F	

Grade: 0.4/1.0

Total grade: 0.4×1/1 = 40%

Feedback:

If the x-axis is normal to the coast and the waves are normally incident to the coast or if the x-axis is taken as the (possibly oblique) wave propagation direction, the expressions for the radiation stresses can be simplified substantially. In general, there is no wave orbital velocity in along-crest direction, which under the above assumptions means no wave orbital velocity in y-direction. So $uy = 0$. Which terms are zero as a result? Further, the shear terms are zero (assumption of irrotationality, look this up in your Ocean Waves lecture notes).

Theory: section 5.5.2 (Radiation stress)

Question 7: *Score 2/2*

A student says that the magnitude of the wave force that drives the longshore current is given by the (absolute value of the) cross-shore gradient of the radiation shear stress.

This is:

Correct

Your Answer: True in the case of an alongshore uniform coast

Feedback: In case of an alongshore uniform coast, the wave force that drives the longshore current is given by the cross-shore gradient of the radiation shear stress:

$$Fy = -\frac{\mathrm{d}\,S\mathrm{yx}}{\mathrm{d}\,x}$$

If the coast wouldn't be alongshore uniform, the derivatives in the momentum equation over the alongshore direction cannot be neglected anymore, causing a more complex situation.

Theory: section 5.5.5 (Alongshore balance: longshore current)

Question 8: *Score 0/2*

Refraction leads to a decrease in wave height:

Your response	Correct response
for waves approaching a headland	

Grade: 0/1.0

Total grade: 0.0×1/1 = 0%

Feedback:

Refraction refers to the fact that wave crests tend to become parallel to the depth contours and thus wave rays become more and more normal to the depth contours (Why does this happen? Does this happen at deep water too?). This leads to convergence or divergence of the wave rays and, consequently, the wave height changes. Which cases lead to convergence and which to divergence? And what is the effect on the wave height?

Theory: 5.2.3 (Refraction)

Question 9: *Score 2/2*

For the same free stream velocity, how does the magnitude of the bed shear stresses depend on the wave period?

The bed shear stresses:

Correct

Your Answer: are larger for shorter period waves

Feedback: The boundary layer has less time to develop with a small wave period if compared to a long wave period. Less development time means a smaller boundary layer. The smaller layer should still account for the large velocity gradient, which means that there will be larger shear stresses.

You could also verify this based on theory of Jonsson. He defined the friction factor f_w through the following expression for the magnitude of the maximum bed shear stress:

$$\hat{\tau}_w = 0.5\rho f_w \widehat{u}_0^2$$

How is the amplitude of the maximum bed shear stress $\hat{\tau}_w$ affected when the wave period varies, but the free stream velocity amplitude $\hat{u}_0$ remains the same? Assuming the same density of the water, the only differences could arise by different friction factors. In the expressions for the friction factors in the book, you can see that the friction factor is larger for smaller particle excursion amplitudes if the same bottom roughness is considered (do you agree?). The particle excursion amplitude is defined as:

$$\widehat{\xi}_0 = \frac{\widehat{u}_0}{\omega} = \frac{\widehat{u}_0 T}{2\pi}$$

So, what would you conclude?

Theory: section 5.4.1 (Wave orbital velocities) and section 5.4.3 (Wave boundary layer, subsection "Bed shear stress")

Question 10: *Score 0/2*

A researcher measures the surface elevation at a location in the breaker zone.

He plots this record in a graph with the time-axis pointing to the right and the positive surface elevation directed up.

The depicted wave shape is probably:

Your response	Correct response
Symmetrical	

Grade: 0/1.0

Total grade: 0.0×1/1 = 0%

Feedback:

In the **shoaling** zone, gradual peaking of the wave crest and a flattening of the trough occurs. This form of nonlinearity is called skewness and is measures by the time-mean of the absolute value of the surface elevation. Check for yourself that this implies positive skewness in the shoaling zone.

In the **breaking** zone, another process dominates. In shallow water, the wave crest moves faster than the wave trough, causing a relative steeping of the face until breaking occurs. If one would look to a spatial plot of the water level at one moment in time, one would see the waves tilted to the right (if the shore is at the right). However, what would the signal look like if one measures the water level at one location over time?

Theory: section 5.3 (Wave asymmetry and skewness)

Question 11: *Score 2/2*

What is the main mechanism shown in the below image?

Your response	Correct response
Refraction	

Grade: 1/1.0

Total grade: 1.0×1/1 = 100%
Feedback:

Shoaling refers to the change of the wave height with a variation in water depth (the wave propagation speed changes).

Refraction refers to the fact that wave crests tend to become parallel to the depth contours and thus wave rays become more and more normal to the depth contours. This leads to convergence or divergence of the wave rays and, consequently, the wave height changes.

Diffraction occurs if obstructions to the wave propagation or abrupt changes in the bottom contours are present, causing a large (initial) variation of wave energy along a wave crest which leads to transfer of energy along the wave crests.

A river bend is an example of a curvature induced flow, a difference in water level across the channel axis is required to balance the centrifugal force, but a net flow is induced by the mismatch of the height at which the net hydrostatic force and the centrifugal force act.

Theory: sections 5.2.2 (Shoaling), 5.2.3 (Refraction), 5.2.4 (Diffraction) and 5.7.6 (Residual currents)

Question 12: *Score 1/2*

Which of the below conditions must be fulfilled for wave forces in breaking waves to be compensated by a water level set-up only?

(a) Normal wave incidence **Correct**

Your Answer: True

(b) Alongshore uniform situation **Incorrect**

Your Answer: False

Comments:

In order to have a water level set-up only, the wave-induced force Fy must be zero. If you look at the general equation for Fy in your lecture notes, you can see that it consists of two parts. What are the conditions for which these parts are zero?

Theory: section 5.5.3 (Wave-induced forces)

Question 13: *Score 2/2*

Trailing-edge coasts potentially have larger storm surge elevations than leading-edge coasts.

This is because they:

1. host broad and shallow seas

Your response	Correct response
True	

Grade: 1/1.0

- have a lower atmospheric pressure

Your response	Correct response
False	

Grade: 1/1.0

Total grade: 1.0×1/2 + 1.0×1/2 = 50% + 50%

Feedback:

Shallow seas amplify storm surges as a larger water level gradient is required to counteract a certain wind shear stress for a smaller depth. You can conclude this from the equations in section 5.6. Further, this water level gradient results in a larger storm surge if the width of this shallow region (over which the water level gradient is imposed) increases. Are broad and shallow seas to be expected in leading-edge or trailing-edge coasts?

It is true that a lower local atmospheric pressure increases the storm surge. This lower atmospheric pressure is for example present in a storm center. But do you think that the atmospheric pressure is also related to whether a coast is leading or trailing?

Theory: sections 2.3 (Tectonic control of coasts) and 5.6 (Wind-induced set-up and currents)